The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING ASTRONOMY IN CANADA

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In Memoriam Jim Bernath

Exploration of the Sky: The *Skies* Sketchbook

A blooming Iris Nebula

The Best of Monochrome.

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

This beautiful image of the Crescent Nebula (NGC 6888) was taken by Andre Paquette. Andre used a Planewave CDK 12.5″ on a CGE Pro with an Apogee U16M camera and an Astrodon Hα 4 nm filter. He guided using Celestron Skyris 274M and processed with Photoshop, Maxim DL, Bliss MetaGuide.

Journal

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Royal Astronomical Society of Canada

Société Royale d'Astronomie du Canada

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The Iris Nebula is a favourite target for many astrophotographers. Shawn Nielson used a Skywatcher Esprit 100 ED APO Triplet and a Moravian G3 16200EC CCD along with Optolong LRGB filters. He also used a Skywatcher EQ6 mount on a Skyshed Pier and Sequence Generator Pro (SGP) for acquisition, with PHD2 guiding. The image was then processed using Pixinsight. But this image is particularly special. "What makes this image more interesting is it was shot from a city with Bortle 8 sky. Kitchener, Ontario," Shawn writes. "Kitchener has a population of 240,000+ and is part of a region of cities and townships with a population of over 500,000. Light pollution is a problem that I must contend with within my astro hobby."

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.

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

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President's Corner

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

This summer we have been looking back 50 years to the flight of *Apollo 11*, the first time humans set foot on another celestial body.

I remember looking up at the crescent Moon on that night in July 1969 and realizing that two humans were there, while another was orbiting nearby. And before the Apollo program was over in 1972, five more pairs of astronauts walked on its surface.

As a member the RASC, I consider myself an amateur space explorer, so I have often thought about what those explorers actually did when they were on the Moon. Many people can recall moments like the flags, the presidential phone call, the golf swing, and the gravity demonstration, but the fact is that most of the time the Apollo astronauts spent on or near the Moon involved the scientific work of trying to unlock its secrets.

Neil Armstrong and Buzz Aldrin, and those who followed them, spent most of their time on the surface collecting samples of lunar rock and soil, taking photos, and setting up instruments that sent back data about the Moon. That sometimes-tedious work is a big reason their lunar explorations never earned big television ratings after *Apollo 11*.

It took years for scientists to absorb the information contained in the rocks, the photos, and the other data that came from the Moon. Earth's companion was created, most experts now believe, when an even larger object struck Earth very early in its history and created a cloud of debris that accreted into the Moon.

Apollo showed that impacts shaped the history of the Moon, and today we know that impacts played a bigger role in our own planet's history than was previously thought.

Something that should be of interest to amateur astronomers but isn't much remarked upon is the fact that the Moon looks different close up than what us Earthbound explorers expected.

Instead of the towering spires and dramatic peaks suggested by our telescopic views and promised by artists' conceptions, Apollo and the robotic spacecraft that preceded and followed it have shown that the mountains of the Moon actually resemble rounded slag heaps.

The Moon's almost lack of an atmosphere means that its surface has been continuously pounded by particles, rocks, and even larger objects from space, and there is little atmosphere to moderate temperature swings between night and day that also erode the lunar surface.

Despite the rounded nature of most features, there are many places on the Moon that are stranger than we have imagined. Images from the last three Apollo flights, which landed in more dramatic moonscapes than the flat terrain of the Sea of Tranquility, hint at even more spectacular territory where astronauts have not visited.

What we see through our 'scopes is a bit of an illusion. Before lunar observing, I like to look at some close-up images of the Moon to remind myself of what the Moon looks like up close, and see if I can make out the rounded quality of the lunar landscape amidst the dramatic shadows.

As for lunar exploration in general, the Apollo expeditions and the robotic visitors have touched only a small part of the Moon. There is a great deal more to learn. That's something I think about whenever I look at the Moon or think back to those exciting days half a century ago. ✶

News Notes / En Manchette

Compiled by Jay Anderson

Stars are bigger in pairs

Something of the order of 70 percent of stars heavier than ten solar masses are paired with one or more companions, a proportion significantly higher than those of intermediate-mass stars. This top-heavy relationship between stellar masses and binarity has been difficult to explain: do the multiple-star systems arise from the chance capture of neighbours in a crowded star cluster or from inception during the fragmentation of a collapsing gas cloud? Observations at visual wavelengths that might answer this question are hampered by the thick dust and gas that usually clouds the stellar nurseries in which stars form.

Fortunately, it is possible to see into this foggy nursery using millimetre wavelengths, so researchers, led by Yichen Zhang of the RIKEN Cluster for Pioneering Research in Japan and Jonathan C. Tan at the Chalmers University and the University of Virginia, used ALMA (the Atacama Large Millimetre/submillimetre Array) to observe, at high spatial resolution, a molecular cloud collapsing to form two massive protostars that will eventually become a binary-star system.

The observations showed that already at this early stage, the cloud contains two objects, a massive "primary" central star and another "secondary" forming star, also of high mass. For the first time, the research team was able to use these observations to deduce the dynamics of the system. The observations showed that the two forming stars are separated by a distance of about 180 astronomical units—a unit approximately the distance from the Earth to the Sun. They are currently orbiting each other with a period of at most 600 years and have a total mass at least 18 times that of our Sun.

According to Zhang, "This is an exciting finding because we have long been perplexed by the question of whether stars form into binaries during the initial collapse of the star-forming cloud or whether they are created during later stages. Our observations clearly show that the division into binary stars takes place early on, while they are still in their infancy."

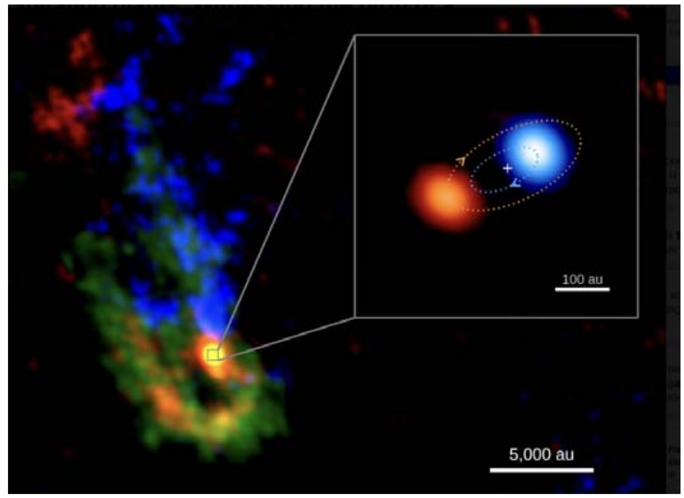

Figure 1 — The background image shows dense, dusty streams of gas (in green) that appear to be flowing towards the center. Gas motions toward the observer, as traced by the methanol molecule, are shown in blue; motions away are in red. The inset image shows a zoom-in view of the massive forming binary, with the brighter, primary protostar moving toward us shown in blue and the fainter, secondary protostar moving away from us shown in red. The blue and red dotted lines show an example of orbits of the primary and secondary spiraling around their centre of mass (marked by the cross). Credit: RIKEN.

Another finding of the study was that the binary stars are being nurtured from a common disk fed by the collapsing cloud and favouring a scenario in which the secondary star of the binary formed as a result of fragmentation of the disk originally around the primary. This allows the initially smaller secondary protostar to "steal" infalling matter from its sibling and eventually they should emerge as quite similar "twins."

Tan adds, "This is an important result for understanding the birth of massive stars. Such stars are important throughout the Universe, not least for producing, at the ends of their lives, the heavy elements that make up our Earth and are in our bodies."

Zhang concludes, "What is important now is to look at other examples to see whether this is a unique situation or something that is common for the birth of all massive stars."

Compiled with material provided by the RIKEN Cluster for Pioneering Research.

Supernova survey sets new standard for detection

By combining one of the world's most powerful digital cameras with the 8.3-m Subaru telescope, a team led by Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) Professor Naoki Yasuda, and researchers from Tohoku University, Konan University, the National Astronomical Observatory of Japan, School of Science, the University of Tokyo, and Kyoto University have been able to identify 1824 distant supernovae candidates, including 58 Type Ia supernovae (SNe Ia) that lie at least 8 billion light-years distant (z>1). In comparison, it took researchers using the *Hubble Space Telescope* about 10 years to discover a total of 50 supernovae located at a similar distance.

A supernova is the name given to an exploding star that has reached the end of its life. The star often becomes as bright as its host galaxy, shining one billion times brighter than the Sun for between one and six months before dimming down. Supernovae classed as Type Ia are useful because their constant maximum brightness allows researchers to calculate how far the star is from Earth, a measure used in the determination of the expansion rate of the Universe.

The 870 mega-pixel Hyper-Suprime Cam (HSC) on the Subaru Telescope is the only instrument among the world's large (8–10-m) telescopes mounted at the prime focus. It is unique in its wide-field of view (1.77 deg^2), with 104 charge-coupled devices (CCDs; 4k×2k pixels) providing a 0.168″/pixel scale. The focal ratio of 1.83 makes the HSC the fastest camera among the large telescopes. The telescope and camera combination were able to reach a median magnitude of approximately 26 during the survey. By taking repeated images of the same area of night sky over a six-month period, the researchers could identify new supernovae by looking for stars that brightened suddenly before gradually fading away.

In recent years, researchers began reporting a new type of supernovae five to ten times brighter than Type Ia supernovae. The unusual brightness of these Super Luminous Supernovae enables researchers to spot stars in the farthest parts of the Universe that are usually too faint to observe. Since distant Universe means the early Universe, studying this kind of star could reveal characteristics about the first, massive stars created after the Big Bang.

In detecting the supernova candidates, the research team relied on a neural network trained on artificial and real supernova transients to screen the images for changes in a sequence of images acquired over the duration of the survey. This initial screening left over 65,000 candidates for further examination using the shape of the light curve and the presence of a host galaxy. This produced nearly 27,000 candidates for visual examination by 9 experts, a process culminating in the identification of 1534 active galactic nuclei and 1824 supernovae. Spectroscopic observations were conducted on 17 of the SNe Ia candidates to further refine their distance and characteristics. At redshifts greater than 1.2, visible wavelengths are shifted into the infrared where the sensitivity of the Hyper-Suprime-Cam drops off and so a limited number of distant SNe Ia candidates were further examined by the *Hubble Space Telescope*.

"The Subaru Telescope and Hyper Suprime-Cam have already helped researchers create a 3-D map of dark matter, and observation of primordial black holes, but now this result proves that this instrument has a very high capability finding supernovae very, very far away from Earth." said Yasuda.

The next step will be to use the data, particularly the distant SNe Ia, to calculate a more accurate expansion of the Universe, and to study how dark energy has changed over time.

Prepared with material provided by Kavli Institute for the Physics and Mathematics of the Universe.

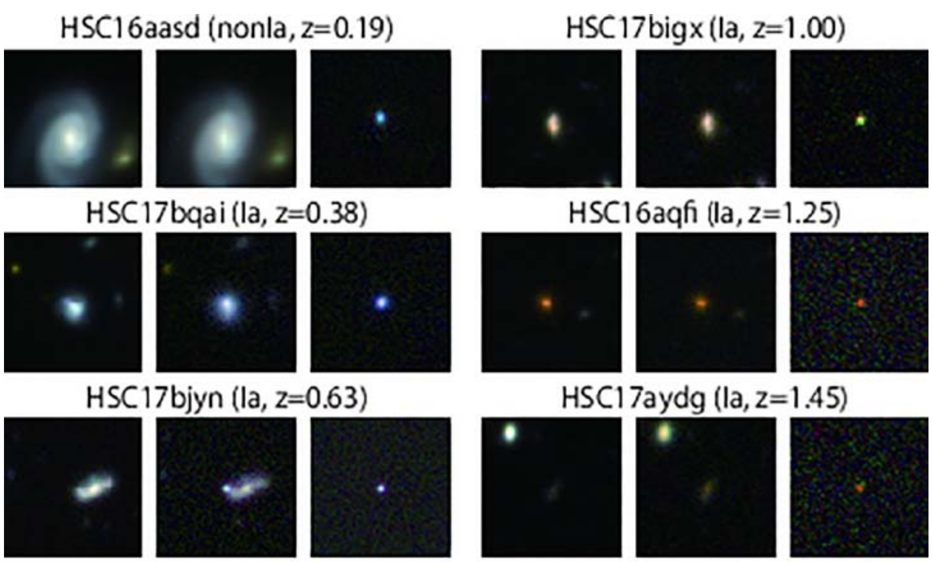

Figure 2 — A sample of some of the supernovae discovered in this study. There are three images for each supernova for before it exploded (left), after it exploded (middle), and supernovae itself (difference of the first two images). Credit: N. Yasuda et al.

Gaia data reveal a new evolutionary pathway in low-mass stars

The *Gaia* astrometry satellite, launched in 2013 by the European Space Agency, is proving to be one of the most scientifically fertile observatories currently in orbit. The satellite is collecting measurements of the position, distance, and motions of billions of stars in the Milky Way and in nearby galaxies along with spectral observations in the near-infrared of brighter stars. The latest catalogue of observations, Data Release 2 (DR2), contains data on more than 1.5 billion stars.

About 26 percent of the variable sources published in DR2 are variable stars that show a periodic variation in their luminosity due to their rotation and to surface inhomogeneities such as spots. This cycle of brightness variations can be used to derive a rotation period for each star and the amplitude of the brightness modulation can be used to infer the strength of the star's magnetic field. The large number of stars observed made it possible to produce, with just the first 22 months of *Gaia* observations, the largest dataset on rotation to date, with rotation period and brightness amplitude of some 150,000 solar-like stars.

When a scientific team lead by Alessandro C. Lanzafame and Elisa Distefano at the INAF-Osservatorio Astrofisico di Catania with Sydney A. Barnes (Leibniz Institute for Astrophysics) and Federico Spada (Max Planck Institute for Solar System Research) inspected the rotational modulation dataset of solar-like stars, they expected to find a general decrease of the modulation amplitude with increasing period, with perhaps a knee separating a faster rotation, "saturated" regime, in which magnetic activity is weakly dependent on rotation, from a slower rotation, "unsaturated" regime, in which magnetic activity is more strongly dependent on rotation. Such a trend is well established from ground-based observations, and it was recently confirmed by the observations of the *Kepler* satellite. To their surprise, however, the *Gaia* data instead revealed a different and completely unexpected picture. The richness of the data made it possible to unveil, for the first

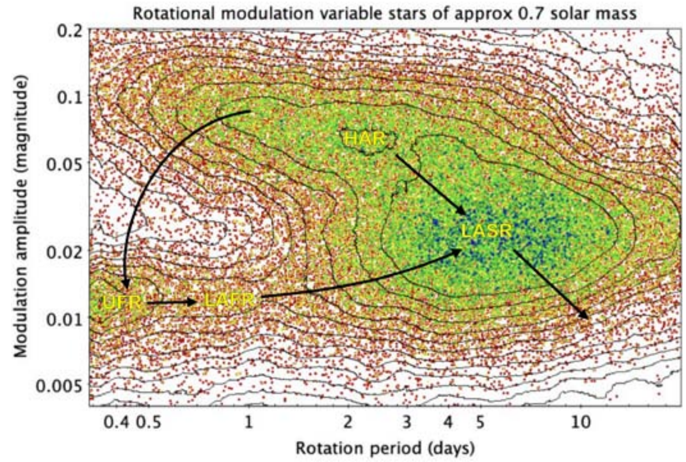

Figure 3 — Gaia DR2 density diagram of amplitude vs period for solar-like stars with mass approximately 0.7 solar mass. The colour pattern (rainbow) indicates the datapoint density. Young solar-like stars having a thick accretion disk (T Tauri) are located on the high-amplitude branch (HAR). From there, stars eventually transit to the unsaturated LASR regime. However, if spin-up leads them almost to breakup velocity, they change their appearance very rapidly into a more axisymmetric surface spots configuration, which produces a much smaller rotational modulation amplitude, populating the ultra-fast rotator (UFR) group. From there the star evolves at a slower pace toward the low-amplitude slow-rotator (LASR) clustering, corresponding to the unsaturated regime where wind-braking dominates the stellar spin-down. Credit: University of Catania.

time, signatures of different surface inhomogeneity regimes in the amplitude-period density diagram. These regimes produce clustering of data in such a diagram that only the richness of the *Gaia* data can reveal.

The saturated weak magnetic regime turned out to be composed of two branches, at high and low amplitude, separated by an evident gap at rotation period shorter than about two days (Figure 3). The low-amplitude branch in turn also resolved itself into two clumps, showing an over-density of data points at a rotation period shorter than about half a day, defined as ultra-fast rotators (UFRs), and another over-density at period larger than about five days, which, by comparison with *Kepler* data, is identified as the tip of the unsaturated regime. Such evidence unexpectedly and deeply challenges our view of the magneto-rotational evolution of young solar-like stars and suggests a novel scenario.

Deeper investigation showed that the high-amplitude branch (HAR) is populated by young stars that have not yet ignited hydrogen in their cores. Stars in the low-amplitude slow-rotator group (LASR) are identified as older unsaturated stars. Ultra-fast rotators and the faster stars on the high-amplitude branch are expected to be stars that are on the cusp of igniting the hydrogen burning in their cores.

Surface magnetic fields in solar-like stars are also responsible for stellar spindown at increasing age. The magnetic fields generate and control the stellar wind, which removes angular momentum from the star, causing it to slow its rotation as it ages. Young solar-like stars that have not yet ignited hydrogen in their cores are still undergoing contraction from the pre-stellar nebula and therefore tend to spin-up. In the early stages of this contraction, the spin-up is prevented by the loss of angular momentum through the interaction with the accretion disk where planets form. When planets begin forming and the gas in the disk dissipates, the star then becomes free to spin-up until the overall contraction phase is over. After that, the spin-up stops and the star begins to spin down.

Placing stars of known age and evolutionary status in the *Gaia* amplitude–period–density diagram permits, therefore, to delineate a new scenario for the magneto-rotational evolution of young solar-like stars. In the earlier phase of their evolution, when they are identified as T Tauri stars with a thick accretion disk, stars lie on the high-amplitude branch. When their disks start to dissipate, they spin-up, although still remaining on the high-amplitude branch until they ignite the hydrogen burning in their cores and stop contracting. Stars subsequently spin down due to the braking induced by magnetic fields, and move toward the low-amplitude, slow-rotators regime. The transition to the slow-rotator, unsaturated regime is somewhat discontinuous, as shown by the lower density in the amplitude–period-density diagram. This lends observational support to the existence of a magnetic transition that has been recently proposed in the literature.

The presence of the ultra-fast rotator over-density at low amplitude, clearly separated from the fast rotators at high amplitude (on the left side of the graph), and the decrease in density of the high-amplitude branch toward very short periods, suggest an alternative magneto-rotational evolution for which there was no evidence before *Gaia*. Stars on the high-amplitude branch that spin up close to their breakup velocity (i.e. when the centrifugal force at the equator is comparable to the gravity force) undergo a very rapid magnetic transition toward a more axisymmetric field configuration, which causes a dramatic decrease in modulation amplitude and brings them into the ultra-fast rotator regime. The very sparse population of stars connecting the ultra-fast rotator group to the low-amplitude slow-rotator group suggests that stars spin-down at a slower pace, and eventually merge into the low-amplitude slow-rotator branch.

Therefore, all stars eventually converge to the low-amplitude slow-rotator branch where the magnetized wind braking controls stellar spin-down. This latter phase of stellar spin-down is being actively investigated by the scientific community, as it may provide an efficient method to derive the age of the star during evolutionary phases when other stellar parameters vary very little. In this respect, the amplitude bimodality found in the *Gaia* data helps in identifying stars that are in the unsaturated regime, when this "gyro-chronology" can be applied.

Compiled in part with information provided by ESA.

New Earth-sized planets in an old dataset

Scientists at the Max Planck Institute for Solar System Research (MPS), the Georg August University of Göttingen, and the Sonneberg Observatory have discovered 18 Earth-sized exoplanets that previous surveys had overlooked. One of them is one of the smallest known so far; another one could offer conditions friendly to life. The researchers re-analyzed a part of the data from NASA's *Kepler Space Telescope* with a new and more sensitive method that they developed. The team estimates that their new method has the potential of finding more than 100 additional exoplanets in the Kepler mission's entire data set.

Of the more than 4000 planets detected outside our Solar System, about 96 percent are significantly larger than Earth; most of them are comparable with the dimensions of

Neptune or Jupiter. This percentage likely does not reflect the actual distribution of exoplanet masses as small planets are much harder to detect than big ones. These small worlds are tempting targets in the search for Earth-like, potentially habitable planets outside the Solar System.

The 18 newly discovered worlds are classified as Earth-sized planets. The smallest of them is only 69 percent of the size of the Earth; the largest is barely more than twice our planet's radius. And they have another thing in common: past search algorithms were not sensitive enough to detect these new worlds in the data from the *Kepler Space Telescope*. In their search for other planets, scientists look for stars with periodically recurring drops in brightness caused by the passage of a planet whose orbital plane is aligned with the line of sight from Earth. The planet occults a small fraction of the stellar light each time it passes in front of the star in its orbit.

"Standard search algorithms attempt to identify sudden drops in brightness," explains Dr. Rene Heller from MPS, first author of the current publications. "In reality, however, a stellar disk appears slightly darker at the edge than in the centre. When a planet moves in front of a star, it therefore initially blocks less starlight than at the mid-time of the transit. The maximum dimming of the star occurs in the centre of the transit just before the star becomes gradually brighter again," he explains.

Large planets tend to produce deep and clear brightness variations of their host stars so that the subtle centre-to-limb brightness variation on the star hardly plays a role in their discovery. Small planets, however, present scientists with immense challenges. Their effect on the stellar brightness is so small that it is extremely hard to distinguish from the natural brightness fluctuations of the star and from the noise that necessarily comes with any kind of observation. René Heller's team has now been able to show that the sensitivity of the transit method can be significantly improved if a more realistic light curve is assumed in the search algorithm.

The researchers used data from NASA's *Kepler Space Telescope* as a test bed for their new algorithm. In the first mission phase from 2009 to 2013, *Kepler* recorded the light curves of more than 100,000 stars, resulting in the discovery of over 2300 planets. After a technical defect, the telescope had to be used in an alternative observing mode, called the K2 mission, but it nevertheless monitored more than another 100,000 stars by the end of the mission in 2018. As a first test sample for their new algorithm, the researchers decided to re-analyze all 517 stars from K2 that were already known to host at least one transiting planet.

In addition to the previously known planets, the researchers discovered 18 new objects that had previously been overlooked. "In most of the planetary systems that we studied, the new planets are the smallest," noted co-author Kai Rodenbeck of the University of Göttingen and MPS. What is more, most of the new planets orbit their star closer than their previously known planetary companions. The surfaces of these new planets therefore likely have temperatures well in excess of 100 °C; some even have temperatures of up to 1000 °C. Only one of the bodies is an exception: it likely orbits its red-dwarf star within the so-called habitable zone. At this distance from its star, the planet may offer conditions under which liquid water could occur on its surface.

