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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Volume/volume 113
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Thomas Lindsay, TAS

Osseo Iron Meteorite Revisited

The Trifid Nebula

The Best of Monochrome.

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

Journal editor Nicole Mortillaro used iTelescope's remote system to image the Centaurus A galaxy. The telescope she could only dream of owning was a Planewave 20" (0.51m) CDK ƒ/4.4 on a Planewave Ascension 200HR mount with an FLI-PL09000 CCD camera.

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Royal Astronomical Society of Canada
Société Royale d'Astronomie du Canada

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Blair MacDonald imaged the much-loved Triffid Nebula (M 20) from Nova East 2019. He used a Canon 60Da DSLR on a SkyWatcher Esprit 120 f/7 APO refractor at ISO 800. He says he took the images on "the second of three exceptionally clear nights." He adds that it "made for an interesting challenge processing as the atmospheric refraction caused the red and blue channels to shift as the object approached the tree line. The solution was to split each sub into its three colour channels and align and combine each red channel, each green channel and each blue channel then rebuild the colour image from the combined colour channels."

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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A Message from outgoing Executive Director Randy Attwood

It is my pleasure to take the editorial area in this issue of the *Journal* normally reserved for the President to address the membership as I step down from the position of Executive Director.

It has been an honour for me to be the Society's Executive Director for the past five years. My goals during my tenure were to move the Society to a new level, which I feel I have accomplished. I saw that we needed to be seen more as a national royal society with attractive programming, interesting publications, and 29 extremely active local Centres. We took the opportunity of the 150th anniversary to promote ourselves through new types of events, such as online and coast-to-coast national star parties. Canada Post's issue of two astronomy stamps, as well as the Canada Mint's coin (with a meteorite attached!), introduced the RASC to many more Canadians.

We have also put more emphasis on fundraising. We created a Fundraising Committee and hired fundraising consultant Lisa Di Veto to guide us through the changes needed to be successful. We provided specific programs for members to support through giving. We also adjusted the way we recognize donors and how we report using the funds to support our educational activities.

We now have an employee who oversees the needs of our youth members, a critical group within the organization.

We have many exciting things to look forward to: the robotic telescope, which has had its delays, should come online early next year. In the near future, the Society will be looking for a new home, which will include larger working space and room for our new Canadian Telescope Museum.

With more staff in the office, we will be able to provide more services and support to Centres. We are also in the midst of planning an upgraded membership system and website.

As we grow, we will need more skilled help in the office—human resources and governance consultants, along with help for our computer and communications systems. With the recent hire of a marketing and communications expert, we will be able to develop and run a coordinated marketing program, enhance our social media presence, and synchronize our internal and external communications.

We are reworking *SkyNews* magazine and its website to attract more subscribers and viewers, with more focus on RASC activities.

I would like to welcome our new Executive Director, Dr. Phil Groff. Phil brings many skills to this position, skills that are required to take the Society through the next steps. As the administration and governance of the growing RASC are tended to, we plan to expand our reach across the country to more Canadians. The Society membership should grow, which will provide a larger volunteer base at Centres as well as an increase in overall income.

Our office staff is amazing: they are all dedicated, hard-working, and supportive. I will miss them very much. Working in a small office for a not-for-profit organization requires a lot of innovation, patience, and hard work. The RASC team has all this, and more. I cannot say enough how much I enjoyed working with Renata Koziol, along with our newer employees, Jenna Hinds, Eric Wickham, and Adela Zyfi. Lisa Di Veto has brought much more than fundraising skills—she has helped move the Society forward to the next level. Thank you all!

Along the way, I have had the support from many RASCals across the country, too many to list here. We have so many dedicated volunteers. I know you are as proud as I am of the Society we have become.

To everyone—old friends and new—I thank you. I would especially like to thank my wife, Betty, who has provided immense support to me during the good times and bad over the past five years; she was always there when I needed her.

I intend to remain active with the Mississauga Centre and I have a couple of interesting projects to work on. I also have a new observatory at our cottage in the Kawarthas that needs some serious time.

Thank you, and clear skies all! Randy Attwood ✶

News Notes / En manchette

Easy come, easy go

Galaxies are evolutionary beasts, born in the intersection of filaments left from the Big Bang, and growing to maturity by the accretion of mass over the course of billions of years. Sometimes the additional mass comes from the absorption of a small galaxy, sometimes by the merger with a like-sized neighbour. All the while, there is an ongoing inflow and outflow of much smaller amounts of material with the surrounding environment. Supernova explosions, stellar winds from massive stars, and supermassive black holes eject material out of the galaxy and into its halo. Much of this falls back where it accumulates to participate in another generation of star formation.