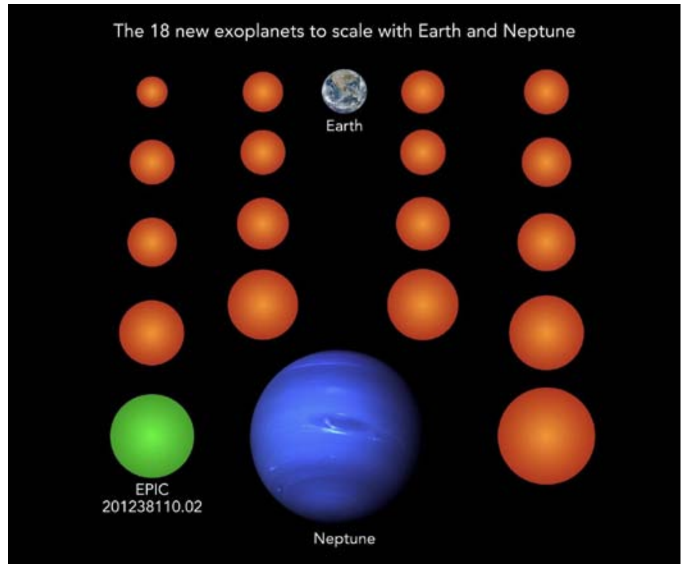

Figure 4 — Diagram showing the relative sizes of the new exoplanets. Planet EPIC 201238110.02 is the only one of the new planets cool enough to potentially host liquid water on its surface. Credit: NASA/JPL (Neptune), NASA/NOAA/GSFC/Suomi NPP/VIIRS/Norman Kuring (Earth), MPS/René Heller.

Of course, the researchers cannot rule out that their method, too, is blind to other planets in the systems they investigated. In particular, small planets at large distances from their host stars are known to be problematic. They require more time to complete a full orbit than planets orbiting their stars closer in. As a consequence, transits of planets in wide orbits occur less often, making their signals even harder to detect.

The new method developed by Heller and his colleagues opens up fascinating possibilities. In addition to the 517 stars now being investigated, the *Kepler* mission also offers data sets for hundreds of thousands of other stars. The researchers assume that their method will enable them to find more than 100 other Earth-sized worlds in the data of the *Kepler* primary mission. "This new method is also particularly useful to prepare for the upcoming *PLATO* mission to be launched in 2026 by the European Space Agency," says Prof. Dr. Laurent Gizon, Managing Director at the MPS. *PLATO* will discover and characterize many more multi-planet systems around Sun-like stars, some of which may be capable of harbouring life.

Compiled using material provided by the Max Planck Society. ✶

Feature Articles / Articles de fond

Jim Bernath In Memoriam 1929 – 2019

by Suzanna Nagy

"One person's trash is another person's treasure–especially if you are collecting old space junk." (excerpt from interview of Jim Bernath by *Flash News*, July 1998). It is with a sad and heavy heart that Vancouver Centre announces the passing of long-time RASC member and good friend, Jim Bernath. Jim was a member of RASC since 1975—that is 44 years.

Jim was best known for his travelling collection of astronomy/space artifacts and memorabilia. To many, he was known as "Mr. Space of Canada" and a self-described "Specialist in NASA and the Space Shuttle Programs." Unlike many collectors, Jim didn't keep his artifacts private but instead chose to display in public and share them.

Jim regularly travelled with his van of curiosities across Canada and the United States. He would set up displays in

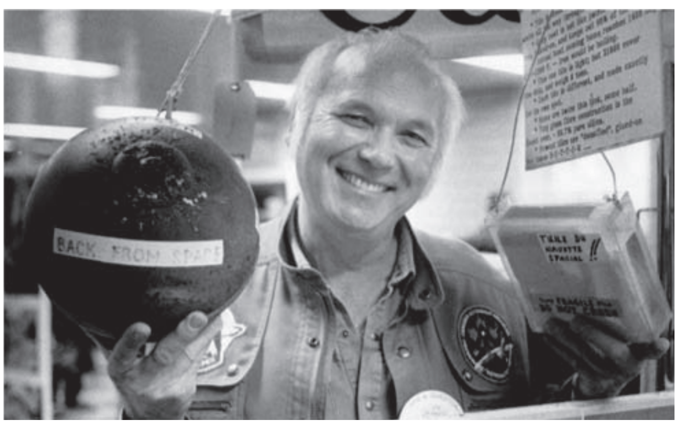

Figure 1 — Jim circa 1980s

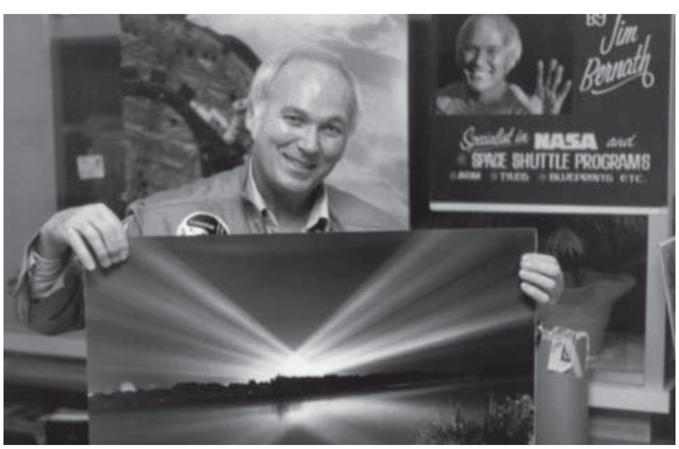

Figure 2 — Jim circa 1980s preparing for a public event

Figure 3 — Jim circa 1990s at a school event

schools, auditoriums, and malls—wherever he could find a crowd. During his travels, he would meet like-minded enthusiasts/collectors and would always be adding to his ever-growing collection.

At the RASC General Assembly in October 1981, Jim was one of the recipients of the Best Centre Display.

I first met Jim 15 years ago during my very first year of volunteering with RASC Vancouver at its annual celebration of International Astronomy Day. Jim was a regular for this annual event. Vancouver Centre's Past President, Pomponia Martinez, was the first to invite Jim to present his display, and ever since, Jim's participation became an annual regular fixture at Astronomy Day.

Pomponia Martinez writes:

" I was sad to hear news of Jim Bernath's passing and it brought to mind his kind, quiet spirit and generosity through his volunteer time with the RASC Vancouver Centre.

As then RASC Vancouver President, I recall meeting with Jim early in 2007 to discuss whether he could volunteer some time for us at the upcoming Astronomy Day in May. Not only

Figure 4 — Jim circa 2000s at a mall event

Figure 5 — Front page of RASC National Newsletter, October 1981, Vol 75, No. 5

did Jim agree to volunteer his time, but he would also create a display of his many space-related curiosities. He had all kinds of interesting artifacts from space missions, a computer-controlled microscope to view the fine layers of a sliver of Moon rock, asteroid fragments, and freeze-dried ice-cream, all while dressed in a very official-looking silver spacesuit. We were always on a shoestring budget, so in addition to a very modest honorarium for gas, he agreed his only need would be a cake slice. Of course, he said this jokingly, unknowing that I would actually bake a cake for the occasion. So, a slice of cake (he loved the corner piece with frosting) along with a bowl of chili on Astronomy Day, became our annual tradition for many years thereafter.

Adults and especially kids buzzed around his display tables and loved to hear him explain all of the details of missions and memorabilia. We were very grateful for his colourful addition to our Astronomy Day activities."

When I took over the role of Event Coordinator for International Astronomy Day, it became my pleasure to work closely with Jim. As his displays were always "hands-on," Jim was the highlight and quite frankly, it wouldn't have been Astronomy Day without Jim Bernath's displays. For children to be able to touch a rocket, a meteorite, or have a slice of NASA dehydrated ice cream was such a bonus to our events.

Over the past four years, with his health failing, Jim knew his time with us was nearing its end. He and I talked many times of my personal wish that the Vancouver Centre would be allowed to carry on his legacy. So, slowly, with funding from the Centre, I began to acquire pieces of Jim's displays and created Vancouver Centre 's Jim Bernath Collection, which has now become an integral part of our outreach programming.

2018's International Astronomy Day event was Jim's last time with us. His fragile health precluded him from bringing the last few pieces of his displays to the event. Instead, I set him up in an area directly next to our tables for the Jim Bernath Collection and Jim spent the entire afternoon giving away autographed posters of space and the Space Shuttle with a line-up of children waiting to meet him. He was a rock-star, and it was a great send-off for him because sadly, shortly after the event, Jim was admitted to long-term care and he passed away a few months later.

Figure 6 — Jim at International Astronomy Day 2016

In conclusion, I offer you Pomponia Martinez's concluding words as I couldn't have said it better:

"His warm charm, wit, and his love of all things astronomical will be missed. Thank you Jim for your generous service on Earth." ✶

Suzanna Nagy, an active member of the Vancouver Centre since 2004, is the immediate Past President and current Membership co-Chair.

Figure 7 — Jim with his 2-metre rocket

Exploration of the Sky: The *Skies* Sketchbook by J.M.W. Turner

by Natalia Bosko

Abstract

J.M.W. Turner, as many Romantic artists, studied nature from a scientific perspective to achieve a comprehensive perception of natural occurrences. Such approach defines the exploration of celestial phenomena in the watercolours of his *Skies* sketchbook. These designs and the paintings, for which the drawings served as a foundation, exist in the context of the 19th-century cultural knowledge based on discoveries in astronomy and other sciences. The *Skies* journal records a rare event of an otherwise unreported planetary occultation and documents changes in weather conditions and atmospheric illumination during the aftermath of a volcano eruption. This Turner's sketchbook exemplifies the visualization of scientific knowledge in art of his time.

Joseph Mallord William Turner created the *Skies* sketchbook as a pictorial exploration of celestial phenomena that included a number of rare events. This sketchbook, produced in the late 1810s and located within the Turner Bequest at Tate Gallery, comprises 65 watercolours of varying weather conditions (Figure 1) and unusual celestial events. These watercolours reflect the artist's grasp of the coeval scientific and cultural understanding of the rendered phenomena.

A tradition of skyscapes had developed already in the 17th-century Dutch and French landscape painting. Such artists as Jacob van Ruisdael, Aert van der Neer, and Claude Lorrain created trends in depiction of clouds and moonlight. They lacked, however, a comprehension of the sky as an air layer that separates the Earth from space (Ruskin, 1848). The accuracy of the heavens' depiction in the 17th century suffered from a deficit of scientific knowledge about the atmosphere.

An unprecedented development in astronomy, meteorology, and aeronautics during the next hundred years produced a new perception of the skies. In the late 17th century, Isaac Newton's (1687) gravitation theory suggested a novel perspective on the universal mechanics. Younger scientists starting with James Ferguson (1756) used this theory to explain astronomical phenomena. The invention of air-balloon flight by the Montgolfier brothers and Jacques Charles, and the discovery of hydrogen by Joseph Black offered a sky-faring experience (Covert, 1985; Busch, 1994). In 1809, George Cayley published his work in aerial navigation that created the foundation of modern aeronautics (Ackroyd, 2002). Such developments supported the exploration of the atmosphere, which led to the early meteorological concepts of Luke Howard (1803) and Thomas Forster (1813). This conglomerate of updated scientific information influenced the artistic comprehension of the sky in the early 19th century.

A number of Romantic painters applied the new scientific knowledge in their oeuvre. Relying on their observations and selenological discoveries, German Romanticists Caspar David Friedrich and Carl Gustav Carus produced multiple renditions of the Moon (Siegel, 1978). British artist John Russell applied discoveries in astronomy to his explorative observations of the

Figure 1 — Joseph Mallord William Turner, Study of Sky, folio 2 from Skies *Sketchbook [Finberg CLVIII]. 1817, watercolour. Tate, London. © Tate, London 2019.*

Figure 2 — Joseph Mallord William Turner, Raby Castle, the Seat of The Earl of Darlington. 1817, oil on canvas. The Walters Art Museum, Baltimore. Courtesy of The Walters Art Museum.

satellite (Steinhoefel, 2007). Johann Wolfgang von Goethe and John Constable heavily relied on Howard's (1803) classification of clouds in their oeuvre (Sauerlandt, 1908; Thornes, 1999). Turner also used scientific data to create accurate depictions of celestial phenomena. Ruskin (1848) praised the "infinite and immeasurable in depth" transparent air layer in this artist's paintings as the true representation of the atmosphere (p. 204). The *Skies* watercolours exemplify Turner's prowess in the pictorial exploration of the sky.

Weather and the Origins of the *Skies* Sketchbook

The *Skies* watercolours became the foundation of skyscapes in Turner's mature oeuvre. Until today, specialists date Turner's sky journal broadly to c. 1816–8. However, some of the sketches permit a more precise chronological placement of the sketchbook. The earliest example of their application is Turner's painting *Raby Castle, the Seat of The Earl of Darlington* (Figure 2), which bears a similarity to a number of the sketchbook's folios. The connection between the *Skies* and *Raby Castle* helps identify the creation date for the watercolour journal. The canvas depicts the estate of William Harry Vane, Third Earl of Darlington, who commissioned its representation from Turner (Hamilton, 2003). The artist sketched and painted the landscape during his visit to Vane's lands in Durham County in mid-September 1817 (Brown, 2012). He masterfully rendered a panoramic view of Raby Castle with the sky that measures about half of the picture (Figure 2). The defining for this skyscape cloud formation consists of two crescents centred over the castle and a darker tail stretched out to the left. This composition is identical to the clouds on the *Study of Sky 2* that opens the sketchbook (Figure 1). Such precise reiteration of the skyscape from the *Skies* journal's first folio in the canvas indicates that Turner may have created this watercolour as a compositional sketch for the heaven of *Raby Castle*. He, then, should have begun this sketchbook in the early autumn of 1817, simultaneously with his work on the painting.

The application of many other elements of the *Skies* watercolours in *Raby Castle* confirms the fundamental relation between the sketchbook and the canvas. Turner used the motif of sunrays beaming through a dark cloud ring from folio 6 to illuminate the castle. The study 4 renders a storm identical to the rainfall behind the building in the painting. The artist relied on folios 7 and 12 to depict the white clouds that thin out into the azure in the upper right corner of the canvas. He repeated the chiaroscuro contrast from folio 3 in the central cloud mass of *Raby Castle* and brightened its skies gradually from left to right as in folio 5. Turner based the entire skyscape of this painting on the *Skies* watercolours.

The *Skies* is the only collection of drawings related to the heavens of *Raby Castle*, although the artist used a number of sketchbooks for other elements of this canvas. In 1817, he began the *Raby* sketchbook to draw land, architecture, and hunters in situ (Imms, 2012). He filled a part of the *Itinerary Rhine Tour* sketchbook with outlines of buildings and animals at Vane's estate (Imms, 2012). However, neither of these journals contains studies for the epic *Raby Castle* sky. At this period of Turner's artistic career, in contrast to his visionary style of the 1840s, such grand skyscape demanded preparatory studies. Brown (2016) concurs that the artist created *Raby Castle* simultaneously with the *Skies* sketchbook. Turner must have started his *Skies* book specifically for this painting while drawing the estate in the autumn of 1817.

The highly unusual weather conditions in England in 1817 correspond to those depicted in the *Skies* watercolours, which confirms this year as the sketchbook's starting date. The powerful eruption of Tambora on 1815 April 10 caused strong global climate changes (Boers, 1995). This explosion produced a lasting dust veil of the "highest score" that covered the skies in many areas including England (Boers, 1995, p. 52). In Tambora's aftermath, heavy rains dominated all seasons in Great Britain in 1815–1816 (Fagan, 2000). A permanent veil of volcanic ashes and rainclouds covered the British skies through 1816 and gradually dissipated only in 1817 (Fagan, 2000). The succession of the *Skies* watercolours indicates a slow abatement of the stormy weather in recovery from the post-eruption consequences. The initial folios show clouds and rains, which begin to alternate with clear skies starting with folio 7. In the sketches 35–37, the skies brighten further into the azure. Turner rendered the evanescent atmospheric effects in the *Skies* journal in a rapid flow of the brush. This manner suggests that he sketched from nature during the depicted weather conditions. Boers (1995) describes the weather change in 1817 from the incessant rains of 1816 into the drought of 1817–1818. The steady thinning of the celestial veil through the first half of Turner's sketchbook indicates that he began the *Skies* in 1817, after the storms of 1816 abated but before the cloud and ash blanket dispersed in 1817–1818.

The artist continued this pictorial journal beyond his work on *Raby Castle*. The sketchbook consistently depicts the daytime planned for Vane's landscape up to folio 38, which displays a sunset. Next pages further digress from the designs for this commission by developing topics of diurnal light changes and astronomical events. A closer study of some watercolours from the second part of the *Skies* reveals that they depict the nightly sky on distinct winter months. Johnston (1982) places the completion of *Raby Castle* within the year 1817. Turner, however, continued the sketchbook in 1818, after his work on *Raby Castle*. The concluding pencil sketches help in identifying the date of the *Skies* journal's completion as June 1818. According to Finberg (1909), Turner depicted June 4 at Eton on folios 64a–66. Brown (2016) connects this date with June 1818, when the artist visited Eton with the Fawkes family. Turner evidently worked on this sketchbook from mid-September 1817 until the summer of 1818.

In the *Skies* journal, the artist referred to coevally popular meteorological theories, such as the classification of clouds by Luke Howard (1803). The latter proposed seven cloud types that included three major classes–*cirrus, cumulus,* and *stratus*– and their combinations. Howard (1803) not only described but also drew the cloud types to illustrate his concept. For example, he supported the description of *cumulus* (pp. 3–4) with representation of this class in a drawing on Plate VIb engraved by Lewis in the 1803 edition of the *Essay*. The *Study of Sky 26* of Turner's sketchbook displays a cloud that conforms to Howard's description and depiction of a *cumulus* cloud. The opening folio 2 contains a *cumulus* in the front cloud mass (Figure 1). Several other watercolours of the *Skies* sketchbook also indicate that the artist may have studied and reflected Howard's classification and visualisation of clouds in his oeuvre.

Scholars offer alternative theories about the origin of the *Skies* journal. Hamilton (1998) suggests that the artist produced these watercolours in Salt Hill in Windsor because several pencil sketches of this township are present at the end of the book (folios 61a, 62a, 63a, 64a). However, this later addition does not define the location for the watercolours' creation. Hamilton (1998) agrees that Turner filled his sketchbooks from beginning to the end. The pencil landscapes differ in date, technique, subject, and placement from the *Skies* watercolours. Furthermore, Turner pencilled these drawings in different locations including central London (folios 67a, 68–68a) and Eton (folios 64a–66). Hamilton's (1998) assumption that the artist sketched the entire *Skies* journal in Salt Hill is inconsistent with the depicted subjects and the sketchbook's structure. Richter-Musso (2011), on the other hand, maintains that Turner produced these watercolours on his journey though the Netherlands in August–September 1817 in preparation for his canvas *Entrance of the Meuse* (1819, Tate). Martin Butlin and Evelyn Joll (1984) recognize that this painting's "cloud effects may owe something" to the *Skies* sketchbook (no. 139). However, the scarce visual connections between the *Skies* watercolours and this canvas are insufficient to claim that Turner created this journal for *Meuse*. He drafted this canvas's composition only in 1818 in the *Farnley* sketchbook (Hill, 2014). The artist could not have created the *Skies* journal in the summer of 1817 preparing for *Meuse* because he had

Figure 3 — Joseph Mallord William Turner, Study of Sky, folio 42, from Skies *Sketchbook [Finberg CLVIII]. 1817, watercolour. Tate, London. © Tate, London 2019.*

no concept for this painting until 1818. Besides, he based this canvas mainly on the studies from his *Dort* sketchbook (Butlin & Joll, 1984). Both the Salt Hill and the *Meuse* hypotheses provide insufficient evidence to define the origin of the sketchbook.

Turner began the *Skies* journal in Durham County in the autumn of 1817 preparing the skyscape of *Raby Castle* and completed it with pencil sketches drawn at different locations in the summer of 1818. The diversity of these sites suggests that also some watercolours created after the sketches for Vane's commission can be produced in different areas. This conclusion helps identify the sites depicted after the folio 38 that begins the digression from the concept of *Raby Castle*.

Turner's Suns

The study of the Sun at various daytimes and seasons became signifying for Turner's artwork. He often centred his tableau around this star, as in the canvases of the Carthaginian series commenced a few years before the *Skies* sketchbook or in the Petworth series started ten years after this journal's completion. In the *Skies* watercolours, the artist focused on the Sun in folios 42 and 45. The *Study of Sky 42* represents this celestial body setting through what appears as a red *stratus* cloud (Figure 3). However, this effect rather represents the phenomenon of *glowing background*. Meinel & Meinel (1983) explain this occurrence as sunrays that obliquely pass through ash aerosol at sunset to produce a flaming atmospheric illumination. Bishop (1884, *Science*) witnessed such lighting as "a uniform sheet of flaming crimson, shading up into lilac and orange," in the aftermath of the Krakatoa eruption of 1883 (p. 157). His report corresponds with the phenomenon depicted on the *Skies* sketchbook's folio 42 (Figure 3) and on Turner's canvas *Petworth Park, Tillington Church in the Distance* (Figure 4). The sunset-focused composition of the latter and other canvases of the Petworth series resembles the arrangement of the *Study of Sky 42*.

In the *Skies* journal, Turner depicted *glowing background* from nature in post-Tambora conditions. Oppenheimer (2011) maintains that the aerosol veil causing this effect existed only until 1817 inclusively, even if the spectacular sunsets lasted in England well into 1818, according to Boers (1995). Then the sunset *Study of Sky 42* can be dated to the late autumn–early winter 1817, after Turner's work on the watercolours for *Ruby Castle*. However, Tambora's atmospheric ash dissipated long before he created *Tillington Church* in about 1828. The artist could have used the study 42 of the *Skies* sketchbook to render *glowing background* in this painting. Alternatively, the latter could depict the consequences of a new eruption, such as Kelut 1826 in Indonesia or, more likely, the eruptions of the nearer Avachinsky in Kamchatka in 1827 and 1828. Turner recorded *glowing background* in his watercolours of the late 1820s, such as *The Deer in Petworth Park* (1827, Tate, London). Presumably drawn from nature, such sketches indicate that in the Petworth series he relied on his observations of the familiar phenomenon in the aftermath of new eruptions.

In the watercolour 42 and *Tillington Church*, Turner also portrayed an occurrence similar to a halo of the Sun that

Figure 4 — Joseph Mallord William Turner, Petworth Park, Tillington Church in the Distance. 1828, oil on canvas. Tate, London. © Tate, London 2019.

backlights a semi-diaphanous cloud. As he rendered *glowing background* instead of a cloud, both depictions reproduce a solar halo occurring in volcanic ash. Archibald (1888, IV(Ie)) describes this phenomenon named Bishop's Ring after its first observer Sereno Bishop. The latter recorded such halos as a result of the Krakatoa eruption of 1883 (Russell, 1888). Turner depicted this atmospheric effect in the *Skies* sketchbook 60 years before Bishop's Ring became known to science. The renditions of a regular solar halo in two versions of his *Sun Rising Through Vapour* created about ten years prior to the *Skies* sketchbook show the difference between these phenomena. Bishop's Ring has a distinct corona-like form in contrast to the indistinct solar halo appearing in the mist (Russell, 1888). The specific halo form on folio 42 of the *Skies* sketchbook and in *Tillington Church* allows identifying them as portrayals of Bishop's Ring. The rendition of this phenomenon in the *Skies* sketchbook is especially important because it confirms the chronological placement of watercolour 42. Asano (1993) asserts that Bishop's Ring can only be observed in the absence of clouds, which according to Meinel & Meinel (1983) is also true for the *glowing background*. Before 1817, Turner could not have drawn the Ring invisible through the constant cloud blanket. The aerosol veil causing Bishop's Ring existed only until the end of 1817, according to Oppenheimer (2011). Then Turner created this sketch in 1817, when the sky over England was clearing but volcanic ashes still lingered in the atmosphere. He probably produced the *Study of Sky 42* in the late autumn–early winter 1817.

Turner could have been aware that *glowing background* and Bishop's Ring are the consequences of an eruption. The early 19th-century culture linked volcanic activity and the resulting unusual atmospheric colouration. In a book written contemporaneously with the creation of the *Skies* sketchbook, Howard (1818) described the glowing sunsets in early February 1811 in London on the same book page with St. Michael's eruption in the Azores on 1811 January 31. Such a close placement indicates that he connected these events without being able to explain *glowing background* as an eruption after-effect, because the Krakatoa Committee studied this phenomenon 70 years later (Russell, 1888). Concurrently with the *Skies* sketchbook, Turner created depictions of Vesuvius's eruptions featuring red ash clouds. This colouration intensifies as the clouds move away from the volcano toward the sunset on the far right, where they must be illuminated by the Sun instead of the explosion. These canvases show that Turner rendered *glowing background* in relation to the eruption. In contrast, an earlier depiction of *Vesuvius in Eruption* by Joseph Wright of Derby shows the red colouration only in the light of the volcano's exhaust. The depiction of *glowing background* in Turner's Vesuvius paintings suggests that he understood this phenomenon as an eruption consequence and reflected this perception in his *Skies* sketchbook and Petworth paintings.

Some studies ascribe the colourful sunsets of the *Skies* sketchbook to warmer climates. Brown (2016) mentions a hypothesis that Turner created several of these watercolours during his "visit to Rome and Naples in 1819" (p. 8). However, both English and Italian sunsets were fiery during Tambora's aftermath (Oppenheimer, 2011). This occurrence of refraction depends on the presence of volcanic ash in the air and the declining position of the Sun (Officer & Page, 2009) in all geographic locations affected by an eruption. Ash aerosol dissipated in 1818 (Boers, 1995; Oppenheimer, 2011), leaving no possibility for Turner to observe and record Bishop's Ring on his European tour of 1819. Moreover, the artist filled the sketchbook's pages in succession (Hamilton, 1998), made the concluding drawings in the summer of 1818 and could not add new studies to the *Skies* journal in 1819. Brown (2016) also refers to the similarity of trees on watercolour 42 to Turner's depictions of Italian pines. The vertical shrinking of the grove in this watercolour, that produces its resemblance to the pines, results from a refraction of light in post-Tambora conditions. Such refraction in an ash-induced haze occurs on the horizon (Volz, 1965). Archibald (1888, IV(Id)) cites witnesses who saw this effect near London in November 1883 as a result of the Krakatoa eruption (p. 222). The *Study of Sky 42* is a record of *glowing background*, Bishop's Ring, and volcanic haze observed in England in the aftermath of Tambora's eruption in late autumn 1817.

The Moon and Planets

Turner was also interested in depicting the Moon, which was a popular pictorial subject in Romanticism. In Germany, the artistic, scientific, and poetic obsession with the satellite resulted in a "lunar period" (Rewald, 2001, p. 10). In England, scientific and artistic interest to the Moon merged in Russell's precise telescopic portrayals of the satellite. British Romantic poets such as Wordsworth (1800) and Coleridge (1802), also contributed to the coeval understanding of the satellite. Continental and British astronomers produced a number of new lunar maps in addition to the existing selenographic depictions (Whitaker, 1999). Turner relied on this resource of coeval cultural and scientific information while recording his observations of the satellite, for example, on folios 52 and 54 of the *Skies* sketchbook. In *Red Sky and Crescent Moon* on folio 54 (Figure 5), Turner rendered the new upturned Moon and Venus accompanied by another speck of light to the right from the satellite.

The depicted red colouration of the sky may reflect the fiery eruption after-effect visible after sunset. Bishop (1884, *Nature*) described such phenomenon in post-Krakatoa conditions, while Howard (1818) relayed this ocurrence seen both after sunset and at sunrise in St. Michael's aftermath. At sunset, the "brilliant red" fills the skies in the west while the eastern horizon remains blue (Officer & Page, 2009, p. 21). As the red glow depends on refraction of sunrays passing through atmospheric ash at a specific slanted angle (Meinel & Meinel, 1983), the location of this lighting effect is reversed at sunrise. In the watercolour 54, Turner must have depicted a post-Tambora atmospheric colouration present at dawn in the east with the rising Moon or shortly after sundown in the west with the setting Moon.

The scholars have not investigated the astronomical situation in *Red Sky* but widely discussed a similar formation in Friedrich's *Two Men Contemplating the Moon* (Figure 6). Wegner (2004) argues that the upturned crescent is uncharacteristic for the northern latitudes. However, the lunar path changes due to the Earth's tilted axis and the Moon's elliptical orbit. Consequently, the wintery illumination of the satellite from the bottom creates an upturned crescent in the northern sky (Bartlett, 1909). Astronomers discussed the eccentricity of the lunar orbit since the mid-17th century, e.g. in Riccioli (1651, rept. 1665) and Schröter (1791). British Romantic poets, such as Wordsworth (1800, rept. 1850) and Coleridge (1802, rept. 2001), referred to the boat Moon in their verses written at the turn of the century.

Figure 5 — Joseph Mallord William Turner, Red Sky and Crescent Moon, folio 54, from Skies *Sketchbook [Finberg CLVIII]. 1818, watercolour. Tate, London. © Tate, London 2019.*

Figure 6 — Caspar David Friedrich, Two Men Contemplating the Moon. 1819/20, oil on canvas. Galerie Neue Master, Dresden. © bpk | Staatliche Kunstsammlungen Dresden | Jürgen Karpinski

Turner must have combined astronomical research, cultural sources, and his own observations to learn about this phenomenon. He consistently depicted the winter crescent on the folios 52 and 54 during the winter of 1817–1818, as he worked on the *Skies* sketchbook from the autumn of 1817 to the summer of 1818. The creation date for *Red Sky* falls on the period from December 1817 to February 1818.

The studies dissent also on Friedrich's placement of Venus, which corresponds to the astronomical formation in *Red Sky* (Figures. 5, 6). Wegner (2004) asserts that after sunset Venus should appear to the left of the Moon. However, Rewald (2001) maintains that this planet can be seen to the right of the Moon rarely but systematically "during the course of the year" (p. 14). Friedrich, as well as Turner, may have depicted astronomically correct positions of the planets.

Red Sky on folio number 54 depicts a very thin new crescent, while the preceding folio 52 represents a fuller waxing Moon. Turner filled the sketchbook pages in succession from the beginning to the end (Hamilton, 1998). One lunar month takes 29.5 days (Reid, 1856; Seeds, Backman, & Preneau, 2016), and the winter months of 1817-1818 had only one new moon each (The royal kalendar, 1817; The royal kalendar, 1818). The artist could have drawn these two Moon phases in different calendar months. He likely drew the upturned crescent of folios 52 and 54 on two consecutive winter months, probably in December 1817 and January 1818, because folios 44–46 still display the ochre of the autumnal foliage. The first new Moon of winter 1817 occurred on December 8 (*The royal kalendar*, 1817). The crescent would have reached the waxing phase of the folio 52 about 1817 December 11–12. The next new Moon occurred on the sixth day of January 1818 (*The royal kalendar*, 1818). Turner could have drawn the thin new crescent of the *Red Sky* around 1818 January 7–8.

The size and brightness of the second light spot situated below Venus in Turner's *Red Sky* allow identifying it as Jupiter. This large planet is situated at a much greater distance from the Earth than Venus and appears in the sky slightly fainter than this nearer celestial body (Lang & Whitney, 1991; Graney, 2015). The *Red Sky* reproduces these astronomical objects in conjunction in early January 1818. On 1818 January 3, Venus occulted Jupiter while passing between this planet and the Earth (Albers, 1979; Westfall & Sheehan, 2015). The rare event of these planets' occultation occurs irregularly once in over 200 years (Moore & Rees, 2011). Westfall (2018) calculated that the occultation and the subsequent conjunction of Venus and Jupiter could have been observed best "low in the east" shortly before dawn, because later sunlight outshone the planets (May 1). This appearance of the planets in the east shortly before sunrise would coincide in time with an ash-induced illumination rendered in the *Red Sky*. A conclusion follows that this watercolour could depict the post-occultation conjunction of Venus and Jupiter on 1818 January 7–8.

However, the *Red Sky* exposes a discrepancy in the Moon's shape and the planets' position. On 1818 January 3, the Moon was a thin waning crescent (*The royal kalendar*, 1818) instead of the thin waxing crescent depicted in the sketch (Figure 5). When the Moon reached its waxing phase after January 6, the planets were further apart than Turner depicted, as their progress and their positions on January 5 show (Figure 7a–c). Furthermore, moonrise followed sunrise with a growing delay after the new Moon of 1818 January 6, as Haig's (2018) calculations demonstrate (Appendix, Table 1). The crescent was invisible to the observer of Venus and Jupiter from January 6 onward. Before the new Moon of January 1818, on the other hand, an observer could have seen both the Moon and the planets' conjunction (Haig, 2018 May 18). Turner should have sketched the formation of the *Red Sky* on 1818 January 3–5 with a flipped crescent.

The artist may have unintentionally altered the true astronomical situation in this watercolour. Haig (2018 May 16, 18) suggests that an image seen through a telescope can be inverted. Such inversion would explain the discrepancy between the composition of the *Red Sky* and the true astronomical situation. Turner used telescopes to observe the sky and land (Hamilton 1998). In early January 1818, he was in London (Brown, 2012) and had access to this equipment. The artist likely used Kepler's and Cassegrain's telescopes suitable also for land observation. These instruments produce a vertically flipped image corrected into a horizontal inversion through a secondary mirror (Norton et al. 2004). Turner evidently used the historical telescopes that reversed the sky representation from left to right. Haig's simulations show that Venus and Jupiter appeared to the left of the waning Moon on 1818 January 3–5 (Figure 7a–c). This imagery is a horizontal inversion of the celestial formation in the *Red Sky*. This watercolour likely represents a reversal of the planets' true positions that occurred due to Turner's usage of a telescope.

Theoretically, the artist could have used telescopic observation also to record the Moon in watercolour 52. Then the latter would render an inverted waning crescent that is somewhat fuller than the one in *Red Moon*. In this case, Turner could have drawn sketches 52, 53, and 54 in late December 1817–early January 1818. He could as well have produced these three watercolours in succession on the first week of December 1817, before the first new Moon of that winter, which would discredit the occultation hypothesis. However, the difference in composition and approach of the elaborate landscape 52 and folios 53–54 that focus on the night sky indicate that Turner applied a telescope only to draw the two latter sketches. Furthermore, the distinct foregrounds show that he produced watercolours 53 and 54 in another location. Sketch 52 depicts the waxing Moon on 1817 December 11–12, while *Red Sky* drawn thereafter reproduces the waning crescent seen through a telescope on 1818 January 3–5.

Red Sky records the occultation of Venus and Jupiter or their conjunction after but not before this event. On January 1–2, both planets were visible just before dawn (Haig, 2018 May 18; Westfall, 2018 May 1) and did not coincide with the Moon on these days. Furthermore, Officer & Page (2009) observed red glow 40 minutes after sunset, when sunrays lit stratospheric ash from beyond the horizon. The red colouration at sunrise should be similarly timed shortly before the first light. On January 1–2, moonrise occurred several hours before sunrise (Appendix, Table 1) and did not coincide with the glowing red skies. On January 3–5, however, moonrise occurred from four to one hour before sunrise (Appendix, Table 1). On one of these three days, Turner could have observed the Moon and the two planets in the red glow.

The apparent distance between the occulting planets and the crescent confirms this idea. Haig's astronomical reconstruction shows a decrease of the apparent distance between the crescent and the conjunct planets from their partial occultation on 1818 January 3 onward (Figure 7 a–c). The comparison of apparent distances between celestial bodies based on the Moon's size in the watercolour and simulations indicate that Turner probably depicted the sky on January 4. On January 5, the Moon was too

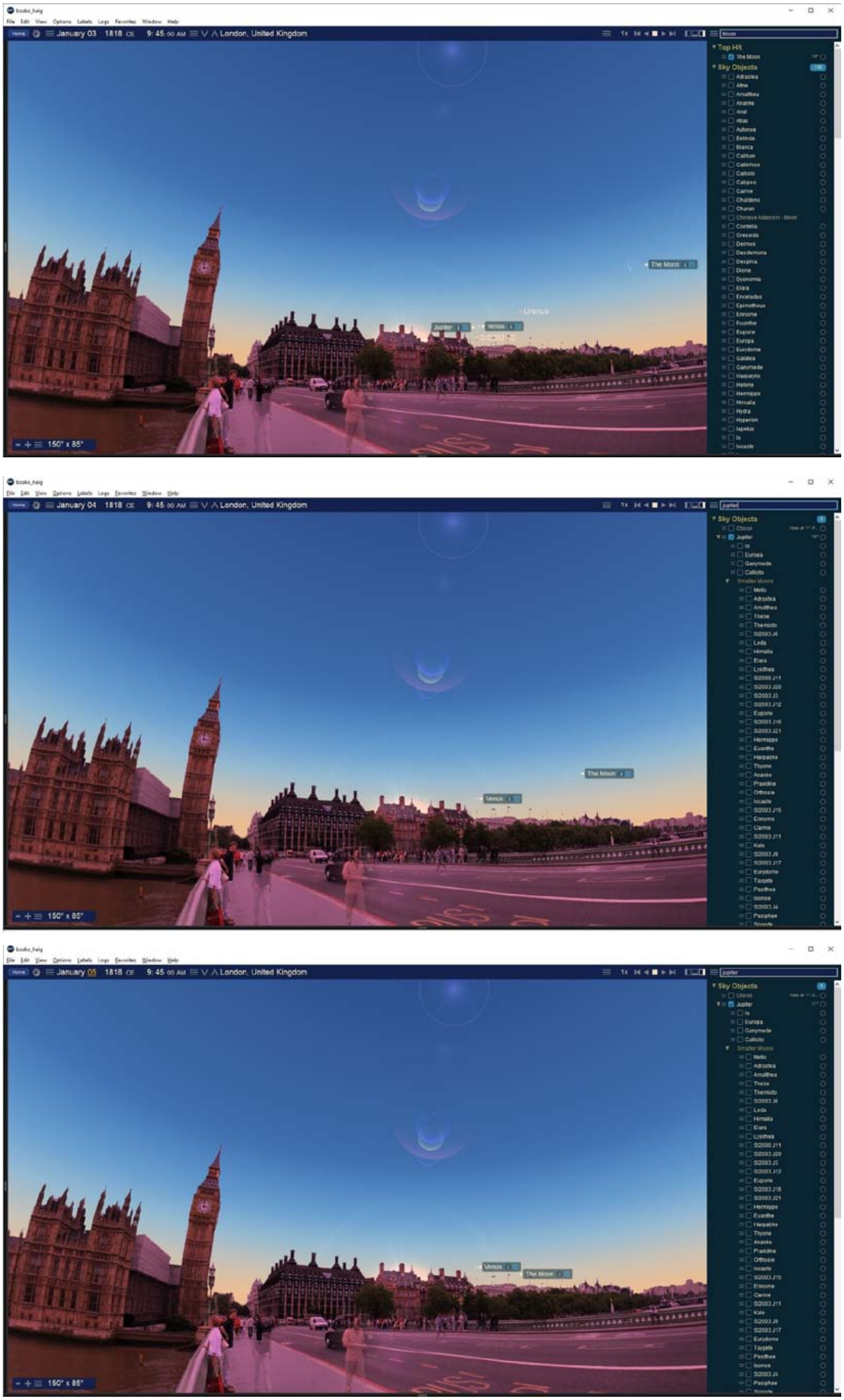

Figure 7 — Colin Haig, Positions of Venus, Jupiter, and the Moon on January 3, 4, and 5 of 1818 in London cityscape, 2018. Figures 7a, 7b, and 7c correspond to the positions of the Moon and the occulting planets on 1818 January 3, 4, and 5. The Starry Night calculation, Simulation Curriculum Corporation. Courtesy of Colin Haig. © Colin Haig | Simulation Curriculum Corporation 2018.

close to the planets, whereas on January 3, the crescent was further remote from the conjunct planets than the artist depicted (Figure 5, 7). In *Red Sky*, Turner likely reproduced Venus and Jupiter one day after the occultation.

His vantage point for *Red Sky* could explain the production of this sketch. The planets were visible low over the horizon early in the morning during the 1818 occultation and conjunction (Haig, 2018 May 18; Westfall, 2018 May 4). The artist could have observed the event from a high ground, such as the roof of his house in 47 Queen Anne Street in London. Instead of the cityscape, however, the watercolour's foreground shows a flat surface a shade darker than the brick-coloured upper part of the sky, which defines this plane as a reflective sheet of water (Figure 5). Thornbury (1862) notes that Turner "kept a boat on the river" to observe and sketch the Thames (vol. 2, p. 331). The artist could have recorded the conjunction of Venus and Jupiter while boating. His usual route took him toward Chelsea (Thornbury, 1877) and reached an undeveloped area on the Thames's northern muddy shore past the Cremorne residence (Porter & Clifton, 1988; Koval, 2013). Such conditions are consistent with the landscape and the low perspective of *Red Sky*. This watercolour likely records the astronomical situation on 1818 January 4, as seen from a boat on the Thames looking toward the northeast.

Turner's usage of the telescope on the river about the time of the occulta-

Figure 8 — Joseph Mallord William Turner, Moonlight [Study at Millbank]. 1795–96, oil on canvas. Tate, London. © Tate, London 2019.

tion indicates his general understanding of this phenomenon, which was known in British Romantic culture. In 1737, astronomer John Bevis surveyed the occultation of Venus and Mercury from the Greenwich Observatory (Westfall & Sheehan, 2015). The 18th- and 19th-century press regularly recorded, for example, Jupiter occulting its satellites (Maty, 1787; D.B., 1801). The early 19th-century astronomers were able to forecast lunar occultations. Turner's friend Mary Somerville referred to this phenomenon in her version of Laplace's treatise *Mechanism of Heavens* (1831), while her memoirs and correspondence (1874) with amateur astronomers prove that they also calculated and observed these events. However, modern scientists found no historical record of the occultation of Venus and Jupiter in 1818 (Albers, 1979; Moore & Rees, 2011; Westfall & Sheehan, 2015). Westfall & Sheehan (2015) maintain that early astronomers mostly observed rare occultations of planets accidentally. It is reasonable to suppose that Turner saw Venus occulting Jupiter on 1818 January 3 by chance and went boating with a telescope the next morning to record this unusual event.

To the Second Star on the Right

Despite the popularity of lunar imagery, the depiction of the stars was rare in Romanticism. The *Skies* sketchbook contains only one study of a constellation on folio 53 that renders the stars in the same fluent manner in which *Red Sky* depicts the planets. The depiction of the starless nightly sky was traditional for English painting. This trend can be traced back to the oeuvre of Wright of Derby. Romantic artists had a strong tendency to obscure the Moon with clouds in their canvases (Rewald, 2001; Siegel, 1978). The same picturesque clouds covered the depicted skies and blotted out the stars. In Turner's oeuvre, stars are also often invisible behind the cloud blanket, as in his early canvas *Fishermen at Sea* (1796, Tate Britain). However, his other early painting *Moonlight, a Study at Millbank* created in the mid-1790s (Figure 8) offers a stellar image.

In *Moonlight*, Turner reproduced the astronomically verifiable positions of the stars, Saturn, and the Moon. The artist exhibited this painting in 1797, a year after his *Fishermen at Sea* (1796, Tate Britain). Nonetheless, Thornbury (1862) describes *Moonlight* as Turner's "first oil picture" (vol. 2, p. 331). The biographer further cites a witness, engraver E. Bell, who saw the artist work on this canvas in 1795. Butlin & Joll (1984) find this evidence inconclusive and perceive *Fishermen* as Turner's earliest oil. However, this artist's accurate depiction of the celestial bodies in *Moonlight* allows refuting this opinion. Recent astronomical studies of the positions of the stars, Saturn, and the Moon in this painting reveal that its creation date is 1796 (Edwards, 2014; Olson, 2018). Edwards

(2014) specifies that Turner reproduced this skyscape at 20:35 GMT on 1796 August 19 "from a point nearly opposite to the present Battersea Power Station." The calculation of the astronomical situation depicted in *Moonlight* defines this picture as contemporaneous with *Fishermen*.

Moonlight can be placed chronologically even before *Fishermen*. Bell describes the artist's work on *Moonlight* in 1795 from a crayon sketch of "a sunset on the Thames, near the Red House, Battersea" made from a boat. Thornbury (1862, vol. 1) explains that the artist sometimes substituted the Sun in his canvases for the Moon. Evidently, Turner began *Moonlight* as a daytime study and changed this canvas into a nightly landscape. However, the subtitle *Study at Millbank* creates a geographical discrepancy, because modern Millbank is situated to the east of Turner's supposed vantage ground. The canvas received this subtitle at the 1797 exhibition (*The exhibition of the Royal Academy*, 1797), but its title within Turner's Bequest did not specify the location (Butlin & Joll, 1984). The Red House mentioned by Bell was a Battersea water sports destination on the southern bank of the Thames popular during the late-18th–early 19th century. This building was situated close to the Battersea Power Station, which is consistent with Edwards's (2014) conclusion about the artist's vantage point. Turner must have rendered a sunset while boating near the Red House in 1795 and repainted it into a moonlit scene in August 1796.