Our Milky Way is no different and it has long been known that our galaxy accretes gas from its surroundings, helping to fund the ongoing rate of star formation over billion-year intervals. Characterizing the rates of inflow and outflow becomes an important part in understanding and validating the stellar birth rate.

To study this symbiotic relationship, a research team led by ESA astronomer Andrew J. Fox (Space Telescope Science Institute) examined the characteristics of gas clouds that are not bound to the Milky Way. These clouds were identified by their high velocities, which were larger than the rotation speed of the galactic disk and so represented inflow and outflow gas. To separate these high-velocity clouds (HVCs) from other dynamic events in the Milky Way, the research team selected only gas clouds with a velocity excess greater than 90 km/s with respect to the local galactic rotation rate.

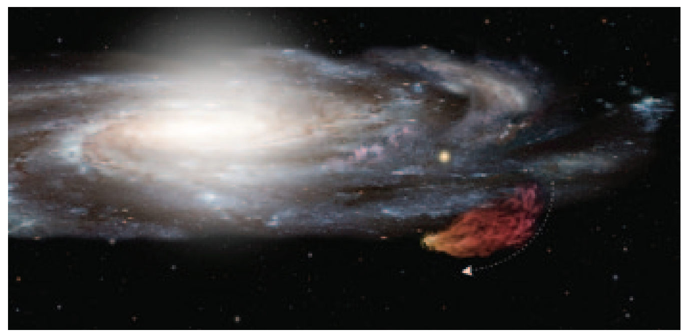

Figure 1 — This diagram shows the trajectory of the high-velocity Smith Cloud as it arcs out of the plane of our Milky Way galaxy and then returns like a boomerang. Measurements made with the NASA/ESA Hubble Space Telescope *show that the cloud, because of its chemical composition, came out of a region near the edge of the galaxy's disk of stars 70 million years ago. The cloud is now stretched into the shape of a comet by gravity and gas pressure. Following a ballistic path, the cloud will fall back into the disk and trigger new star formation 30 million years from now. Image: NASA, ESA, and A. Field (STScI)*

The research team constructed a list of 187 HVCs that lay along the line of sight to a sample of 270 extragalactic quasars. Absorption lines in the quasar spectra attributed to the HVCs were used to determine the line-of-sight velocities of the clouds. The 187 samples were spread across the Northern and Southern Galactic hemispheres. HVCs associated with the structures streaming from the Magellanic Clouds were removed from the sample, as were samples matched with the Fermi Bubbles (two enormous blobs of material extending above and below the plane of the Milky Way). Using the spectral lines of silicon as a proxy, the research team calculated the amount of neutral and ionized hydrogen along the line of sight through the gas clouds. A model of the gas clouds was then used to determine the total mass contained within each member of the sample. The authors caution that the calculated masses are a lower limit, particularly because slower-moving gas clouds were not included in the sample.

Ultimately, the research team found that the amount of material flowing back into the Milky Way disk was about three times that flowing outward, amounting to about 0.53 solar masses per year of inflow and 0.16 solar masses of outflow. The study authors concluded that the Milky Way appears to be in an inflow-dominated phase, but insufficient to sustain the galactic star formation rate of 1.7 +/– 0.7 solar masses per year. Because high-velocity clouds have a lifetime of about 100 million years, the calculated rate is "instantaneous" and cannot be used to infer the history of Milky Way accretion. The study also identified a "mass loading factor" of 0.1 for the Milky Way using a measure of the current rate of star formation. This factor means that about 10 percent of the mass incorporated into the creation of stars is ejected back into the galactic halo.

Twists and turns in stellar evolution

Binary stars form in a protostellar disk of dust and gas that fragments into separate stars as a result of gravitational instabilities. Theoretical models suggest that, in a system with two unequal components, the high-angular-momentum dust will accrete onto the less massive protostar while the low-momentum material falls onto the larger. The result is a binary system with two equally massive stars. Using ALMA, a high-altitude microwave telescope assembly in Chile, astronomers have now obtained an extremely high-resolution image that exposes the accretion pattern in detail and sheds new light on the earliest phases of the lives of stars. The two young stars in the study—about 100-200 million years old—were located in a small stellar cluster in the Barnard 59 dark nebula, popularly named the Pipe Nebula.