In *Moonlight*, the artist recorded the true positions of the celestial bodies. To accomplish this task, he could have relied on his observations and stellar maps. Turner could have used popular cartographic works published between the 17th and the early 19th century. To their number belong Johann Bayer's *Uranometria*, *Uranographia* by Johannes Hevelius, a newer *Uranographia* by Johann Bode, and *Atlas Coelestis* by John Flamsteed (Kanas, 2019). Between these atlases, the work of British astronomer Flamsteed (1729) was easily available to the artist. Turner's inscriptions in the Lowther sketchbook of 1809 reveal his reading of astronomical sources. The folio 48 verso of this journal contains, for example, a reference to the distance between the Sun and the Earth evidently derived from Ferguson's (1756) interpretation of Newton's mechanics. Turner may have used stellar maps additionally to his observations to document the correct configuration of stars and planets in his painting in the 1790s. He repeated his explorative approach to astronomical phenomena in *Red Sky*. This method suggests that the sketch on folio 53 may render an existing constellation, perhaps in a horizontal telescopic inversion. This watercolour, situated between Turner's studies of the upturned winter crescent, could have been produced in late December 1817–early January 1818. A calculation of the stars' positions during this period would help to identify the single constellation of the *Skies* sketchbook.

Conclusion

The *Skies* watercolours' pictorial documentation fuses Turner's empirical studies with the coeval scientific knowledge and an aesthetic dimension. The initial watercolours of the *Skies* sketchbook firmly define this journal as the skyscape studies for *Raby Castle*. This connection places the sketchbook's starting point as Durham County in the autumn of 1817. The concluding pencil drawings locate the finalization of the *Skies* to summer 1818 in different sites near London. These dates allow identifying the atmospheric phenomena depicted on the watercolours past folio 38 as *glowing background*, Bishop's Ring, and volcanic haze caused by the Tambora eruption of 1815. The depiction of these occurrences in Turner's landscapes confirms his understanding of these phenomena as a result of volcanic activity ahead of the scientific discoveries of his time. Turner's depiction of clouds, on the other hand, conforms to the coeval meteorological standards. The Moon shape in watercolours 52 and 54, which corresponds to the understanding of lunar orbit in Romanticism, determines their creation during the winter of 1817–1818. This chronological placement defines two aligned planets of *Red Sky* as the occultation of Venus and Jupiter of 1818. The astronomically true composition in Turner's early painting and his accurate record the weather changes and atmospheric effects confirm that he likely correctly represented this otherwise undocumented occultation. Turner established his method of artistic exploration in his earliest canvases, developed it in the *Skies* sketchbook, and furthered this practice in his mature paintings.

Acknowledgements

I express my sincere gratitude to the museums and libraries that assisted me in my work on this paper. I am indebted to Colin Haig for his calculations of the positions of Venus, Jupiter, and the Moon on 1818 January 3–5, as well as of sunrise and moonrise times in January 1818, and for pointing out that an image seen through a telescope can appear reversed. I am very grateful to John Westfall for his calculations of the positions of Venus and Jupiter in early January 1818. ✶

Appendix

Date	Moonrise	Moonset	Sunrise	Sunset	Begin Twilight	End Twilight
1818-01-01	01:03	12:13	08:06	16:02	06:03	18:05
1818-01-02	02:28	12:30	08:06	16:03	06:03	18:06
1818-01-03	03:57	12:52	08:06	16:04	06:03	18:07
1818-01-04	05:29	13:22	08:06	16:05	06:03	18:08
1818-01-05	06:56	14:04	08:06	16:06	06:03	18:09
1818-01-06	08:11	15:05	08:05	16:08	06:03	18:10
1818-01-07	09:08	16:22	08:05	16:09	06:03	18:11
1818-01-08	09:47	17:47	08:05	16:10	06:02	18:12

Table 1. Colin Haig, Calculations for moonrise, moonset, sunrise, sunset, and twilight begin and end times on 1818 January 1–8. From Haig (2018 May 16).

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Endnotes

1 See, e.g. the chronological placement of folio 42 of the sketchbook to c. 1816–1818 on the museum's display caption. Tate Gallery. (n.d.). Display caption: Turner, Study of Sky. Retrieved from www.tate.org.uk/art/artworks/turner-study-of-sky-d12490.

2 The artist exhibited this canvas at the annual RA exhibition in the summer 1818; see *The exhibition of the Royal Academy* (1818), 10, no. 129.

3 Cf. Brown (2016), pp. 6–8.

4 Cf. Brown (2016), p. 8.

5 Cf. Fagan (2000), p. 170.

6 Cf. ibid., p. 14–16.

7 See Brown (2016), p. 14; cf. Finberg, 1909, pp. 452–3.

8 Cf. Brown (2016), pp. 13–14.

9 Cf. Butlin & Joll (1984), and Brown (2002).

10 See description of stratus clouds in Howard (1803).

11 On creation date of *Petworth Park, Tillington Church in the Distance*, see no. 283 in Butlin and Joll (1984).

12 See Siebert, Simkin & Kimberly (2010), pp. 137, 259.

13 J.M.W. Turner, *Sun Rising Through Vapour* (1807, National Gallery, London) and *Sun Rising Through Vapour* (1809, The Barber Institute of Fine Arts, Birmingham).

14 J.M.W. Turner, *Vesuvius in Eruption* (1817–20, Yale Center for British Art, New Haven) and *Bay of Naples* (Vesuvius Angry) (c. 1817, Williamson Art Gallery & Museum).

15 Joseph Wright of Derby, *Vesuvius in Eruption* (c. 1776–80, Tate, London).

16 Howard (1818) referred to a "highly coloured sunrise" on the morning after the 1811 St. Michael's eruption to indicate the unusual effect produced by volcanic ash (n. pag.). He described a "fine red" in "apparently calm region," i.e. unpolluted air in calm weather, which leaves only the glow of volcanic ash as this phenomenon's explanation (Howard, 1818, n. pag.).

17 William Wordsworth, "*Peter Bell: A Tale*" (1800), in Wordsworth (1850), 291–332, lines 4, 6, 15f, and 17f; Samuel Coleridge, "*A Soliloquy of the Full Moon, She Being in a Mad Passion*" (1802), in Coleridge (2001), 691–692, line 32.

18 Tate curators date *Red Sky* to "c. 1818." Tate Gallery. (n.d.). Display caption: Turner, Red Sky and Crescent Moon. Retrieved from www.tate.org.uk/art/artworks/turner-red-sky-and-crescent-moon-d12502.

19 Meeus (1970) described partial, annular, and total occultation as possible for Venus and Jupiter but did not study the occultation of 1818.

20 On Turner's house in Queen Anne Street, see Thornbury (1862), vol. 1, pp. 166-7.

21 See, e.g. the forecast for the lunar occultation of Jupiter on 1802 January 21 and of τ Leonis on 1802 January 23 in D.B. (1802), 401.

22 Cf. Smith & Bemrose (1922), p. 131; Darley (2011), p. 85.

23 Bell, E. (n.d.). "*Early Recollections of Mr. E. Bell, Engraver.*" Manuscript, qtd. in Thornbury (1862), vol. 1, p. 75. Cf. Thornbury (1862), vol. 1, p. 19.

24 *On the Red House*, see Cragoe (2016).

Second Light

My flight on SOFIA

by Leslie J. Sage
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"NASA 747 heavy, you are cleared to taxi."

That was how my flight began, on Wednesday, May 22, in the cockpit of the converted 747 carrying the Stratospheric Observatory For Infrared Astronomy (SOFIA). Regular readers will remember that my last column was about the discovery of the helium hydride ion in a planetary nebula. That discovery was made using the GREAT instrument on SOFIA. The lead author of that paper, Rolf Güsten, kindly arranged for me to fly on SOFIA as a guest. For flights in the Northern Hemisphere, the aircraft is based at Palmdale Regional Airport, in Palmdale, California. We took off from Palmdale about 7:35 p.m., heading initially toward the sunset, and climbed to 38,000 feet.

My flight adventure began on Monday, May 20, where I watched an orientation video, and had "egress training"—this is far more comprehensive than the basic security instructions provided to passengers on a commercial jet. SOFIA is certified to fly as an experimental aircraft, and everyone on board has to carry with them at all times an emergency smoke hood that will seal out smoke and provide oxygen. The training is actually quite scary, as the trainer acknowledged at the end.

I got to tour the aircraft while the equipment was being readied for the Monday evening flight. I attended the flight briefing at 5:30 p.m. as an observer. There was a lot of bad weather rolling across the flight path (a southerly route that went as far east as Alabama), and much discussion of whether the flight path could be modified sufficiently to achieve the most critical science objective, which was to point and calibrate the German Receiver for Astronomy at Terahertz frequencies (GREAT) instrument in preparation for the deployment to New Zealand. Flights in the Southern Hemisphere—to cover that part of the sky—are based in Christchurch, next to Antarctic operations, on the grounds of Christchurch's commercial airport. After about an hour's discussion, during which weather alerts kept popping up, it was decided to scrub the mission. This is where I, and the other astronomers, got introduced to SIGMETs—aviation warnings of turbulence.

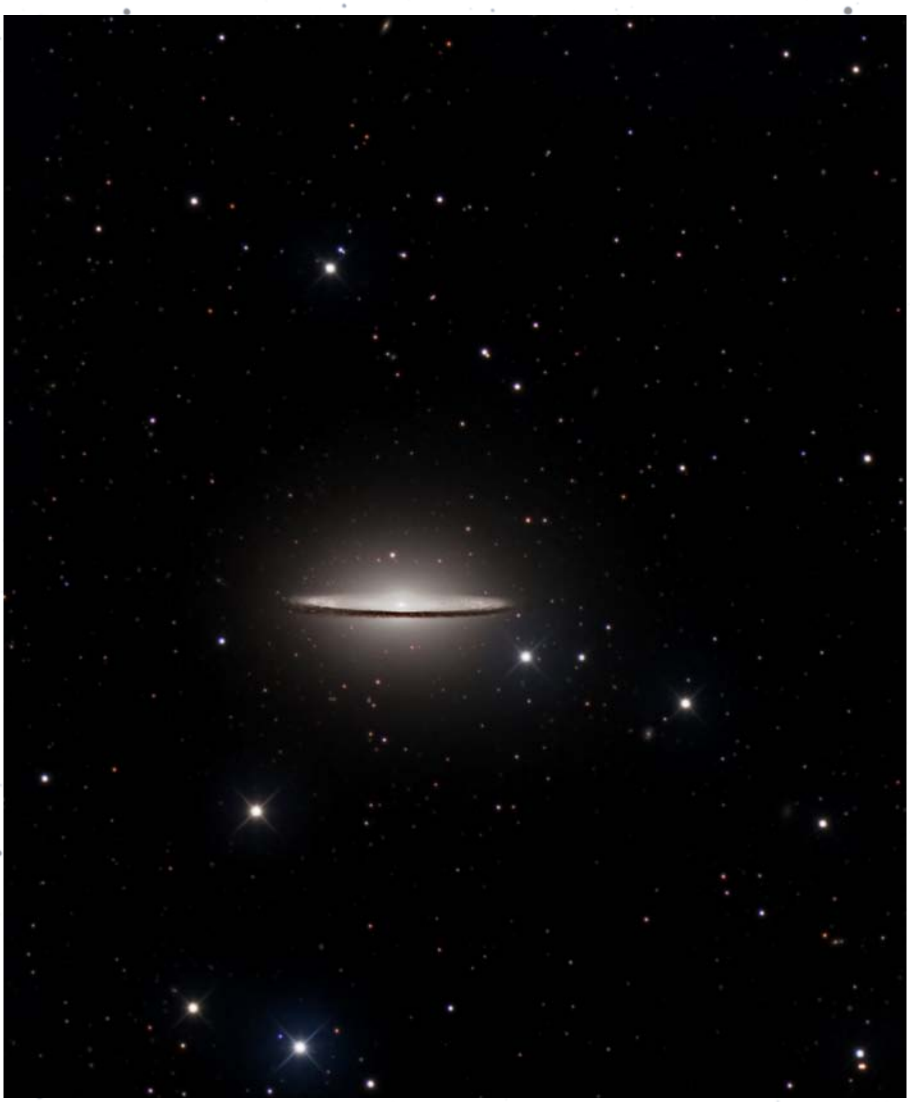
I was scheduled to fly on Tuesday, May 21, with Wednesday being the backup. All of the astronomers (myself included) were following the Significant Meteorological Information (SIGMETs) all day Tuesday, and even before the mission briefing started at 5:45 p.m., we had concluded that the mission would likely be scrubbed—severe turbulence over the airfield, down to the ground, and across much of the flight path. The mission director handed out the flight information, saying that "This is where we won't be flying tonight," but the final call is made by the pilots, who are usually the last to arrive in the briefing room. They came in and said this was going to be a short meeting, the flight is scrubbed. I've been an astronomer for 35 years and have had my share of observing runs cut short (and even lost a whole week's observing on Mauna Kea back in 2001), but I was still disappointed, as were the others. We drowned our sorrows with a very nice sushi dinner.

On Wednesday, we were again monitoring the SIGMETS, and again there was a turbulence warning over the airfield, but it was light turbulence in a restricted altitude range. In the mission briefing that evening, the pilots thought that with some modifications to the flight path, we were a go. We boarded the plane, and the outer doors were closed at 6:20 p.m. We got a safety briefing, and then I went up to the cockpit for take-off. It was fascinating to watch and to listen to air traffic control. Once the telescope cavity door opened, I came back down, and started writing my column. It was well over an hour before the science observations began, because of the diversion.

SOFIA is an extraordinary aircraft. The 2.5-m telescope is actually isolated from the aircraft. The mirror goes between elevations of 23 and 60 degrees, and it can track in azimuth

Continued on page 154

Pen & Pixel



Dan Meek imaged M104 using the RASC's new Robotic Telescope at the Sierra Remote Observatory (SRO) in California. This is a 14-hour LRGB image taken in April 2019. The image was pre-processed using ImagesPlus and processing was done using PixInsight.

If you think you need to cart out your gear to the middle of nowhere to get a stunning deep-sky image, think again. Adrian Aberdeen took this image of the Orion Nebula (M42) and the Running Man Nebula (NGC 1977) from his balcony in Toronto in Narrowband false colours. Adrian writes: "Coming in at almost 12 hours of sub exposures, this is by far the deepest exposure on one target I've done since starting this hobby. I used the Sulfur II data as my Red channel, Hydrogen Alpha as my Green channel, and Oxygen III as my Blue channel = SHO edit or Hubble Palette with a twist." Adrian used a Skywatcher Esprit 80mm on a Celestron CGEM mount with a ZWO ASI1600MM-COOL. He used a Baader 36mm Hα, OIII, and SII narrowband filters with Sequence Generator Pro and PHD2 for guiding. Processing was done using PixInsight with final tweaks in Photoshop.

Pen & Pixel

Ron Brecher captured the magnificent globular cluster M13 from his SkyShed in Guelph using a Sky-Watcher Esprit 150 *f*/7 refractor, QHY 16200-A camera, Optolong L, R, G, and B filters, Paramount MX. He acquired it with TheSkyX unguided, except for 10m subs guided with OAG and QHY5-III-290 and focused using Optec FocusLynx focuser. Automation was done with CCD Commander. All pre-processing and processing was done in PixInsight. 37x3m L, 31x5mL, 33x10m L, 14x5m R, 15x5m G and 16x5m B, unbinned frames (total=16hr46m).

Our beautiful Luna was taken by Paul Owen who used an 8″ Edge and ASI294MCPRO camera. The final image is made up of 250 exposures stacked in Autostakkert and sharpened in Registax.

Continued from page 151

plus or minus 3 degrees. The flight plan is developed uniquely for each flight, with legs devoted to single sources. The first science observations on my flight looked at the line of singly ionized carbon emitted from a galaxy (the next leg was a different galaxy for the same project). The principal investigator of the project, Alberto Bolatto, is in my department at the University of Maryland. He couldn't make the flight, due to other commitments, but instead sent the graduate student Laura Lenkic, who happens also to be a Canadian, from London, Ontario. Anyone who has flown on commercial aircraft knows that they bounce around a bit. But once the telescope is locked on source, it tracks independently of what the aircraft is doing—within certain limits, of course. It's quite a sight to watch as the instruments (which are inside the pressurized part of the aircraft) move around to compensate for the jitter of the aircraft. Surprisingly, there is no change in the ambient noise level after the door has been opened. While the back of the aircraft, where the observers and instrument specialist sit, is colder and noisier than a commercial jet, I've been on some pretty cold trans-Atlantic and trans-Pacific flights, so I thought the warnings we received were rather overblown.

The GREAT consists of 21 independent "pixels," which operate close to the fundamental quantum noise limit. The data are fed to 21 spectrometers. The instrument can be tuned between 63 microns and 650 microns, covering lines of astronomical interest such as the singly ionized carbon line at 158 microns. That line is an important coolant in star-forming regions. The data are collected continuously, with a ten-millisecond time resolution and then digitally processed into spectra and averaged into scans that could be anywhere in length from a few tenths of a second to a few seconds. It means that a huge amount of data (more than a terabyte per night) is collected. The data flow is managed by what is, effectively, a supercomputer.

High school science teachers and journalists fly on some missions, and occasionally various VIPs are also taken up. In New Zealand, some diplomats will fly on the upcoming deployment, and last year the aircraft was based in Hamburg for several months. So, if you are in one of those categories, ask if you can go along on a flight. I highly recommend it. ✶

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

Observing Tips

What is an Observation?

by Chris Beckett

[Note from Chris Beckett: by the time this edition of the *Journal* arrives in members' mailboxes (and inboxes) Dave Chapman will have stepped down as Observing Chair relinquishing our version of the Iron Throne to Blair Stunder, who I look forward to working with as our new Observing Chair. The RASC Committee has never been stronger or more active than it is today as recently demonstrated by the discussion detailed below. While Dave has contributed much to the RASC, I feel his greatest accomplishment is getting people involved in our organization by encouraging their projects and interests. Well done, Dave and all the best on your new endeavour!]

Figure 1 — Mike O'Brien and Rick Huziak observing and sketching sunspots in Grassland National Park 2019 May 11. Image Courtesy of the author.

> *"The exhilaration of exploring the sky, seeing for yourself the remote planets, galaxies, clusters and nebulas—real objects of enormous dimensions at immense distance—is the essence of backyard astronomy."*
>
> – The Backyard Astronomer's Guide

Debate became heated, alliances were forged then disintegrated, factions broke off, but eventually came around. No, I'm not talking about *Game of Thrones*; instead I'm referring to the RASC Observing Committee's recent undertaking to answer one seemingly simple question, "What is an observation?"

When I attended my first star party, I heard the words "observer" and "visual observing" for the first time. While these sounded better than just "doing astronomy," I have often asked "What does it mean to observe?" And on rainy nights I love the pub discussions, learning about what everyone has

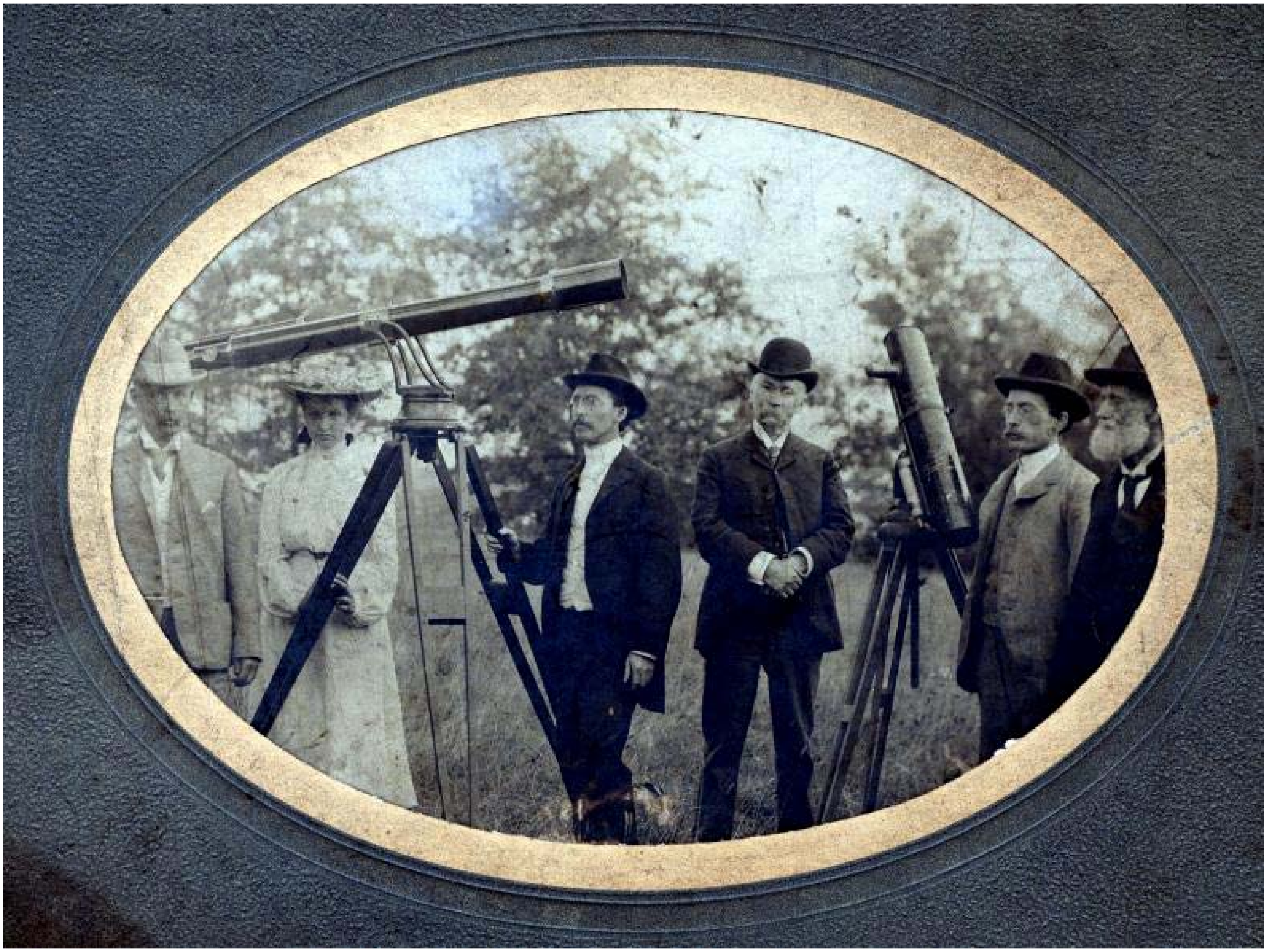


Figure 2 — RASC Early Star Party 1900. Image Courtesy of the RASC Archives.

been observing lately, and how they are going about these observations. With experience, my views have changed, and this winter I had time to reflect and provide my input as these questions became the focus for a task force made up of several members of the RASC Observing Committee of which I am fortunate to be a member. Other passionate observers and task-force members include: Melody Hamilton (task-force lead), Dave Chapman (past Observing Chair), Blair Stunder (now current Observing Chair), Randy Boddam (Observing Committee member), and Dale Armstrong (document author extraordinaire). The output of the task force now appears as a detailed resource on the RASC Observing webpages linked throughout this article. I don't want to reproduce that work so it should be noted that this article is a personal takeaway from my involvement, though it has been edited by the Observing Chair. The purpose here is to raise awareness of new resources created by the Observing Committee and to support and encourage visual observers.