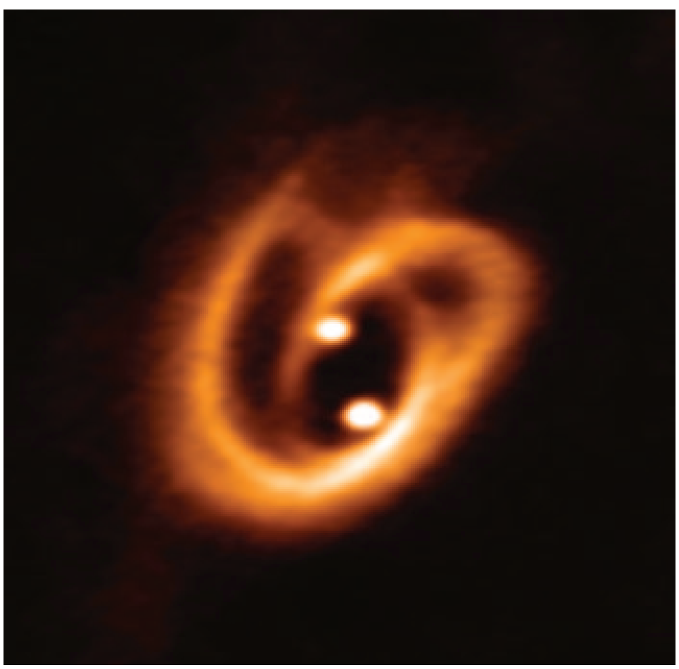

Figure 2 — The Atacama Large Millimeter/submillimeter Array (ALMA) captured this unprecedented image of two circumstellar disks, in which baby stars are growing, feeding with material from their surrounding birth disk. The complex network of dust structures distributed in spiral shapes resemble of the loops of a pretzel. These observations shed new light on the earliest phases of the lives of stars and help astronomers determine the conditions in which binary stars are born. Image: ALMA (ESO/NAOJ/NRAO), Alves et al.

"We see two compact sources that we interpret as circumstellar disks around the two young stars," explains Felipe Alves from Max Planck Institute for Extraterrestrial Physics who led the project. "The size of each of these disks is similar to the asteroid belt in our Solar System and the separation between them is 28 times the distance between the Sun and the Earth (an astronomical unit, au)." The circumstellar disks themselves have a radii of 2-3 au. The masses of the circumstellar disks is estimated to be similar to the mass of Jupiter. In the case of the Barnard 59 protostars, the two circumstellar disks are in turn surrounded by a complex network of dust structures distributed in spiral shapes, giving it the appearance of a pair of pretzel loops. This spiral structure has a total mass of about 79 Jupiter masses, too small to be dynamically unstable and so unlikely to fragment into additional protostars. Instead, the filaments appear to be inflow streamers, transferring matter from the circumbinary disk into the circumstellar disk at the rate of about 1 ten-thousandth of a solar mass per year. Measurements of the velocity of the gas in the circumbinary loops show that the smaller component of the pair of protostars in accreting material into its circumstellar disk more rapidly than the larger protostar. However, when accretion from the circumstellar disk onto the protostar itself is measured, it is the larger star that is ingesting dust and gas at the fastest rate.

"This is a really important result," stresses Paola Caselli, managing director at MPE and co-author of the study. "We have finally imaged the complex structure of young binary stars with their feeding filaments connecting them to the disk in which they were born. This provides important constraints for current models of star formation."

The young protostars accrete mass from the bigger disk in two stages. The first stage is when mass is transferred to the individual circumstellar disks in beautiful twirling loops, which is what the new ALMA image showed. The data analysis also revealed that the less-massive but brighter circumstellar disk—the one in the lower part of Figure 2—accretes more material. In the second stage, the stars accrete mass from their circumstellar disks. "We expect this two-level accretion process to drive the dynamics of the binary system during its mass accretion phase," adds Alves. "While the good agreement of these observations with theory is already very promising, we will need to study more young binary systems in detail to better understand how multiple stars form."

Complied in part with material provided by the ESO.

Cosmic filaments knit galaxy clusters

Cosmological models of the early Universe predict that the majority of the dust and gas in this early epoch is distributed in a web of sheets and filaments, with galaxies and massive black holes forming preferentially at the intersection points of the various structures where the accumulation of matter is greatest. The material required to form these early galaxies comes from streams of cool gas falling along the filaments into the developing galactic cores. Now, an international group of scientists led by Hideki Umehata of the RIKEN Cluster for Pioneering Research, a branch of Japan's largest scientific research organization, has made detailed observations of the filaments of gas connecting galaxies in a large protocluster in the early Universe.

Models of the early Universe suggest that at a redshift of 3, about 60 percent of the dust and gas resides in filaments. Until now, they have been difficult to observe because of their low density and brightness. They have been visible as absorption lines in the ionized hydrogen spectra of distant quasars (Lyman-alpha radiation), but those observations were only able to provide line-of-sight detections toward the background source. The filaments also emit Lyman-alpha radiation from the absorption and re-radiation of background ultraviolet light, but the intensity of the background sources was generally too low to raise the filaments' fluorescent emission to visible levels. In order to see the filaments, a brighter light source was needed.

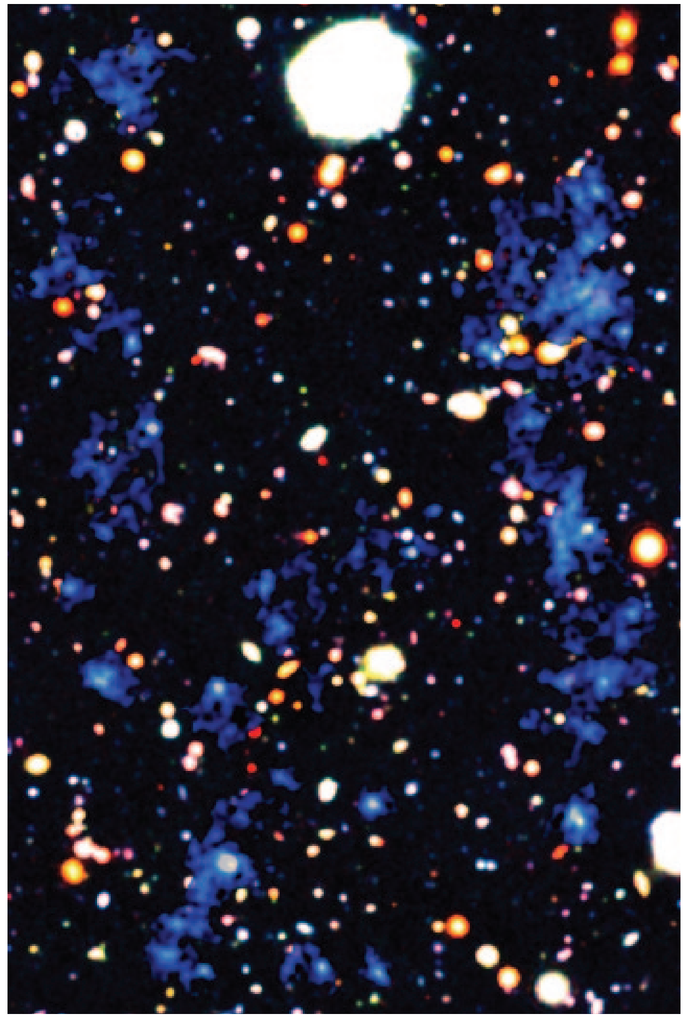

Figure 3 — Image showing the blue hydrogen-emission filaments, with white dots showing very active star-forming galaxies. Image: Riken Institute, Hideki Umehata

To find that brighter light, the research team focused on a location where a concentration of star-forming galaxies and active galactic nuclei boosted the local ultraviolet flux. Their choice of light source was the core of the galaxy protocluster SSA22 lying at a distance of 12 billion light-years (z=3.1) in Aquarius. Using the Subaru Telescope and the W.M. Keck Observatory in Hawaii and the ESO's Very Large Telescope (VLT) and ALMA array in Chile, the researchers assembled a data mosaic acquired by the Multi Unit Spectroscopic Explorer (MUSE) attached to the VLT and, using information gathered by the other participating observatories, identified and characterized extended filaments of Lyman-alpha emission in the field of SSA22. The ultraviolet radiation formed a pair of north-south aligned filaments that extended over a length of more than 3 million light years. The scale of the emission was so large that the research team concluded that it forms a coherent structure that unites at least several galaxies. The filaments extended to the edges of the MUSE field and probably continued beyond.