Observe: To Notice, To See

– The Cambridge Dictionary

The RASC Observing Committee recently clarified our definition of an "observation" as "a brief description of what you see." Such clarification was necessary for the Committee to provide guidance for observers wishing to submit their observations and eventually be awarded certificates. The RASC observing programs (www.rasc.ca/certificate-programs) vary greatly, spanning levels of beginner to advanced, with each observer taking a personal journey and we do not want to stand in the way. Instead, we wish to focus our efforts on supporting and encouraging observing skill development. During analysis, the task force identified the challenge that observers face as they transition from the Explore the Universe (ETU) program to the Messier Catalogue, and beyond. By design, the ETU requirements are less stringent, as the program is meant to be an easily obtained certificate and to provide a gentle learning slope for visual observing newcomers. However, while the ETU has significantly increased the numbers of certificates being awarded, the task force determined that additional guidance would benefit many budding observers, especially those "Unattached" to Centres or Centre members in remote areas, not to mention those whose busy lives may not line up with group-observing activities where many of us have learned observing skills.

Task-Force Recommendations

The Committee encourages observers to be creative and it remains steadfast against making observing overly prescriptive, and we only request general requirements be met. Therefore, observers submit just a few basic descriptive sentences along with the following details:

Your Location
Date & Time
Instrument(s) used
Magnification(s)
Sky Conditions

The task force also makes the following recommendations. Observers should avoid taking a "checklist approach," as observing is an examination of the object and an analysis of what is seen. This is the enriching experience the committee wishes to see from observers, in one form or another. The hope is that, through a deep and meaningful experience, many nights will be spent enjoying the sky. An optional observing form is also available for download here: rasc.ca/sites/default/files/obsform.pdf, though many suitable forms are widely available. Observers may also wish to consult the new observing resource, an additional support recently created to help guide observing exploration, which can be found here: www.rasc.ca/observing/tips. While not required, the committee applauds observers who work to develop sketching skills to supplement descriptive notes as they transition from a beginner to a more experienced observer. Most RASC observers will already be familiar with the "Optics and Observing" section at the front of the *Observer's Handbook*—as noted by Alan Dyer in his "Deep-Sky Observing Hints," descriptions and sketching work together to help train the eye to see subtle detail at the eyepiece. Those wishing to learn the art of sketching should check out Mark Bratton's article:

www.skynews.ca/become-a-better-observer-sketch.

Seeing is in some respects an art that must be learnt.

– William Herschel

Back to my first star party, Nova East. At the time it was held in Fundy National Park, now an RASC-designated Dark-Sky Preserve, where I was indoctrinated into the ranks of *visual observers*. Sure, I had been watching meteor showers, lunar eclipses, and finding planets among the constellations from an early age, but the experience of setting my telescope alongside others in the observing field was something wholly different. It was like seeing the sky anew as some of the most experienced observers in the RASC began filling in my knowledge gaps and introducing me to entirely new paths for exploration.

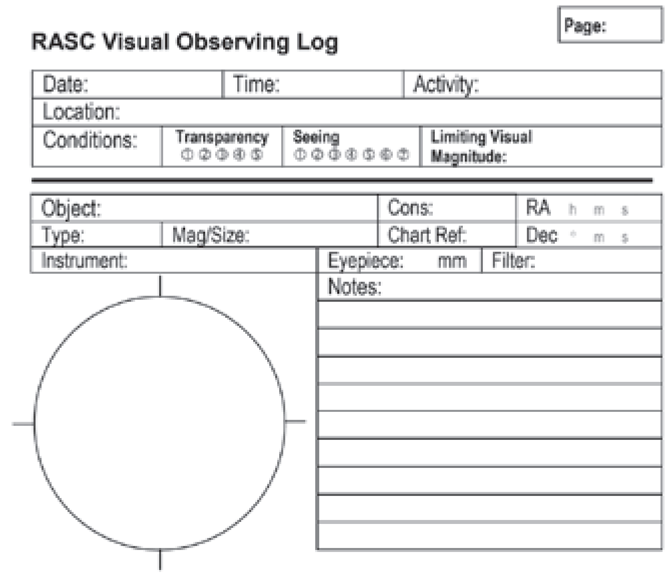

RASC Visual Observing Log
Page:
Date: | Time: | Activity:
Location:
Conditions: | Transparency ① ② ③ ④ ⑤ | Seeing ① ② ③ ④ ⑤ ⑥ ⑦ | Limiting Visual Magnitude:
Object: | Cons: | RA h m s
Type: | Mag/Size: | Chart Ref: | Dec ° m s
Instrument: | Eyepiece: mm | Filter:
Notes:

Figure 3 — RASC Observing Log Form Example.

I had never heard the phrase "visual observing" before Nova East and this activity was different from the stargazing I had become accustomed to. Visual observing was focused, purposeful with an atmosphere of discovery, all with the sense that these clear, dark skies are precious, few and far between, and the night is never long enough.

In the earliest days of the RASC, like-minded individuals, *always* in formal dress, set up their instruments to observe and document night sky happenings. In fact, the *Observer's Handbook* title dates back to 1912, with the work comfortably referring to those of us who undertake these nocturnal explorations simply as *observers*.

The hope of the RASC Observing Committee is that observers will use the new resources with our RASC observing programs to improve their skills so they will have a more enriching experience. I hope that a century from now visual observers will still exist and that they will continue looking up and maybe chuckle at our attire but remain connected to us through the shared experience of setting up an instrument as the night grows dark, and that they too will forge a relationship with the night, if only for a few hours. ✶

Chris Beckett is a past chair and now a regular member of the Observing Committee, a long-time binocular and small telescope observer and author of the RASC Observer's Handbook WIDE-FIELD WONDERS. *Since 2012, he has been the Continuing Education Astronomy Instructor at the University of Regina and enjoys observing under the dark skies of Grasslands National Park in the desert environment of southwestern Saskatchewan.*

Astronomical Art & Artifact

The Republic of Letters

by R.A. Rosenfeld, RASC Archivist
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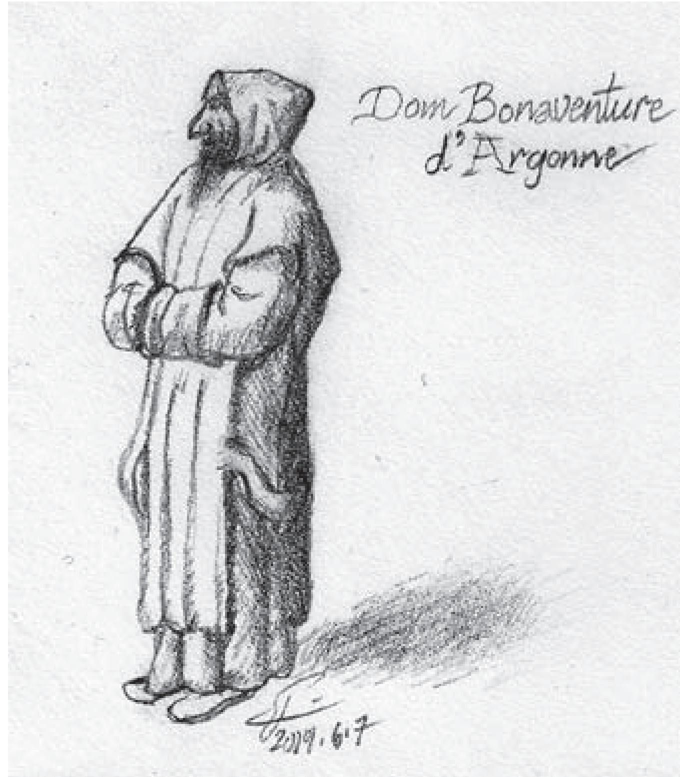

Figure 1 — There are no known surviving portraits of Dom Bonaventure d'Argonne, so one was commissioned for this paper. It shows a speculative Dom Bonaventure in the Carthusian habit of his day. Image reproduced courtesy of the Specula astronomica Minima.

Abstract

The Republic of Letters (16th–18th centuries) was a constructive ideal of cooperative intellectual endeavour that created the space in which meritocratic learned societies such as the RASC could exist. Its legacy includes both modern internet-based amateur astronomical communities with participants located across the globe, and professional big-science projects, such as the Large Hadron Collider (LHC), the Thirty Metre Telescope (TMT), and the Maunakea Spectroscopic Explorer (MSE) with their multi-national personnel. An important early description of the Republic of Letters was by the Carthusian monk Dom Bonaventure d'Argonne (1640–1704), who had an interest in astronomy. His text is notable for its acknowledgment of the legitimacy of female participation in the republic of letters. His essay is translated in full for the first time here.

The Republic of Letters (heyday 16th–18th centuries)

The Republic of Letters, a meritocratic, open, and international community of scholars, was in concept and reality a voluntary commonwealth that flourished chiefly from the 16th to the 18th centuries. As a constructive ideal of cooperative intellectual endeavour, it was a powerfully formative influence in shaping the space in which the earliest meritocratic learned societies existed, such as Accademia dei Lincei (1603–1639), the Royal Society of London for Improving Natural Knowledge (1660), and the Académie royale des sciences (1666–), and their younger siblings, including the Royal Astronomical Society (1820–), and the RASC (1868–). The Republic of Letters can be seen as a direct distant progenitor on the one hand of self-governing internet amateur astronomical communities with worldwide reach, and, on the other, of professional big-science projects, such as the Large Hadron Collider (LHC), the Thirty Metre Telescope (TMT), and the Maunakea Spectroscopic Explorer (MSE), with their multinational personnel. It was a concept of undisputed power and lasting influence, remarkable for a diffuse association that in reality lacked direct control of any of the levers of political power.

The October *Journal* deadline for submissions is 2019 August 1.

See the published schedule at www.rasc.ca/sites/default/files/jrascschedule2019.pdf

An expert on Pierre Bayle (1647–1706), a notable and deservedly apotheosized citizen of the Republic of Letters, has usefully characterized it as follows:

"The expression [Republic of Letters] was used…to refer to the shared pursuit of knowledge for the common good, and it never lost this primary meaning, although it was invested over time with other meanings and symbolic powers of representation…. Scholars such as Erasmus also thought in these terms, seeing themselves as citizens of the world…and members of the respublica litteraria, which united all like-minded people everywhere, past, present, and future. The Republic of Letters was, then, a conceptual space defined in terms of cosmopolitanism and universality…. It was, however, also an actual space defined by a common language, Latin (the language of education in this period), networks of communication, and cooperative enterprise. Although scholars did travel between different centers of learning and acted as vectors of information, communication was for the most part by correspondence" (Whelan 2003, 437).

An excellent introduction to the history and meaning of the concept was published by Tony Grafton in 2009, and is available online (Grafton 2009; a similar, though less far-ranging treatment is in Waquet 2017; and for some oddly illuminated corners of the concept, see Daston 1991).

The Republic of Letters depended in every respect on intellectual interchange. The sites for local face to face discourse were as various as "…printing shops, salons, museums, libraries, schools, universities, and, academies," while over further distances "The international networks of men of letters were knitted together by correspondence and publications, and by travelling scholars" (Dixhoorn & Sutch 2008, 12). Looking back over the broad course of the Republic, the letter appears as the essential technology for communication. A direct line of descent can be discerned from the handwritten letter, to the typed letter, to email and latter modes of electronic communication (Potts 2011). And a letter was frequently more than just a letter in our sense; a manuscript letter was another legitimate form of publication alongside the printed word. Some treatises in epistolary form enjoyed a wide circulation in manuscript before they were ever printed, and some were never set in type at all (such as Copernicus's *Commentariolus*; Copernicus 1985, 75).

Astronomers were certainly part of the Republic of Letters from its early modern rise (see above, and Mosley 2007, 33–38). It is likely that nearly every attempt to bestow or attract astronomical patronage, call to join a research group, invitation to exchange views on research questions, request for or offer of data, support or criticism of a theory, gift of books or instruments, and well- or ill-mannered prosecution of an academic dispute, can best be read as transpiring within the context of the Republic of Letters. Even figures who we do not now view primarily as astronomers, could take part in the discussion of astronomical topics. Sticking to cometography alone, Pierre Bayle, mentioned above, who is usually thought of as a philosopher and proto-encyclopedist, first rose to prominence with his *Lettre sur la comète* (1682), subsequently expanded into the *Pensées diverses sur la comète* (1683), both editions of which argued against popular superstitious interpretations of celestial events as supernatural omens, among a manifold host of other matters. And Dr. Charles Burney, the great Georgian musicologist, published a treatise on modern comets in 1769 (he was a good friend of William Herschel; Burney 1769). This was, after all, the age of the polymath.

One of the most often-cited descriptions of the Republic of Letters in modern secondary literature is by the Carthusian monk Dom Bonaventure d'Argonne (1640–1704), an exact contemporary of Bayle's. Dom Bonaventure, like Bayle and Burney, had an interest in astronomy—he even collected telescopes at one time. His text is notable for its acknowledgment of the legitimacy of female participation in the common-

Figure 2 — Moon rise over the Grande Chartreuse, the mother house of Dom Bonaventure's order. It was remotely sited to give the monks some solitude. Carthusian houses could be located in urban areas, but the monks everywhere habitually led austere and mostly solitary lives. Miraculously, Dom Bonaventure avoided being intellectually isolated, or remote from the intellectual life of his contemporaries. Image reproduced courtesy of the Specula astronomica Minima.

wealth of intellect. Most readers of the *Journal* would not expect a monk to take that stand. Who was Dom Bonaventure?

Dom Bonaventure d'Argonne, O.Cart.

The Carthusian order, founded by Bruno of Cologne in 1084, was among the most austere forms of the coenobitic life. In the 16th to 18th centuries, when it seems all forms of monasticism were under attack from numerous quarters, and not just Protestant ones, and charges of decadence were not infrequent, the Carthusian was one of the few orders that was not thought to be in need of reform. The other side of that coin is that one rarely hears of any Carthusians having played an active role in the Scientific Revolution, or Enlightenment. One expects to read of Benedictines, Servites, Minims, and Jesuits actively contributing to natural philosophy as part of the literary scene, but not Carthusians. Except for Dom Bonaventure.

Dom Bonaventure is chiefly remembered today for his role in a literary quarrel outside the sciences, but he was a many-sided figure with competencies in the sciences as well as the arts (and he was hardly unique in that regard, if one thinks of Marin Mersenne, Athanasius Kircher, and Bernard de Fontenelle, to name a few). His modern biographer notes that Dom Bonaventure was familiar with the "…discoveries and theories of Bacon, Boyle, Hooke, and Newton, and the activities of the Royal Society.…", and, while on a version of the Grand Tour, in contrast to his companions who spent their money on clothes, he bought telescopes and microscopes (Rountree 1980, 56–57). He was at home with the cosmologies of Descartes and Gassendi, and probably knew the latter personally (Rountree 1980, 149). And he was said to have "…strongly disapproved of the attitude of the church in the Galileo affair.…" (Rountree 1980, 74). In some respects, he almost seems like a figure from the mid- to later-18th century: "So intent was he to reform, to bring a new liberalism, a, new flexibility onto pedagogy, so anxious was he to wage war on pedants" (Rountree 1980, 79).

Dom Bonaventure on the Republic of Letters

"The Republic of Letters is very ancient.[1] It seems that this Republic existed before the deluge, on the testimony of the columns mentioned by Josephus, on which all the principles of all the sciences were engraved.[2] At least one knows not to deny that soon after this great catastrophe, the sciences neither blossomed forth in the world, nor were much advanced.

The Republic has never been greater, more populous, more free, nor more glorious than it is now. It extends throughout the Earth, and is comprised of people from all nations, of every condition, of all ages, and of all sexes—women are no more excluded than the young. All kinds of languages are spoken there, living and dead. The sciences are joined to the arts, and manual works have their place; but religion is not consistent, and the morals, as in all the other Republics, are a mix of the good and the bad. One finds piety, and licentiousness.

The politics of this state are conducted more through words, in the form of maxims and vague reflections, than through actions and things. The populace derives all its strength from eloquence and reasoning. Its trade is entirely spiritual [*i.e.* intellectual[3]], and its riches are very meagre. It strives after glory and immortality, above all things. The magnificence of the vestments is not very great, and there are few cases of people who work only out of avarice, or to gain sustenance [*i.e.* the citizens of the Republic of Letters till its fields out of love rather than for material gain].

There are sects there in great number, and new ones form every day. The entire state is divided between philosophers, doctors, theologians, jurists, historians, astronomers, orators, grammarians, and poets, who each have their particular customs.

Justice is administered there by the critics, often with more severity than judgement. The populace has much to endure from these people, chiefly when they are punctilious[4] and visionary. They reduce, cut, or add as it pleases them; and no author can answer for his destiny when once he falls into their hands. When they [the authors] emerge, they are so cruelly ill-treated and mutilated, that they lose their sense, and reason. The trouble which they [the critics] give to authors to make them speak the truth, ordinarily serves only to make them speak against their intent, and their conscience.

Shame is the greatest torture for those culpable, and, in this land, the loss of one's reputation is the loss of life. And yet there are some who are shameless, and some 'knights of industry,'[5] who permit themselves to live at the expense of others; and some scroungers, who take the good portions, and snatch the bread from the hands of meritorious people.

The Public distributes the glory—but often with much blindness, and too much haste. This causes great complaints, and excites unfortunate murmurings in the Republic.

The dominant vices of this state are presumption, vanity, arrogance, jealousy, and gossiping. There reigns also a nearly incurable illness, which is called Fame, which desolates the entire country.

This Republic also has the misfortune to be infected with plagiarists, who are a species of bandit despoiling the countrymen. The corrupters of books and forgers, all very dangerous people, include rhapsodic schemers, and worthless fortune tellers entirely dependent on the public.

There one can find an infinity of the illustrious idle, and of the voluptuous, who seek out only readings concerning pleasure, who live off the state, and contribute nothing towards either its progress, or its glory. There are misanthropes, born werewolves, and pedants who are the terror of small infants, and the enemies of courtesy and decent manners.[6] There are found some among them, nevertheless, who have merit, concealed as under the skin of an ass, their cheerfulness under the skin and the form of the most stupid of all the animals.

I will not treat of the debauched of the Republic, those who have engineered their own untimely demise though quarrelsomeness of spirit, and excess of study; nor of certain ones who are so delicate that they know not how to endure anything,[7] nor of visionaries who revel in hollow fancies, and false systems. All this ought to be assumed in a Republic as vast as that of the Republic of Letters, which all sorts of people are permitted to reach, and to inhabit in imagination;" d'Argonne 1713, 67–71.

Dom Bonaventure's essay is notable, beyond the fact that it was penned by a Carthusian who was a citizen of the Republic of Letters. It offers a candid and not uncritical view of the community. There is a gentle hint of possible satire in some of it, but on the whole, the good of the concept outweighs the negative. Most striking is that dom Bonaventure considers the Republic of Letters in his day to be at a pinnacle. Membership is open to all, and national identity, social position, wealth, gender, and age form no barriers to participation. The ideal is cooperation in pursuit of knowledge. It is a concept which a century and a half later made it possible for four members of the working class to join forces with four members of the modest middle class in 1868 Toronto to form the group that in time became the RASC. And which encouraged full female participation in the pursuit of science before the franchise was won by women in the political sphere. It's a concept that is the embodiment of international cooperation, strives for fact-based judgement, and disinterested research. It is the very anthesis of narrow populism, destructive nationalism, and worse trends. And it has a clear timeliness for the present. ✶

Acknowledgments

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

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(accessed 2019 June 4)

Endnotes

1 According to Grafton, the concept became a reality *ca*. 1500 (2009, 1), while Waquet states that the first recorded use of the term dates to 1417, but that the "modern" meaning of the term is not fully found till the end of the 17th century (yet she cites convincing evidence that this happened in the century before; 2017, 66–67). Dixhoorn & Sutch (2008), and their colleagues experiment with finding the origins of the republic of letters as early as the late 12th century in Northern Europe—with variable success. Br. Bonaventure's discovery of the concept in early biblical history is a type of backdating not uncommon to his era.

2 The story as recorded by Josephus in his Jewish Antiquities is as follows; "…they [Adam's grandchildren] also discovered the science of the heavenly bodies and their orderly array. Moreover, to prevent their discoveries from being lost to mankind and perishing before they became known—Adam having predicted a destruction of the universe. at one time by a violent fire and at another by a mighty deluge of water—they erected two pillars, one of brick and the other of stone, and inscribed their discoveries on both; so that, if the pillar of brick disappeared in the deluge, that of stone would remain to teach men what was graven thereon and to inform them that they had also erected one of brick. It exists to this day in the land of Seiris[!];" Josephus, 1930, 5, I, 32-33, ls. 70-71.

3 "Spiritual, is also said of an enlightened spirit, and of one who possesses excellent wisdom and excellent knowledge. A person is very spiritual, who possesses much spirit. [*E.g.*] The invention of clocks is very spiritual, very ingenious;" Furetière 1690, 2, n.p.

4 Punctilious (*vétilleux)*, that is to say, those who possess a mediocre spirit, *e.g.* "This man is someone of small spirit, who is only amused by trifles and trivialities;" Furetière 1690, 2, n.p. It is in some respects the opposite of those who are ingenious (see note above). Visionaries (*visionnaires*) are those who act extravagantly, *e.g.* "Visionary…he who is subject to visions, to follies, and to faulty reasoning;" Furetière 1690, 2, n.p.

5 "They are proverbially called Knights of Industry, men who possess no worldly goods, who subsist by their adroitness and industry, as swindlers, flatterers, despoilers, and advisors;" Furetière 1690, 1, n.p.

6 One might be tempted to see these as ancestors of the modern internet troll.

7 The modern insult "snowflake" does not appear to have been in use at the time.

I'd like to bring to readers' attention a source I'd missed in The Pleiades, the Deluge, and the Dead: How the RASC Became a Publisher of Anthropology in the Service of Theology, JRASC 113, 3 (2019 June), 98-104. In response to Chant's serial reprinting of Haliburton's treatise, Dr. Herman S. Davis recounted his encounters with Haliburton in C.A.C. (1920). Recollections of R.G. Haliburton, JRASC 14, 2, 84-87. I wish to thank Dr. Donald C. Morton for this reference."Recollections of R.G. Haliburton, JRASC 14, 2, 84-87. I wish to thank Dr. Donald C. Morton for this reference.

Skyward

Trinity

By David Levy, Kingston and Montréal Centres

As the world prepared for war in 1939, a group of physicists was studying how to reproduce the behaviour of a star on Earth: to split an atom, either quietly to provide a virtually unlimited source of power, or explosively to create a weapon of mass destruction. Worried that the Germans might develop an atomic bomb first, astrophysicist Leo Szilard wrote a letter to President Roosevelt suggesting that Americans develop the bomb first. Thinking that the letter would have more impact if it were signed by the foremost scientist of that time, Szilard made two visits to Albert Einstein's summer home in Cutchogue, Long Island, New York. They persuaded him to sign the letter.