Two of the features within the MUSE field were associated with extended nebulae with bright UV hydrogen emission. These two brighter blobs, detected by previous observations, were part of a collection of 35 similar features that formed a large megaparsec-scale structure. The authors interpret these bright spots as knots within a larger network of filaments that extends well beyond the observed field around SSA22. Galaxies within the SSA22 field closely matched the location of the filaments in both position and distance, confirming that the filaments are intimately associated with the population of active galaxies and super-massive black holes. According to Umehata, the lead author of the paper, "This suggests very strongly that gas falling along the filaments under the force of gravity triggers the formation of starbursting galaxies and supermassive black holes, giving the Universe the structure that we see today."

"Previous observations," he continues, "had shown that there are emissions from blobs of gas extending beyond the galaxies, but now we have been able to clearly show that these filaments are extremely long, going even beyond the edge of the field that we viewed. This adds credence to the idea that these filaments are actually powering the intense activity that we see within the galaxies inside the filaments."

Co-author Michele Fumagalli from Durham University, UK, says, "It is very exciting to clearly see for the first time multiple and extended filaments in the early Universe. We finally have a way to map these structures directly, and to understand in detail their role in regulating the formation of supermassive black holes and galaxies."

While theoretical models predicted the general nature of the structure of the early Universe, confirmation can only come from visible evidence collected for the purpose. Other evidence of similar structures suggests that such filaments are likely a general feature of early protogalaxy clusters.

Compiled in part with material provided by Keck Observatory and the ESO.

TESS and the ASASSN

A NASA satellite searching space for new planets gave astronomers an unexpected glimpse at a black hole ripping a star to shreds. It is one of the most detailed looks yet at the phenomenon, called a tidal-disruption event (or TDE), and the first for NASA's *Transiting Exoplanet Survey Satellite* (more commonly called *TESS*.)

The milestone was reached with the help of a worldwide network of robotic telescopes headquartered at The Ohio State University called ASAS-SN (All-Sky Automated Survey for Supernovae). "We've been closely monitoring the regions of the sky where *TESS* is observing with our ASAS-SN telescopes, but we were very lucky with this event in that the patch of the sky where *TESS* is continuously observing is small, and in that this happened to be one of the brightest TDEs we've seen," said Patrick Vallely, a co-author of the study and National Science Foundation Graduate Research Fellow at Ohio State. "Due to the quick ASAS-SN discovery and the incredible *TESS* data, we were able to see this TDE much earlier than we've seen others—it gives us some new insight into how TDEs form."

Tidal-disruption events happen when a star gets too close to a black hole. Depending on a number of factors, including the size of the star, the size of the black hole, and how close the star is to the black hole, the black hole can either absorb the star or tear it apart into a long, spaghetti-like strand. Models of such events predict that about half of the material will be ejected from the system and the rest will go into orbit around the black hole.

"*TESS* data let us see exactly when this destructive event, named ASASSN-19bt, started to get brighter, which we've never been able to do before," said Thomas Holoien, a Carnegie Fellow at the Carnegie Observatories in Pasadena, California. "Because we discovered the tidal-disruption quickly with the ground-based ASAS-SN, we were able to trigger multiwavelength follow-up observations in the first few days. The early data will be incredibly helpful for modeling the physics of these outbursts." Because the event happened in

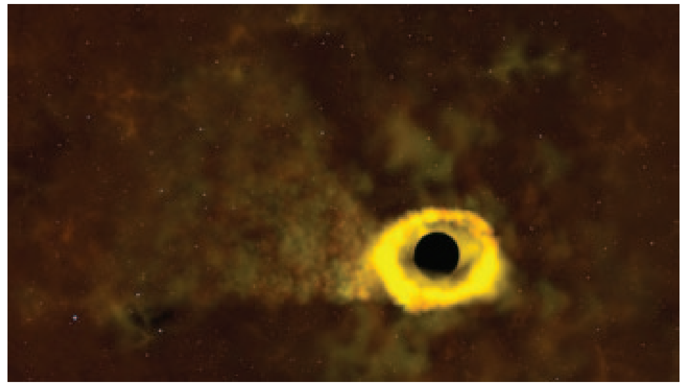

Figure 4 — When a star strays too close to a black hole, intense tides break it apart into a stream of gas. The tail of the stream escapes the system, while the rest of it swings back around, surrounding the black hole with a disk of debris. Image: NASA's Goddard Space Flight Center.

TESS's Continuous Viewing Zone, the research team was able to obtain 30-minute observations through the disruption.

ASAS-SN was the first system to see that a black hole was ripping a star apart. Holoien was working at the Las Campanas Observatory in Chile on 2019 January 29, when he got an alert from one of ASAS-SN's robotic telescopes in South Africa. Holoien trained two Las Campanas telescopes on the tidal-disruption event and then requested follow-up observations by other telescopes around the world. *TESS* already happened to be monitoring the exact part of the sky where the ASAS-SN telescope discovered the tidal-disruption event. It was not just good luck that the telescopes and satellite aligned—after *TESS* launched in July 2018, the team behind ASAS-SN devoted more of the ASAS-SN telescopes' time to the parts of the sky that TESS was observing.

But it was fortunate that the tidal-disruption event happened in the systems' lines of sight, said Chris Kochanek, professor of astronomy at Ohio State. Tidal disruptions are rare, occurring once every 10,000 to 100,000 years in a galaxy the size of the Milky Way. Supernovae, by comparison, happen every 100 years or so. Scientists have observed about 40 tidal-disruption events throughout history (ASAS-SN sees a few per year). The events are rare, Kochanek said, mostly because stars need to be very close to a black hole—about the distance Earth is from our own Sun—in order to create one.

And because ASAS-SN caught the tidal-disruption event early, Holoien was able to train additional telescopes on the event, capturing a more detailed look at the early stages of the disruption. Astronomers could then look at data from *TESS*—which, because it came from a satellite in space, was not available until a few weeks after the event—to see whether they could spot the event in the lead-up. Data from *TESS* meant that they could see signs of the tidal-disruption event in data from about ten days before it occurred.

"The early *TESS* data allow us to see light very close to the black hole, much closer than we've been able to see before," Vallely said. "They also show us that ASASSN-19bt's rise in brightness was very smooth, which helps us tell that the event was a tidal-disruption and not another type of outburst, like from the centre of a galaxy or a supernova." Astronomers think the supermassive black hole that generated ASASSN-19bt weighs around 6 million times the Sun's mass. The destroyed star may have been similar in size to our Sun.

Holoien's team used UV data from NASA's *Neil Gehrels Swift Observatory*—the earliest yet seen from a tidal-disruption—to determine that the temperature dropped by about 50%, from around 40,000 to 20,000 degrees Celsius, over a few days. It's the first time such an early temperature decrease has been seen in a tidal-disruption before, although a few theories have predicted it, Holoien said.

More typical for these kinds of events was the low level of X-ray emission seen by *Swift*. Scientists don't fully understand why tidal-disruptions produce so much UV emission and so few X-rays. Because the early observations of the tidal-disruption in ASASSN-19bt are unique, they are limited in their ability to characterize other tidal-disruption events.

Compiled with material provided by Ohio State University ✶

Feature Articles / Articles de fond

Thomas Lindsay, Toronto Astronomical Society Member — A Remarkable Life

by Clark Muir (Kitchener-Waterloo Centre)
cmuir10@rogers.com

All RASC members sooner or later are asked how they got involved in astronomy. What piqued your interest? If you are of a certain age (the author included), a common answer is the Apollo missions that set humans on the Moon. It was a historic moment and now is celebrating its 50th anniversary this year.

Some may recollect the beginning of the space era as a motivation for getting involved in the hobby or perhaps even (pardon the pun) launching a career. Whether it was *Sputnik*, *Alouette*, Apollo, the *Space Shuttle* missions or other memorable moments, we all have had that spark.

Before this incredible era of spaceflight, individuals would have had other motivations that inspired them to study or observe the stars. Common, and still relevant today, is a childhood memory of seeing the Milky Way in a truly dark sky during a summer evening. In this instance though, it was through the science of celestial navigation.

Thomas Lindsay was born in Edinburgh, Scotland, on 1855 April 25. After his father's death in 1858, his family relocated to Toronto in 1862. He spent the rest of his childhood there and finished his schooling at what is now called Jarvis Collegiate Institute in Toronto.

After finishing his proficient education, Lindsay, at age 16 in 1871, left Toronto and went to sea. It is during these years as a very young man that he had his introduction to astronomy.