Figure 1 — Inscription on the obelisk at Ground zero.

Einstein's letter had an immediate and powerful impact on Roosevelt. He immediately set in place the initial research that led to the start of the Manhattan Project in June 1942. Within three years, the first plutonium nuclear device was test-detonated near Socorro, New Mexico, in the Jornada del Muerto (ironically translated to Dead Man's Journey) desert. J. Robert Oppenheimer named the actual test site Trinity, after the first lines in John Donne's Holy Sonnet 14:

> *Batter my heart, three-person'd God, for you*
> *As yet but knock, breathe, shine, and seek to mend;*
> *That I may rise and stand, o'erthrow me, and bend*
> *Your force to break, blow, burn, and make me new.*

On 1945 July 16, at 5:29:45 a.m., the nuclear device detonated, and the atomic age began. Just one month later, two bombs were exploded over Hiroshima and Nagasaki, Japan, and the Second World War came to a sudden end.

Figure 2 — The remains of a footing from the tower that supported the bomb, and which was incinerated that day.

It is now 73 years later. On April 6 our daughter Nannette, son-in-law Mark, grandson Matthew, friend David Rossetter, and Wendee and I visited Trinity Site. It was a special and emotional experience for us. We felt the shudder and silence of those who witnessed the blinding flash of light that turned dawn into noon across that lonely desert. The power and force of the detonation reinforced the feeling of scientists there that this weapon was not a joke. It was used in combat twice, and it is now a part of history. We visited that day to experience the effect on people who felt the shock wave from 257 kilometres away and who had to replace broken windows in Albuquerque, where our family lives today. We didn't see much trinitite there, as the army did an excellent job removing the radioactive glass. We did not get much exposure to radiation either; according to army statistics, our one-hour visit to Ground Zero gave us at most one millirem of radiation exposure, compared to an average annual dose of 620 millirems from medical and natural sources.

As we left the site, we passed a protest going on at the entrance. After all these decades, what happened that rainy July day in 1945 still has a profound effect on the people who lived and live in the atomic age. For a second that day, humanity witnessed the process of a star here on Earth. And when I got home that night and looked up at the peaceful stars, I shuddered again.

Figure 3 — The Schmidt-McDonald house, where the bomb was assembled. All photographs were taken by David Levy.

Jeopardy James

Of all the programs that Wendee and I enjoy on our television set, the game show *Jeopardy* is one of our favourites. For a half hour each day, Wendee and I play along as the three contestants try to respond correctly to host Alex Trebek's clues. In our tradition, if Wendee or I get a question answered, we applaud each other. It's fun. We were saddened to learn of Trebek's cancer diagnosis, and we hope he will continue to enjoy a long life. Last month the show has been unforgettable. In his first 31 days as a contestant, James Holzhauer has earned an astonishing $2,462,216 in winnings. On the show that aired Friday, May 31, Holzhauer won $79,633.

Wendee and I particularly enjoy the astronomy clues that come up on shows like *Jeopardy*. Here is a clue from last Friday: "On November 12, 1833, these meteor showers were seen across all of North America, sparking the serious study of meteor showers." Jeopardy James got it right: "What are the Leonids?"

The Leonids are a meteor shower that occurs whenever the Earth punches its way through the sand-grain-sized debris left by a comet. The debris spreads out across the comet's entire orbit about the Sun. In the case of the Leonids, when the parent comet Temple-Tuttle itself appears in the sky once every 33 years, a meteor storm, rather than a shower, sometimes occurs when meteors, or shooting stars, can fall at rates of a meteor per second. It happened in 1833, the year of the *Jeopardy* clue, in 1966, and somewhat less intensely over the period from 1996 to 2002.

Figure 4 — On 2019 April 23, I took this picture of a bright Lyrid meteor falling in the sky north of our Jarnac Observatory. It is not often I can actually capture meteors using a camera.

As I watched this program, my mind harked back to our visit to Australia in 2001 where we saw 2,406 meteors scratch the sky over the course of a few hours. The display that night began as our group was relaxing on a dry lakebed. A bright shooting star appeared in the east, brightened rapidly as it soared across the sky, then disappeared in the west. Before the cheering ended a second meteor repeated the event. At the height of the show, I witnessed nine meteors appearing simultaneously. We continued to see meteors well into the morning twilight.

I have observed meteors on more than 200 nights that began with a night at the original Jarnac cottage north of Montreal. I saw a magnificent, brilliant shooting star low in the southwest. The picture that accompanies this article is of a brilliant Lyrid that appeared to wave at me from the northern sky in late April of this year. Even though I have, and use telescopes each night, perhaps my favourite observing session happens when I sit down outside, look up, and watch the sky for these always welcome messages from space that we call meteors. Maybe someday, James Holzhauer will get to enjoy the shooting stars as well. ✶

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.*

Binary Universe

Attention Space-Flight Geeks

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

The new space race

Okay, this may not be strictly, completely, totally astronomy related but the mobile-device app reviewed herein does have a fair amount of astronomical content. Full disclosure: I'm a space-race geek. Arguably, a lot of us are.

I regularly follow many of the space agencies around the world. Now, I don't watch every single rocket launch and I don't monitor every event on the *International Space Station*, but when something has a significant science component, is about astronomy, cosmology, exoplanets, or space telescopes, or features a new probe landing on a distant SolarSystem body, I perk up.

It seems to me of late there is a new "race" emerging with commercial companies directly involved, more and more efforts at reusing rocket components, countries creating new agencies, space tourism set to start, etc. Lots going on around the world and in the Solar System.

NASA in your pocket

The biggest space organization, of course, is NASA south of the border.

I frequently go directly to NASA's main website or www.spaceflightnow.com for up-to-date information. But did you know there's an app you can load on your iPhone or your Android that will aggregate US spaceflight and astronomy information for you? I'm talking about the official NASA app. It's free and fun and gives us access to a massive collection of material, words, images, videos, audio, tweets, and occasional live-streamed content from the agency created way back on 1958 July 29.

iOS: https://itunes.apple.com/ca/app/nasa/id334325516

Android: https://play.google.com/store/apps/details?id=gov.nasa

I tested version 4.0.14 for the Apple product and 1.87 on my Android device.

Modes

The main starting screen (Figure 1) shows a wide All News tile at the top. The other tiles are Images, TV and Audio, Videos, Missions, Tweets, and Featured. To catch your eye, the tiles update automatically and cycle.

Figure 1 — NASA app on iOS. Dynamic main screen with wide News tile and smaller mode-specific tiles

Tapping the News tile brings up current and late-breaking information as it occurs across the expansive US government agency. This section alone could keep you busy for quite a while. I noted there are more than 8000 articles available for our reading pleasure. Happily, a search button allows whittling down to a short list with a good keyword.

The Images section (Figure 2) displays random photographs and digital images. Some of these are as evocative of those appearing on the APOD website, perhaps a well-processed image of a galaxy. Sometimes you'll spot an old black-and-white shot from an early Gemini or Apollo mission. You may perhaps notice an annotated stitched image from a Mars rover. You'll find many astronaut pics. The images can be shown full screen or with accompanying text. They can be downloaded or you can run a slide show. In News mode, the helpful search

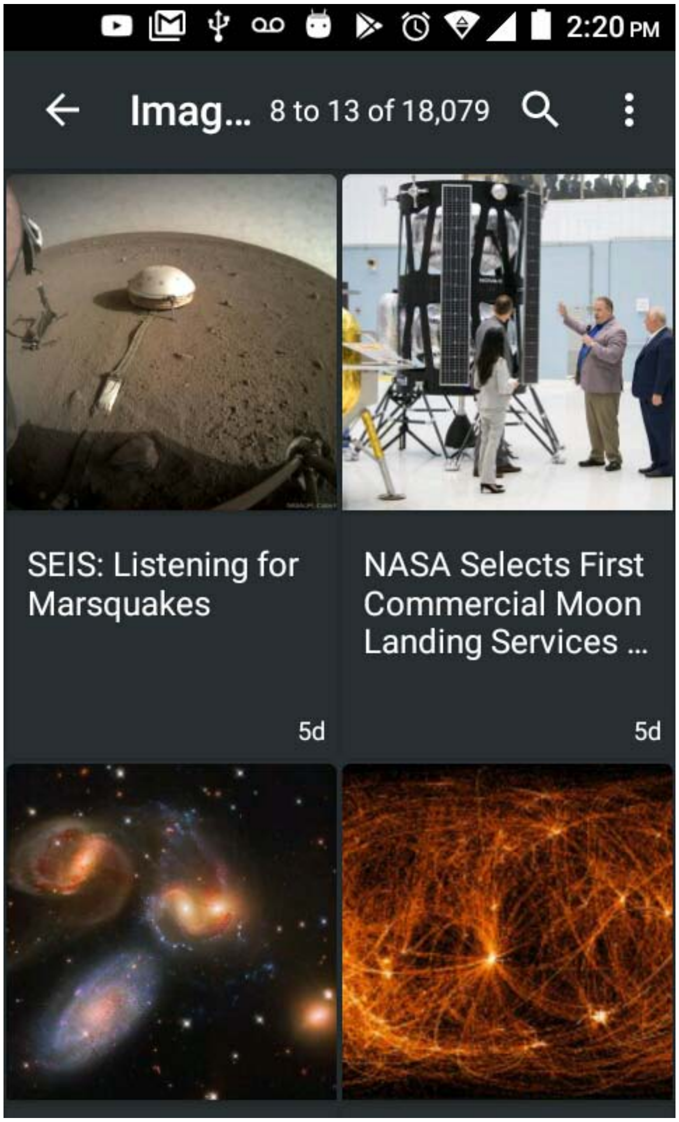

Figure 2 — NASA app on Android. Images section.

feature allows the user to find particular shots from the library of over 18,000!

A fun little feature you can use is telling the app that you want to make an image serve as the "wallpaper" for your device. Easy-peasy.

The TV and Audio section obviously lets you pick a video or sound clip to play, including items aimed at the public as well as media press content. You can view the Earth from orbit with the ISS Views section. There is a Podcast area giving you access to various audio recordings along with the regular This Week @NASA (TWAN) updates.

In the Audio Podcasts section, there are many items one might access. The menu button allowsyou to apply filters to shorten the list.

The Videos section enables you to peruse many archived video clips in a few different formats, including 4K and 360˚ content.

Figure 3 — In the NASA app watching a video full screen.

I found and watched a short movie in full-screen mode (Figure 3) celebrating the 29th anniversary of the *Hubble Space Telescope*.

The Missions tile offers a great deal of information on space telescopes, landers, rovers, and so on, and not always ones entirely under NASA control. At the top is the Launch Schedule, good for planning a rocket launch viewing road trip. The Sighting Opportunities for the ISS lets you check for local passes. Below is an alphabetic listing of future, current, and past missions.

I loaded up the *Transiting Exoplanet Survey Satellite* (TESS) page and reviewed the associated images, Videos, and News items (Figure 4). When viewing the ISS page, the Globe and Map options are available. These dynamically update of course.

If it's your thing, you can also review Tweets from NASA. You can monitor all short messages via Twitter-verse or filter from specific groups, centres, or astronauts (Figure 5).

Finally, the Featured Items mode appears to draw curated content from the various categories together thematically with topics on the solar system, the NASA centres, and the Earth as Art image collections and maps, to name a few.

In various places inside the NASA app it is possible to mark items as a "favourite" and to share content.

Via the Settings panel from the main screen, app notifications can be configured, including alerts on flyovers of the *International Space Station*. On Android, a dark theme may be toggled on.

There is much to explore in this little app!

Summary

With this simple app channelling official source content from NASA, you're sure to stay current on general events,

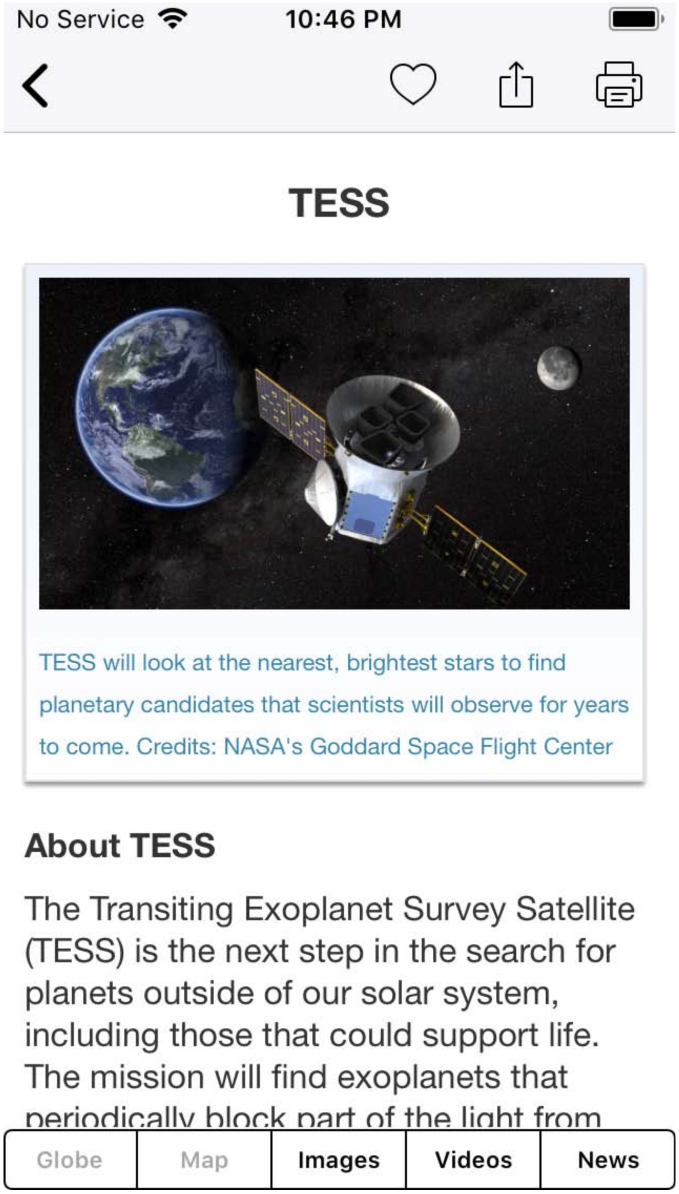

Figure 4 — NASA app on iOS. A specific mission page.

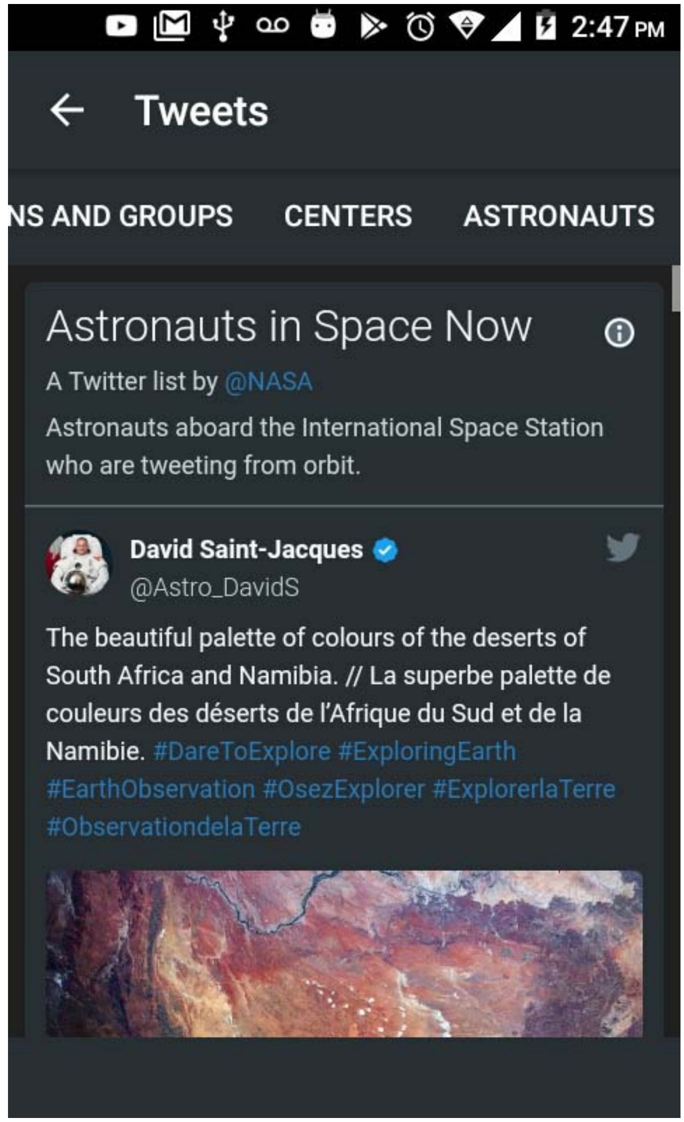

Figure 5 — Twitter feed within the NASA app for Android.

learn about space missions, science, history, and enjoy many fine images. It is a fun app for long-time fans of NASA; the jam-packed mobile application is great for kids and youth interested in the planetary science, astronomy, cosmology, human spaceflight, and so on. It should also prove handy too for homework assignments and projects with careful searching of the extensive content.

The software programs on iOS and Android are nearly the same. I do prefer the appearance of the app on Android with a more pleasing Dark Mode theme.

The NASA app is very network dependent and doesn't work if you're offline. Unless you have a generous data plan on your mobile device or smartphone, you may want to be judicious in using the app when out and about.

Now if you'll excuse me, I've got some NASA geeking out to do…

Bits and Bytes

The 1903 update for Windows 10 improves on RAW camera image support. Until now, you couldn't open RAW files in Windows. With the RAW Image Extension tool from the Microsoft Store you can. ✶

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

CFHT Chronicles

40 Years and a Users' Meeting

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

Every three years, CFHT hosts a Users' Meeting in one of the countries in its partnership. This year's meeting was held May 19–22 in Montréal, Canada. The User's Meeting gives CFHT staff and users the opportunity to discuss the science, instrumentation, and overall state of CFHT. For many CFHT staff members, the meeting is the first time they can meet people in person who they exchange regular emails with. And for our constituency of astronomers, they meet the people who ensure they receive the highest quality data.

The Users' Meeting was full of exciting science and discoveries, some of which are so new that they simply cannot be shared yet. But we can provide a summary of other science programs, with a special emphasis on our large programs, which shared status updates at the meeting.

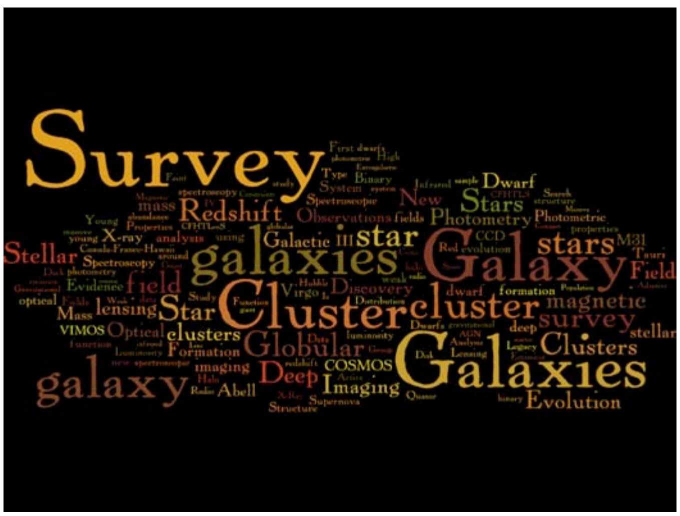

Figure 1 — Word Cloud of CFHT publication keywords. Credit: Dennis Crabtree, NRC

Before we dive into the Users' Meeting, let us take an in-depth look at our latest news release from Rodrigo Ibata and his collaborators, long time CFHT users.

Omega Centauri's lost stars

A team of researchers from the Strasbourg Astronomical Observatory, Bologna Observatory, and the University of Stockholm has identified a stream of stars that was torn off the globular cluster Omega Centauri. Searching through the 1.7 billion stars observed by the ESA *Gaia* mission, they have identified 309 stars that suggest that this globular cluster may actually be the remnant of a dwarf galaxy that is being torn apart by the gravitational forces of our Milky Way Galaxy.

In 1677, Edmond Halley gave the name "Omega Centauri" (ω Cen) to what he thought was a star in the Centaurus constellation. Later in 1830, Sir John Herschel realized that it was in fact a globular cluster that could be resolved into individual stars. We now know that Omega Centauri is the most massive globular cluster in the Milky Way: it is about 18,000 light-years from us and contains several million stars that are about 12 billion years old. The nature of this object has been the subject of much debate: is it really a globular cluster, or could it be the heart of a dwarf galaxy whose periphery has been dispersed by the Milky Way?

This dwarf galaxy hypothesis is based on unique features found in ω Cen and no other globular clusters. It contains several stellar populations, with a large range of metallicities (i.e. heavy element content) that betray a formation over an extended period of time. Most other globular clusters are composed of a seemingly a single generation of low metallicity stars, implying they all formed at roughly the same time from the same molecular cloud. If ω Cen is a tidally disrupted dwarf galaxy, astronomers would expect to find debris from the cluster scattered along its orbit in the Milky Way.

We have discussed the topic of galactic cannibalism before, about a year ago in a column on Stephan's Quintet. A short recap: Galactic cannibalism occurs when the gravitational forces from a larger galaxy or group of galaxies slowly tear apart a smaller galaxy. Characteristic features of galactic cannibalism are streams or halos of stars orbiting the larger galaxy.

Astronomers see evidence of galactic cannibalism around our Milky Way in streams of stars orbiting the Milky Way that were torn off by gravitational tidal forces. These stars remain visible for a time as stellar streams, before becoming dispersed in the vast volumes of interstellar space surrounding the massive galaxy.

By analyzing the motions of stars measured by the *Gaia* satellite with an algorithm called STREAMFINDER developed by the team, the researchers identified several star streams. One of them, named "Fimbulthul" (after one of the rivers in Norse mythology that existed at the beginning of the world), contains 309 stars stretching over 18° in the sky.

By modelling the trajectories of the stars, the team showed that the Fimbulthul structure is a stellar tidal stream torn off ω Cen, extending up to 28° from the cluster. Spectroscopic observations of five stars of this stream with the Canada-France-Hawaii Telescope show that their velocities are very similar, and that they have metallicities comparable to the stars of ω Cen itself, which reinforces the idea that the tidal stream is linked to ω Cen.