The navigator at sea has a unique perspective on the night sky. As of the mid-20th century, there are formally 58 stars used for this purpose. These stars were chosen for their relative brightness and they encompass the entire sky serving all declinations and right ascensions. At any one moment, if the sky is clear and dark, wherever the location on the planet, several of these stars will be visible for use in navigation.

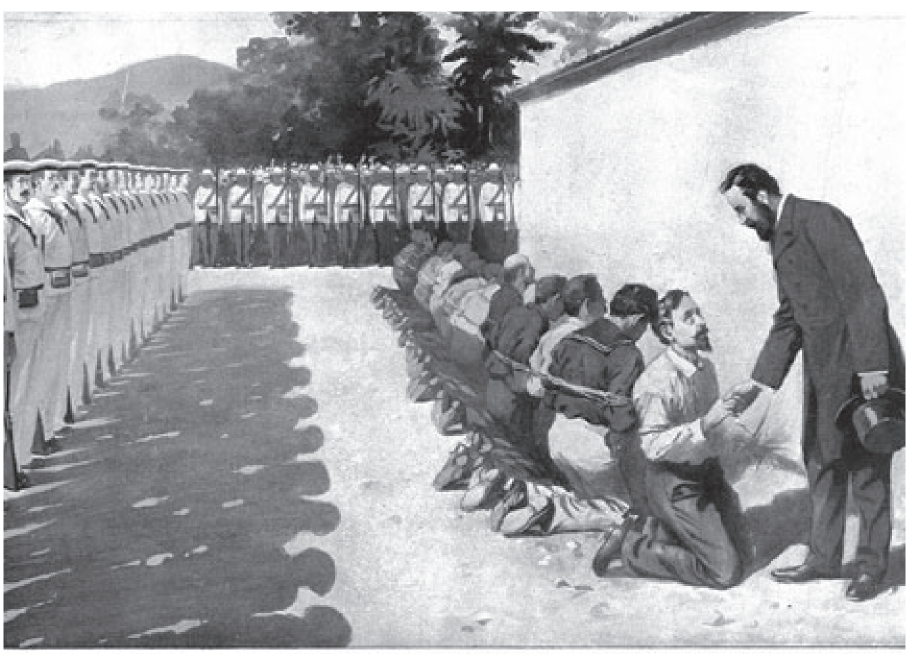

Figure 1 — Dramatic depiction of the execution of crew of the Virginius. *Thomas Lindsay was spared this fate. Virginius Affair Wikipedia.*

Included with these stars are the five bright planets, the Moon, and, of course, the Sun. For navigators to learn the craft, they needed to have a keen awareness of the position of all these stars and the Solar System objects. They learned how the sky moved nightly and through the seasons. The planets were monitored regularly as well. For example, they would likely know whether the apparent position of Venus was moving away from or toward the Sun at a given time.

If the ship were travelling south in the Northern Hemisphere, the seasoned navigator could visualize how the sky would look from night to night. They knew which stars would transit lower toward the horizon, while others would rise higher. Polaris would get lower. They would anticipate where the Moon would be compared to the previous night.

Navigators needed certain tools to do their work, which included instruments like chronometers, sextants, and quadrants. An endless number of charts and tables were also used. Next, meticulous measurements of the position of the preselected stars and/or planets relative to the local horizon needed to be obtained. Finally, sight reductions using the tables and charts could determine the latitude and longitude of their vessel. At least that was the theory.

Interestingly though, the rest of the sky did not matter. At sea, even the casual observer using no optical aid would have noted the myriad of deep-sky objects. These include the countless other stars, star clusters, the Milky Way, dark patches, and even galaxies. It is reasonable to assume that many but not all navigators would have had a fascination or curiosity about these other objects. Thomas Lindsay certainly did.

This wonderment caught the attention of the young Lindsay while at sea. Later in his life, Lindsay would share some personal experiences in a few articles that he wrote for *Popular Astronomy*, an American magazine that started in 1893 and was published through to 1951.

Lindsay recalls that on a ship in 1873 October 28–29, in the Caribbean Sea, an "old sailor" (Lindsay had forgotten his name) asked him if he wanted to learn some basics about navigation. Decades later, Lindsay shares the lesson with readers that he was taught about Polaris and how the sky seemed to "turn" around the North Star. Lindsay declared that this was one of the pivotal moments in his young life that began his interest in astronomy.