"The stars that the team observed were quite faint," says Dr. Nadine Manset, instrument scientist for Espadons and

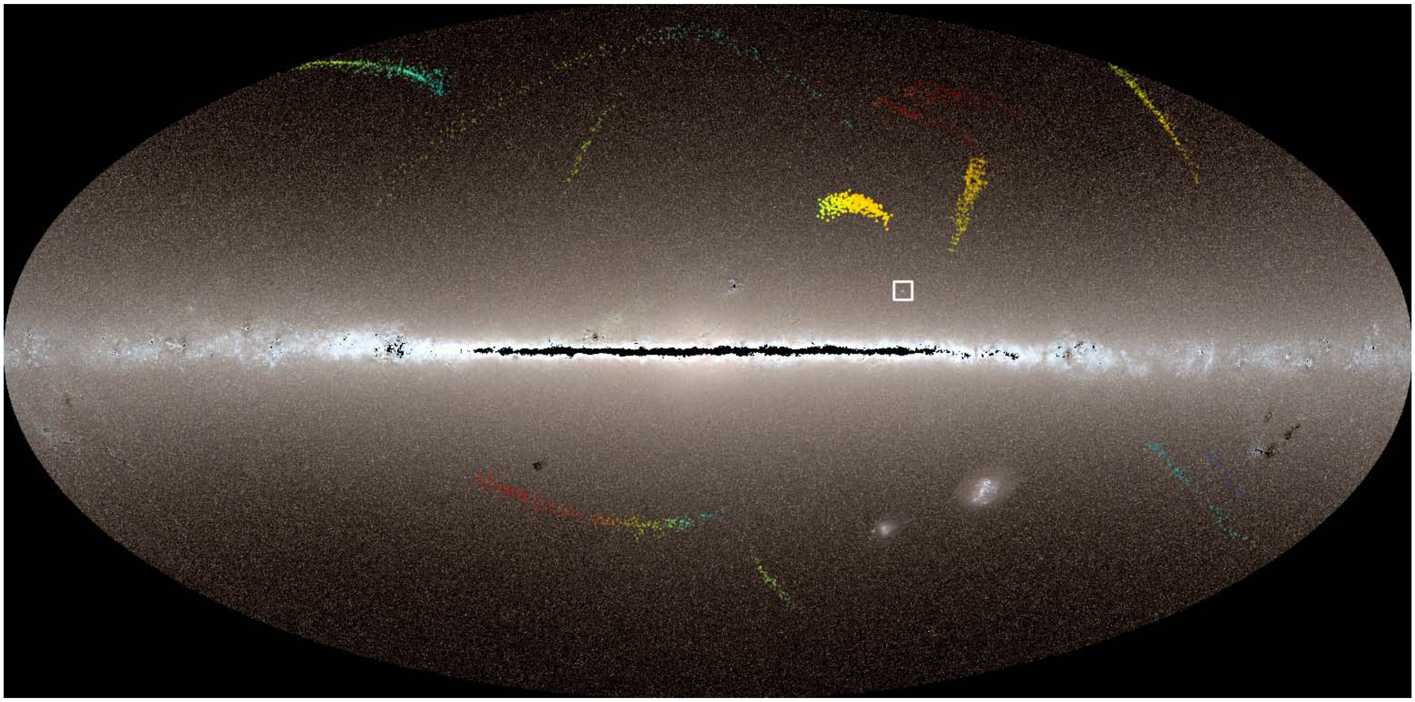

Figure 2 — The Milky Way, as seen by the Gaia *satellite. Streams of co-moving stars are shown coloured according to their motions as measured by* Gaia. *The "Fimbulthul" stream, which is due to stars lost from the omega Centauri globular cluster (white box), has been highlighted. Credit R. Ibata.*

CFHT's astronomy group manager. "It is great to see such challenging observations reinforce the Fimbulthul structure's link to ω Cen."

The researchers were then able to show that the stream is also present in the very crowded area of sky in the immediate vicinity of the cluster. Further modelling of the tidal stream will constrain the dynamical history of the dwarf galaxy that was the progenitor of ω Cen, and allow us to find even more stars lost by this system into the halo of the Milky Way.

The team's paper appeared in the April 22 edition of *Nature*.

CFHT's Users' Meeting Large Program Recap

On to the large programs! The first large program was the CFHT Legacy Survey or CFHTLS, which started in mid-2003 and finished in 2009. More than 2300 Megacam hours over 5 years (about 450 nights per year) were devoted to CFHTLS. I promised I would devote an upcoming column to the CFHTLS survey in my column on our large surveys last year. I have not forgotten…

In 2008, CFHT moved to smaller and more numerous large programs. The observing time can use several instruments and can be spread evenly over all semesters or concentrated on fewer, specified semesters. Multi-agency proposals are greatly encouraged, with the Principal Investigators (PIs) spread across the CFH partners. We currently have five large programs:

- The Canada-France Imaging Survey (CFIS)
  PIs Jean-Charles Culliandre and Alan McConnachie
  Megacam, 271 nights
- VESTIGE: A Virgo Environmental Survey Tracing Ionized Gas Emission
  PI Alessandro Boselli
  Megacam, 50 nights
- The CFHT Infrared Parallax Program: Mapping the Brown Dwarf-Exoplanet Connection
  PI Michael Liu
  Wircam 60 nights.
- The SPIRou Legacy Survey (SLS)
  PI Jean-Francois Donati
  SPIRou, 300 nights
- The Star Formation, Ionized Gas and Nebular Abundances Legacy Survey (SIGNALS)
  PI Laurie Rousseau-Nepton
  SITELLE, 54.7 nights

As a note, I will include text provided by the PIs found on either the CFHT or individual project webpages.

Let us start with CFIS, led by Jean-Charles Culliandre and Alan McConnachie (www.cfht.hawaii.edu/Science/CFIS/) and using Megacam. CFIS began observations in February 2017. CFIS is a critical component of the data needed for photometric redshifts in the *Euclid* space mission. For those unfamiliar, *Euclid* is a medium-class space mission through the European Space Agency (ESA) aimed at understanding why the expansion of the Universe is accelerating, and understanding the nature of dark matter. To achieve this, *Euclid* will track two complementary cosmological probes: weak gravitational lensing and galaxy clustering. *Euclid* has two instruments, a panoramic visible imager (VIS) and a near-infrared 3-filter photometer. VIS has a single, broadband filter covering a wavelength range of 550–900 nm.

VIS does not cover the ultraviolet, which is where CFIS fits in. *Euclid*'s ambitious goals are achievable only with homogeneous, multiwavelength data covering large areas of the sky. CFIS exploits the unparalleled u-band sensitivity, and excellent r-band image quality (IQ) of CFHT through two related survey components, enabling discoveries about structure formation from the Milky Way to high redshifts. The legacy value of CFIS will be its contribution to existing and future deep, wide-field northern surveys, leveraging the premier capabilities of CFHT. CFIS is also designed to complement existing northern sky imaging and the SDSS and DESI spectroscopic surveys, enabling countless new discoveries.

During the Users' Meeting, Cuillandre and McConnachie provided updates on the progress of CFIS and some new developments. Maunakea's winter weather the past two years (the worst in 30 years) has put the survey behind schedule. That is likely a topic that arose at the CFHT Science Advisory Committee (SAC) meeting following the Users' Meeting, so no comment on that yet.

On the bright side (a mini pun, CFIS requires dark time), Cuillandre discussed UNIONS, another program where CFIS joins forces with the University of Hawaii's Pan-STARRS program, providing the group unprecedented deep imaging of the northern sky. UNIONS or Ultraviolet Near-Infrared Optical Northern Sky adds the i- and z-bands from Pan-STARRS to the u- and r-band observations of CFIS. The team is pursuing a wide-area g-band survey with Hyper Suprime Cam at the Subaru Telescope. The combination of Pan-STARRS, CFIS, and HSCg will provide a five-band ugriz survey: the Hawaii UNIONS Survey. The Hawaii UNIONS Survey will be the dominant ground-based multi-band ugriz wide-field survey for the extragalactic sky in the Northern Hemisphere. Eugene Magnier, current UH astronomer and former CFHT astronomer, spoke in depth at the meeting about UNIONS.

Moving to another survey, VESTIGE! Did we mention Maunakea experienced the worst winter in the past 30 years….? VESTIGE noticed as well. VESTIGE or the Virgo Environmental Survey Tracing Ionized Gas Emission is a narrow-band imaging survey of the Virgo Cluster. For frequent readers of this column, you may recall the last column highlighted a recent discovery made by the VESTIGE team regarding M87.

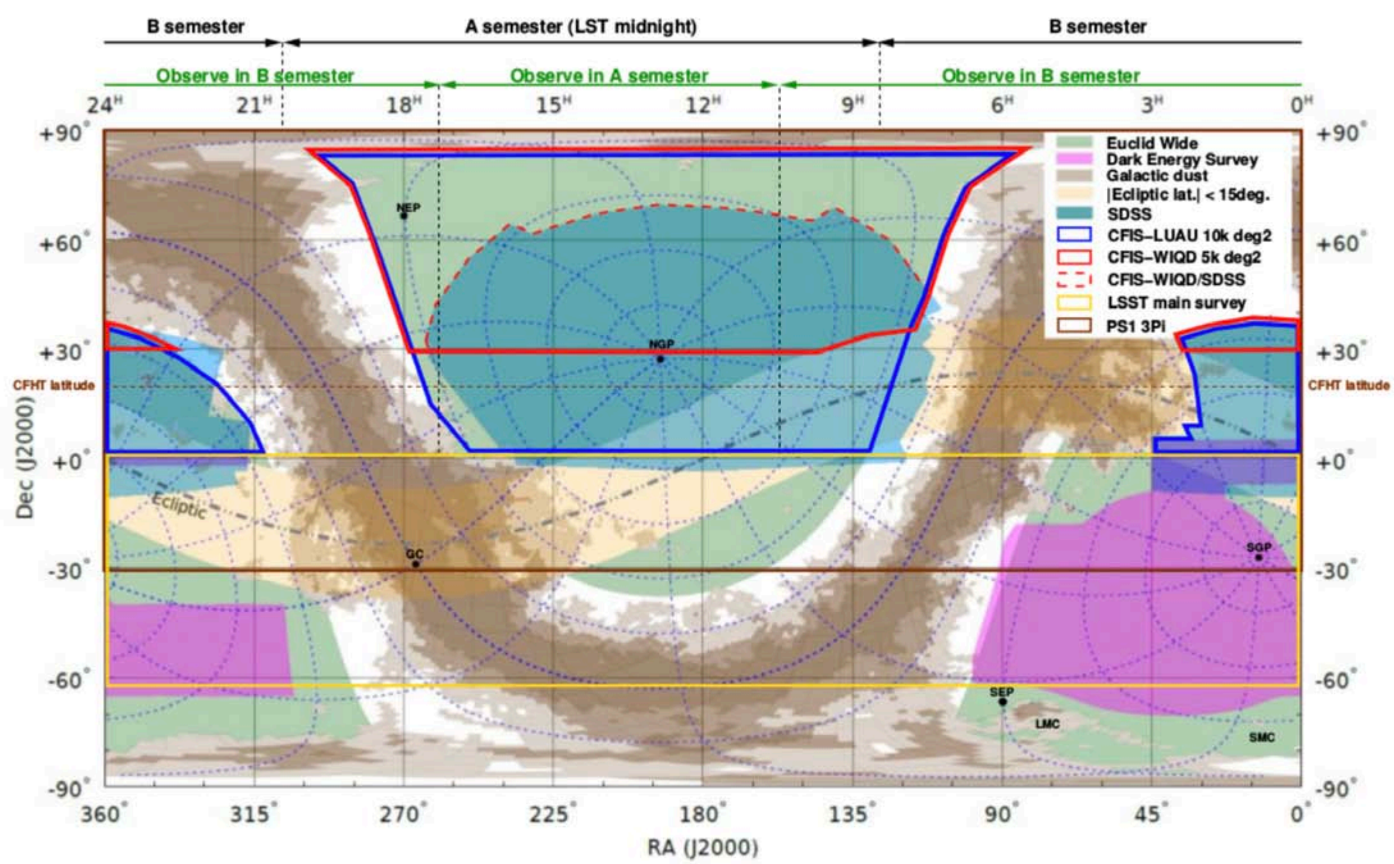

Figure 3 — The CFIS sky. Photo credit: CFIS team.

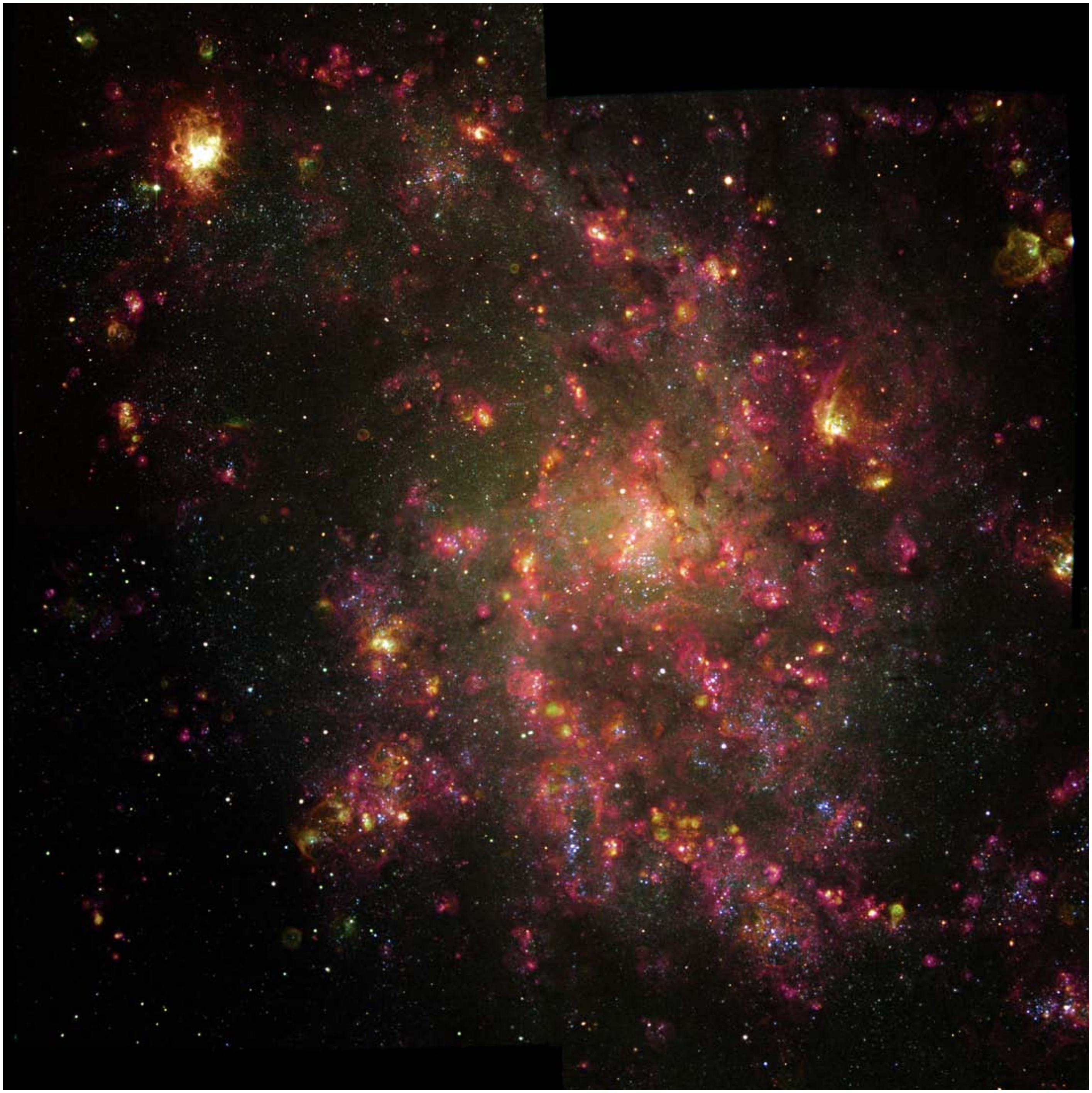

Figure 4 — Four-field mosaic of the centre of M33 with SITELLE. The colours are associated with blue, green, and red SITELLE filters. The image was made by combining emission lines and continuum. Photo credit: Laurie Rousseau-Nepton

The VESTIGE team proposed their program to understand the role of the environment on galaxy evolution. VESTIGE begins where the Next Generation Virgo Cluster Survey large program left off. With Laura Ferrarese as PI, the NGVS survey ran over 771 hours from 2008–2012 creating the deepest map yet of the Virgo Cluster. VESTIGE continues on the NGVS legacy with an H-alpha imaging survey of the Virgo cluster over ~200 square degrees. VESTIGE is the first deep blind H-alpha survey of a nearby cluster. The combination of data gathered with VESTIGE and simulations will allow astronomers to address a wide range of astrophysical questions: the star-formation process in galaxies, the fate of the stripped gas in clusters, the dynamical structure of the nearest galaxy cluster, extragalactic planetary nebulae and the origin of the diffuse intra-cluster light, the ionized gas emission in the Milky Way, and the star formation activity of high-z line emitters. The VESTIGE survey aims to be the definitive study of the perturbing mechanisms in high-density regions for years to come, but will yield the benchmark observational database against which the next generation of cosmological models will be tested. CFHT's narrow-band imaging capability is unique in its class for years to come.

With Virgo best observed in the spring semesters the VESTIGE team, much like CFIS, bore the brunt of the poor weather over the past two winters.

Our current crop of large programs includes the first LPs for two of our instruments, WIRCam and SITELLE. The WIRCam large program, the CFHT Infrared Parallax Program: Mapping the Brown Dwarf-Exoplanet Connection also holds the distinction of being the first large program without an acronym, a rarity in astronomy. Michael Liu from the University of Hawaii's Institute for Astronomy is the PI of the program. Much like VESTIGE, frequent readers of this column will be familiar with some of the work of Liu's program. We highlighted the discovery of a planet discovered by the team, 2MASS 0249c, in a 2018 column devoted to the search for other worlds at CFHT.

The story of Liu's program harkens back to 2008 when WIRCam was first installed at CFHT. Liu and his team have used WIRCam since the instrument's commissioning for a long-running parallax program. In 2017, using a decade of data, Liu and his collaborator Trent Dupuy (former UH grad student, current Gemini Observatory astronomer) constrained the mass limit on the brown dwarf/star boundary at 70 Jupiters. To do so, they studied 31 faint brown-dwarf binaries using CFHT and the W.M. Keck Observatory, plus the *Hubble Space Telescope*. They measured the mass of the binaries and created the first large sample of brown-dwarf masses. We covered this research in a 2017 column called "Wannabe Stars and CFHT in Canada."

With these new brown-dwarf discoveries probing the extremes of temperature, gravity, and age, extending into the planetary-mass regime and deepening the connection between brown dwarfs and directly imaged exoplanets, Liu received 60 nights on WIRCam to continue his PI program, now a CFHT large program. He and the team use accurate distance measurements via trigonometric parallaxes, including faint objects inaccessible to astrometry in the optical (e.g. *Gaia*). The three-year Large Program continues to use WIRCam to obtain high-precision infrared astrometry of these objects, in order to measure their fundamental parameters and to robustly test theoretical models of substellar evolution and ultracool atmospheres.

On to SITELLE! A quick primer on the instrument, SITELLE is an optical imaging Fourier transform spectrometer (IFTS) providing integral field unit (IFU) spectroscopic capabilities in the visible (350 to 900 nm) over an 11′ by 11′ arcminutes field of view, with a variable spectral resolution from R=2 to R>10^4, which allows for low to high spectroscopic studies. SITELLE is the direct successor of SpIOMM, a similar instrument attached to the 1.6-m telescope of the Observatoire du Mont-Mégantic in Québec. CFHT's excellent optical seeing of 0.8″ arcseconds measured in the R band is well sampled by the 0.32″ pixel scale of SITELLE. Mounted at the Cassegrain focus of CFHT, SITELLE is the largest visible IFU at this time. The SITELLE focal plane is made of two 2048 x 2048 pixels, low noise, e2V CCD231-42 cameras with a 5e readout noise in one-second read time and 3.5 electron in 2 seconds.

Put simply, SITELLE combines high-resolution images and spectroscopy over an 11 x 11 arcmin field of view, potentially providing 4 million spectra per observation, making it an awesome instrument on an awesome site. The beauty of Maunakea is that the high altitude permits superior transmission of UV light on the summit.

The first SITELLE LP is the the Star Formation, Ionized Gas and Nebular Abundances Legacy Survey (SIGNALS) led by CFHT's own Laurie Rousseau-Nepton. With 54 nights, SIGNALS aims to study 50,000 star-forming regions in nearby galaxies. The main goals of SIGNALS are: 1) to quantify the impact of the surrounding environment on the star-formation process; 2) to link feedback processes to the small-scale chemical enrichment and dynamics around star-forming regions; and 3) to measure variations of the resolved star-formation rate with respect to the indicators used for high-redshift galaxies. SIGNALS' datasets will be extremely rich and valuable for investigating many other physical mechanisms as well. It will produce complementary results to study planetary nebula abundance distributions and luminosity functions, supernova remnant ionization conditions, occurrence, and feedback contributions, background emission line objects (e.g. [OII] and Ly-α emitters), and much more.

Over the course of the SIGNAL program, Rousseau-Nepton estimates 800 GB of raw data will be created. However, SITELLE generates cubes of data as opposed to individual images. A single SIGNALS cube may be 10 GB in size. Loading the data is computationally intense, let alone analyzing it. To work around the size of the data, the SIGNALS team is working with the Canadian Astronomical Data Centre (CADC) to give PIs access to the data virtually. They are piloting a program where the SIGNALS team can access and analyze their data via a web portal. The portal will contain the most up-to-date versions of the data-reduction software and ease collaboration between the 68-member science team spread across 17 countries. We can not wait to see how the data turn out!

The SPIRou large program just started science observations this semester, so I will hold off on describing it in depth until I have a bit more information.

A huge mahalo to everyone who attended our Users' Meeting and helped us celebrate 40 years of science! ✶

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

John Percy's Universe

Donald A. MacRae (1916–2006): An Under-Recognized Canadian Astronomer

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

In my previous column, reflecting on the evolution of computing at the University of Toronto, I noted the pioneering work of Don MacRae (Heard and MacRae, 1957). Since then, I have been reminded of several other important contributions that Don made to astronomy in Canada. But he is relatively unknown now. He doesn't appear in the RASC's *Encyclopaedia Uranica* (1) and is mentioned only in passing in Peter Broughton's (1994) centennial history of the RASC, presumably because he was not particularly active in our Society. He is mentioned only briefly in Richard Jarrell's (1988) *The Cold Light of Dawn: A History of Canadian Astronomy.* He made no great astronomical discoveries. He was elected a Fellow of the Royal Society of Canada in 1962, early in his career, but otherwise his honours were few. He doesn't have an asteroid named after him. Yet he had a significant effect on astronomy in Canada—and on my own career. Broadly speaking, the reason for his influence was his wisdom, his ability to motivate and inspire his colleagues, and his broad interest in new developments in the field of astronomy.

Brief Biography and Research

Don was born in Halifax, N.S., received his BA from the University of Toronto (winning the RASC Gold Medal in 1937), and his Ph.D. from Harvard, working with Bart Bok on the structure of the Milky Way Galaxy from a study of stars in regions not in the galactic plane. After short stays in several U.S. institutions, including several years at Case Western Reserve University, he took a position at the University of Toronto in 1953. He served as Head of the Department of Astronomy from 1965 to 1978 (and automatically as Director of the David Dunlap Observatory: DDO) and retired as Professor Emeritus in 1982. His own research contributions were modest, but he catalyzed important developments in radio astronomy and space astronomy, and the developments of observatories in Hawaii and Chile, He served as a member and later as Chair of the Corporate Board of the Canada-France-Hawaii Telescope in 1978–79, at a crucial phase of CFHT development. As a department head, he built the University of Toronto into a powerhouse of astronomical research, undergraduate and graduate education, and public outreach. See (2) for more complete personal and professional biographical information, including a formal obituary by his former Ph.D. student and colleague Ernie Seaquist (2007).

Figure 1 — Don MacRae accepts a light-hearted award of "Best Astronomical Actor of 1960" from his staff and student colleagues at DDO. Source: University of Toronto, Department of Astronomy & Astrophysics.

Radio Astronomy

Don published a few papers in his first area of research—stellar astronomy—including one paper with me: Gulliver et al. (1972), but he quickly developed a special interest in radio astronomy stemming, perhaps, from earlier contacts with Charles Seeger and Ralph Williamson. This led to collaborative projects with the University of Toronto Department of Electrical Engineering (notably Allen Yen), the installation of small radio telescopes at DDO, and supervision of graduate student research projects by Don, Ernie Seaquist, and others, using local, national, and international facilities. This led, among other things, to Yen's involvement in the award-winning development of Very Long Baseline Interferometry (VLBI), along with a group of other Canadian university and government astronomers (Broten et al. 1967). VLBI is a powerful technique enabling independent radio telescopes to combine to obtain very high-resolution images of radio sources—including the widely publicized image of a supermassive black hole at the core of M87, released earlier this year.

Lunar and Space Science

In the 1960s, Don developed an interest in the nature of the lunar soil, and speculated that it might contain water ice, analogous to Arctic features called *pingoes*. Subsequent research has confirmed that water ice does indeed exist in some parts of the lunar surface. The Moon was of great interest in the 1960s, of course, and Don may also have been influenced by his geology colleagues at the Royal Ontario Museum, who had been studying terrestrial impact craters at the time. At my department's annual "Christmas countdown" in 1961, consisting of humourous skits and songs created by the students, I remember reference to the usefulness of Don's lunar water ice for cooling astronauts' beer.

On a more serious note, he ensured that our department was represented on the Canadian National Research Council's Associate Committee for Space Research. He was a member of the Board of Trustees of the U.S. Universities Space Research Corporation, serving as Chair in 1973, and was a member of the Lunar and Planetary Institute in Houston.

Education

I was an undergraduate in Astronomy and Physics at the University of Toronto from 1958–1962 and continued as a graduate student in 1962–63 and 1965–68. At that time, at least half of my fellow students continued in astronomy, rather than physics. That was partly because it was the "golden age" of astronomy (it still is!), but also because of the relative quality of teaching in the two departments. Don taught a third-year course. I remember him as prepared, organized, interesting, and approachable. He supplemented the core course and lab material with current techniques and topics such as radio astronomy. He introduced computing as part of courses and labs, perhaps reflecting his own pioneering work in astronomical computing (Heard and MacRae, 1957).

As a department head, he gave equal weight to research and teaching when hiring, mentoring, and promoting new faculty (such as me). He supported our large "bread and butter" courses in introductory astronomy for non-science students, while also overseeing a rigorous astronomy and physics curriculum for undergraduate majors such as me. Ernie Seaquist has reminded me that he also strongly supported the teaching of astronomy to physics students, because they could then understand how the physics that they were learning applied to the real world.

Two dozen graduate students were enrolled and, primarily for them, he encouraged and supported our annual four-day "June Institutes" to expose them to distinguished astronomers from outside the university. Our graduates have had a significant impact on astronomy around the world. If there had been teaching awards at the university at the time, I am sure that he would have been nominated for one.

Public Outreach

Don supported public outreach in many ways, including doing it himself, but is perhaps best known for his part in planning for the McLaughlin Planetarium, and for his "starring" role (Figure 1) in the award-winning National Film Board documentary, *Universe*—which can still be found on-line today (3). The planetarium was the brainchild of the Department of Astronomy, and the RASC, and was hosted by the Royal Ontario Museum (ROM). The ROM was part of the university at the time but separated in 1968 just as the planetarium opened. It was one of the world's major planetaria until its untimely closing in 1995. *Universe*, a half-hour documentary, shows Don during a night of observing at DDO (wearing a tie), while the film provides an overview of the excitement of modern astronomy. *Universe* is said to have inspired Stanley Kubrick as he began *2001: A Space Odyssey.* I showed it dozens of times at DDO as part of public and school outreach and, at one time, I could have recited the entire script by heart.

Administration

Don was Head of the Department of Astronomy from 1965 to 1978, the last department head with a career appointment, rather than a fixed term. His achievements can best be appreciated by reading the detailed annual reports—each several pages of two-column, single-spaced text—which heads were expected to publish in the *Bulletin of the American Astronomical Society*. The first was MacRae (1969); the last was MacRae (1979). He also contributed to the "Notes from Observatories" column in this *Journal*. Don oversaw a huge "baby boom" increase in undergraduate enrolment, staffing two new campuses, moving the department to four floors in the new McLennan Physical Laboratories building, installing and maintaining new telescopes and instruments on campus, at DDO, and at the University of Toronto Southern Observatory, as well as encouraging faculty whose work ranged from astronomical instrumentation, to infrared astronomy, to theoretical cosmology. To quote Seaquist (2007): "…his friends and associates shared an enduring respect for his wisdom, generosity, sense of humour, powers of observation, and rigorous attention to accuracy and detail" (even to the point of carefully editing the scientific publications of department faculty—including me—before they were submitted).

Reflection

This article causes us to wonder: what determines whether a memorable or influential person is recognized and remembered, and how can we ensure that our predecessors and their contributions are remembered? Jarrell's (1988) book covers the history of Canadian astronomy up to that time, but the subsequent history is more scattered. The Canadian Astronomical Society (CASCA) does have an active History Committee, but not much on its website. My department does not have an official historian, but several faculty members have contributed to the extensive history pages (4) on our website. The RASC has an excellent *de facto* historian Peter Broughton, and an equally excellent archivist Randall Rosenfeld, as well as several other history enthusiasts whose print and on-line publications document our history very well. But how can we ensure that these publications are read?

One way is by ensuring that both RASC and CASCA maintain active History Committees, to create resources and also to ensure that they are disseminated—presented at meetings, on websites, and in print. Perhaps they could offer tutorials or workshops on the basics of history and heritage research and publication. The majority of RASC members are "older" (and getting more so, like me), and are likely to have developed some interest in history and heritage. But it is less obvious how we can interest young professional and amateur astronomers in our astronomical history and heritage.

Acknowledgements

Much of this article is based on information in the history section of my department's website, and on my own personal experience. I thank our historians, archivists, History Committees, and all others who are keeping the history of Canadian astronomy alive. I also thank my colleague Ernie Seaquist for reading and commenting on a draft of this article. Most of all, I thank Don MacRae. He was my valued teacher and mentor, my department head when I began and developed my astronomical career, and my colleague for over two decades. ✶

Websites

1 www.rasc.ca/encyclopedia-uranica
2 www.astro.utoronto.ca/about/history/donald-alexander-macrae
3 www.nfb.ca/film/universe
4 www.astro.utoronto.ca/about/history

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Dish on the Cosmos

Seeing the Event Horizon

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

In April of this year, the Event Horizon Telescope (EHT) published the first images of material around a black hole, showing the telltale shadow of the event horizon (Figure 1). These images represented over a decade of effort to produce, making another amazing discovery through aperture synthesis, a key technique in radio astronomy. While the images showing the black hole were not a striking as many artistic renditions, they represent the first real view of the influence of black holes on the light around them

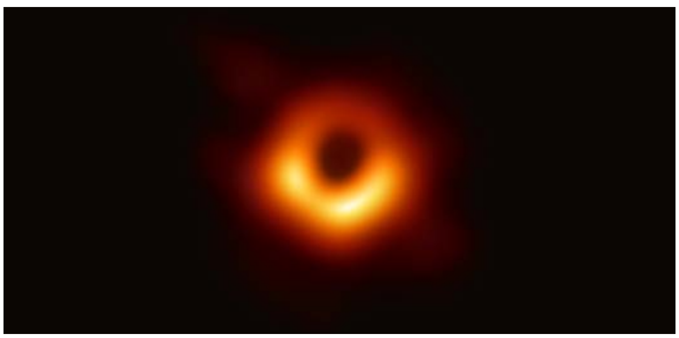


Figure 1 — The Event Horizon Telescope image of the shadow from black hole in M87. The black hole bends the emission from nearby plasma around it, casting a shadow from which we measure its mass and the presence of an event horizon.

Observing the size of a black hole is particularly challenging because black holes are the most compact objects in the Universe. The black hole in M87 has a huge mass (6.5 billion solar masses) but is only 120 AU across. The ring of emission seen in the images has a diameter of 42 micro-arcseconds, which is a factor of 1000 times smaller than a single pixel on the *Hubble Space Telescope*'s best imager. Reaching these incredible resolutions relies on the techniques of radio interferometry. This method relies of the wave properties of light, where the electric and magnetic fields oscillate up and down in a sine-wave pattern. Radio waves of emission from the same source are received by two different telescopes at different locations. The waves leave the source of emission in lock-step, with the electric fields moving up and down together while the wavefront spreads out. This wavefront is received at two telescopes at different locations on the Earth. Because the wave travels different distances to reach the telescopes, the two telescopes can receive the wave at different parts of its cycle, which is called the phase difference.

This analysis of the different parts of the wavefront to measure the phase difference is called interferometry. However, the full technique amplifies the capability of the interferometer through aperture synthesis. From the perspective of the emitting source, the Earth is turning underneath the arriving wavefronts. As the Earth turns, the relative positions of the telescopes change, and the phase difference also changes. With this method, the relative phases between different parts of the interferometer will slowly vary with the turn of the Earth. With multiple telescopes, the analysis of these changing phases gives us a precise understanding of the location of the radio source.

Aperture synthesis thus represents an excellent technique for determining the location of sources on the sky. It can easily pinpoint the location of bright sources to the precision of about 1000 micro-arcseconds precision, and with good effort to 10 times better precision. Doing so requires excellent understanding of the relative positions of the telescopes that compose the interferometer. The rule of thumb is that the distances must be known to 1/20th of a wavelength. Since interferometry uses centimetre or millimetre wavelengths, this amounts to knowing the separation between the telescopes to the precision of a hair's width. One the main applications of interferometers is for geodesy, measuring how the surface of the Earth is moving. To do this, the logic is reversed, and the sky source is assumed to be a known position, so the phases can be used to measure relative motion of the telescopes and the associated plate tectonics. Even after continental drift is considered, other effects like slight changes in the Earth's rotation speed and the effects of gravitation on the passage of time also need consideration.

Aperture synthesis can also be used to make images of the sky because it can measure the positions of astronomical sources precisely. Here the approach is used to distinguish the positions of different emitting sources that are nearby on the sky. The angular resolution of an interferometer depends on λ/D where λ is the wavelength of the light considered and D is the separation between the receiving telescopes. To get the best (smallest) resolution, the shortest wavelength light must be considered combined with the largest separations between observatories. The EHT pushes this limit to the extreme: observe with the shortest possible wavelengths for telescopes scattered across the Earth (Figure 2). The EHT combines nearly every telescope in the Western Hemisphere that can observe light with a 1.3-mm wavelength.

The EHT effort has been ongoing for over a decade with most of the effort focused on uniting these many observatories into a single facility. Some facilities had to get special upgrades to participate in the EHT network and the separations between the telescopes had to be carefully calibrated. At 1.3 mm, weather is a factor, so a successful campaign requires clear, dry skies at all the participating observatories. Finally, every telescope needs to coordinate their busy observing schedules to dedicate time to the EHT. The real success of EHT has been enabled by recent improvements to the observatories in

Figure 2 — Map of the telescopes participating in the Event Horizon Telescope network. By using telescopes across the globe, we are able to make images with the best possible resolution that is a requirement for resolving the black hole's event horizon.

the network, particularly the new Atacama Large Millimetre/Submillimetre Array. The new additions have dramatically increased the capabilities enabling the detection of the shadow from the M87 black hole.

The target choice is also key: more-massive black holes are larger, but more-distant targets are farther away. M87 has a huge black hole, even by galaxy standards (over 1000 times the mass of the black hole in the centre of the Milky way). In addition, the emission around the black hole needs to be steady. The black hole doesn't give off light of its own, but instead it casts a shadow, bending away or swallowing the light passing nearby. While the Milky Way's black hole is closer, it is smaller, and the emission is not as bright and steady as the light from the M87 black hole.

The actual light itself in the image arises from plasma (protons and electrons) near the event horizon. As the electrons in the plasma are accelerated by passing by protons or by twisting around magnetic fields, they give off light at radio wavelengths including the 1.3-mm wavelength observed by the EHT. Understanding the emission is difficult since it requires understanding how the light is moving around an object that bends and distorts the spacetime through which the light is moving.

Many scientists participating in the EHT focus their efforts on mapping out the expected patterns of light for different models of the black hole. The images that are shown of the black hole are actually the best-fitting models to the observed data from the radio telescope. However, these models also tell us a great deal about the black hole's properties. The size of the shadow tells us the mass of the black hole, since more-massive black holes are bigger. The direct detection of a black hole's shadow is a key success, proving the existence of the black hole. However, the prior evidence for these objects has been so strong that many astronomers focused on what else the image told us. First, the image is brighter on one side of the black hole compared to the other. This is the effect of the plasma orbiting around the black hole at speeds approaching the speed of light, so the light waves are compressed by the Doppler effect brightening in intensity. The other feature of note is that the black hole is round, showing that it is unlikely to be rapidly rotating, which would cause some flattening.

As with so many astronomical discoveries, this image is just the beginning of the study and not the end. Studying the changes in the black-hole emission over time will show how this black hole is being fed by the surrounding plasma. There are other targets too: our own supermassive black hole in the Milky Way is also being observed, though the conditions are slightly less favourable for a clean image detection. Even so, the differences will reveal more about the different environments hosting black holes and provide sensitive tests of Einstein's theory of relativity. Finally, new advances in observations will push to even shorter wavelengths where new targets become possible to observe. Black-hole astronomy has made a major leap but there are more lessons to come.✶

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

The Royal Astronomical Society of Canada

Vision

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

Mission

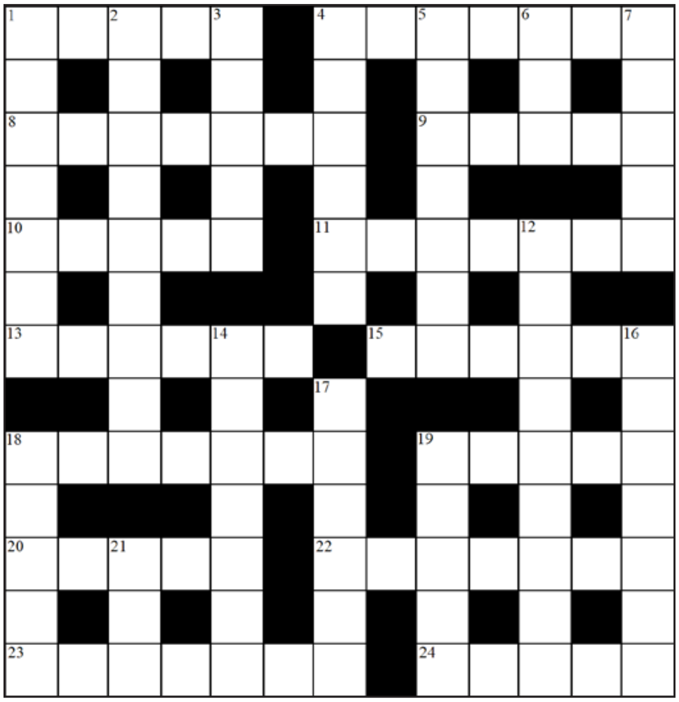
To enhance understanding of and inspire curiosity about the Universe, through public outreach, education, and support for astronomical research.

Values

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

Astrocryptic

by Curt Nason



ACROSS

1. The Big Bang was not in the cards, according to him (5)
4. It gives sharp views with the ins and outs of a telescope (7)
8. Music of the spheres guy (7)
9. Got an A+ on a lunar marsh (5)
10. Relatives of Corvus seen on board (5)
11. Col. Baum sky dove in the south (7)
13. Fly to the capital of Turkey from Oman (6)
15. Fathers hug everyone on a large asteroid (6)
18. Stellar sister seen around Jupiter of late (7)
19. She endured pain in Telesto ice fields (5)
20. Swelter from the heat of an eruptive O star (5)
22. He found a nearby star that's apt to be in key northern positions (7)
23. Chase doctor about a gem on the queen's breast (7)
24. A nest disturbed by Earth-crossers (5)

DOWN

1. Mare with funny sense of hesitation (7)
2. He has a moving effect on meteoroids (9)
3. Those rotating eyepieces are pricey (5)
4. Sue the writer who has gone by way of Houston (6)
5. LaPlace transformed a bright star (7)
6. Han didn't quite finish a voyage to this star (3)
7. Follows Jah as a star rotates (5)
12. Bartels leads men in Poe tribute to an asteroid (9)
14. Rod's vision indirectly prevented (7)
16. Study in SEDS program for a short time (7)
17. Karmen vortex is brightest in the whale (7)
18. M57 looks like a doughnut, sounds like a bull (5)
19. Early astrophotos were the colour of stewed peas, I imagine (5)
20. Popular observatory dome has rotated (3)

Answers to June's puzzle

ACROSS

1 CLUSTER (C(L)uster); **5** SONIC (anag); **8** VESTO (anag); **9** SILVERS (2 def); **10** RAMPART (ram+part); **11** TIAKI (ti(a)ki); **13** CANES VENATICI (anag); **15** LYRID (2 def); **17** ESTATES (anag); **19** ROULEAU (2 def); **21** LITRE (hid); **22** SAMOS (anag); **23** ALGIEBA (anag)

DOWN

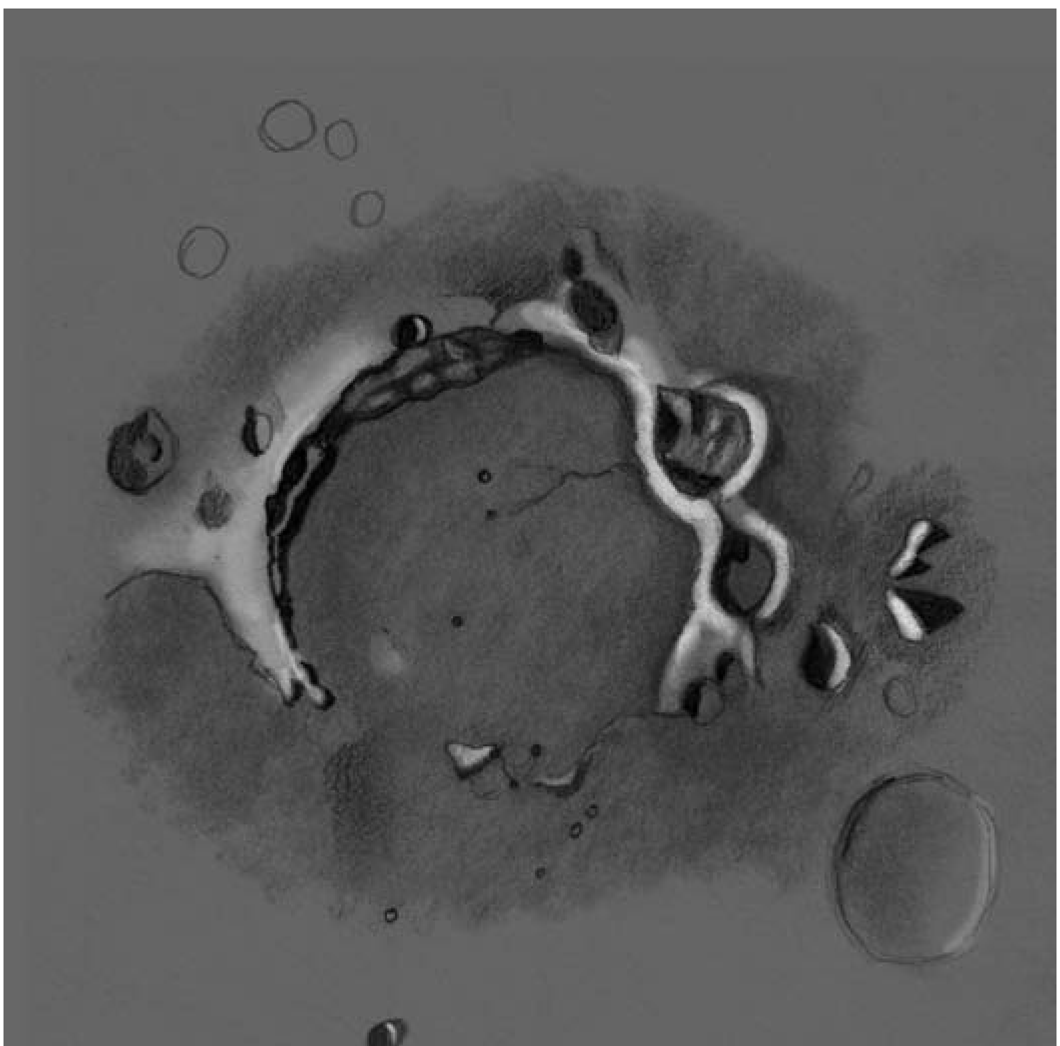
1 COVER (2 def); **2** URSA MINOR (anag); **3** TROJANS (2 def); **4** ROSETTE NEBULA (anag); **5** SPLIT (2 def); **6** NYE (2 def); **7** CASSINI (Cass+in+1); **12** ARISTOTLE (anag); **13** CALORIS (anag); **14** ANTILOG (anti+log) **16** DEEPS (hid); **18** SIENA (anag); **20** ULM (2 def)

It's Not All Sirius

by Ted Dunphy

Great Images

by Michael Gatto



Another sketch as I work on the RASC Explore the Moon *observing program. This time it is crater Fracastorius, #46 on the* Observer's Handbook *lunar map. This sketch was made between 9:00–10:00 p.m., 2019 July 07, from my home in Cole Harbour, Nova Scotia. Sketching was done at the eyepiece of my 8-inch ƒ7.5 reflector, hand-tracked on a Dobsonian mount, using a 17-mm Vixen LVW eyepiece with a 2X Barlow, under pretty good seeing conditions. The completed sketch was scanned, then additional shading added in Photoshop.*

Journal

It's been a rare spring/summer outbreak of noctilucent clouds which have thrilled skywatchers across the northern hemisphere. Alan Dyer captured a stunning display on June 17 just east of Calgary. Alberta. Alan used a Sony a7III and shot one second exposures at ƒ/2.8 with a 50mm lens at ISO 400.