This casual but memorable introduction to astronomy clearly symbolized the end of what was perhaps an ordinary life for a young man. The events that would immediately follow were by any standard an unforgettable human experience.

The ship Lindsay was on that night was the steamer *Virginius*. Lindsay was offered a job on the *Virginius* while the ship was anchored in Colon, Panama. The evidence suggests that Lindsay had travelled from Jamaica to Panama on a ship called the *American*. Why Lindsay, now just an 18-year-old from Toronto, was left in Panama is unknown. What is known is that Lindsay accepted the wage as a quartermaster and boarded the *Virginius* sometime during the autumn of 1873.

Figure 2 — Formal portrait of Thomas Lindsay published in 1901. Courtesy Will Caldwell.

The *Virginius* was involved in a complex web of military and diplomatic events in the late 1860s through to 1873. Lindsay was a witness and survivor in what is now colloquially called "The *Virginius* Affair."

The ship had been purchased by wealthy American sympathisers of the Cuban resistance a few years after the U.S. Civil War. The Spanish had control of the island of Cuba and some of the inhabitants of the island were involved in a rebellion. A plan was hatched to secretly run munitions to Cuba to resist the Spanish. During these runs, the *Virginius*—under false pretenses—sailed under the American flag to secretly deliver these supplies.

The Spanish, for their part, were aware of the ship and were actively pursuing it. On 1873 October 30, the very next day after Lindsay's informal astronomy lesson, the Spanish warship *Torpedo* spotted the rebellious *Virginius* and sailed after it.

After a vain attempt to outrun the faster warship, the *Virginius* was caught and escorted to Cuba with the crew and all its passengers still on board. On 1873 November 1, the two ships reached the port of Santiago de Cuba.

The events that transpired after arrival at the port were truly horrifying. The entire crew was tried for and convicted of piracy and quickly sentenced to execution. These executions started on 1873 November 4. British and American diplomatic efforts eventually put a stop to the executions but not before some 53 crew and passengers had been executed. One hundred and fifty-five crew and passengers were on board. Thomas Lindsay's life was spared, perhaps due to his youthful age or his nationality. Lindsay wrote that among those murdered was the man that he called the old sailor, the same man who had given him his introductory astronomy lesson just days before.

A few depictions of the tumultuous events included in news accounts of the executions show the victims lined up, blindfolded, and kneeling, while behind them a row of soldiers stand with their rifles aimed and ready to fire execution-style. Behind the row of the firing squad, other soldiers and perhaps civilians are seen watching the episode unfold. It is not known precisely where Lindsay was during these actions.

The details of The *Virginius* Affair go well beyond this brief introduction. The astonishing saga is surely worth the attention of Hollywood. It is astounding that a young man from Toronto found himself in such a predicament. The experience must have had a profound impact on his life. The survivors of this incredible incident—including Lindsay—were eventually handed over to U.S. custody and were escorted to Bahia Honda, an island in the Florida Keys.

Lindsay's ordeal finally ended when he left the Florida Keys with other survivors for New York City.

In late December 1873, Lindsay, still a student of navigation, returned to Toronto after this harrowing ordeal and settled to a more archetypal life. Lindsay, skilled in mathematics, worked in the insurance industry, perhaps as an actuary. Lindsay married Elizabeth Magowan in 1884 September 12.

In 1890, Thomas Lindsay, now in his mid-30s, joined the Toronto Astronomical Society (TAS). He contributed greatly to the society and eventually became one of its Board of Directors.

Fortuitously, his articles in *Popular Astronomy* give us further clues to his interest in astronomy as a hobby.

Among them is an admission to his frustration in dealing with people who seemingly believe the Earth is flat! It is noted he referred to these people as Earth flatteners, a variation to the term "flat Earthers" commonly used now.

Other articles he wrote are more significant. For example, we learn that Lindsay was fascinated with occultation timings. These are events where a distant star is suddenly hidden by the approaching Moon. As the Moon orbits the Earth, it will occasionally pass in front of bright stars. By recording the exact time the star disappears (or reappears), and with the help of the appropriate tables and instruments, it is, once again in theory anyway, possible to determine the latitude and longitude of your location. While this requires more complex mathematics than conventional navigation methods, the purpose in Lindsay's case was for practice and instruction.

In the late 1890s, Lindsay wrote that members of the TAS were initiating a program of recording these types of events, presumably with his leadership. Using tables obtained from the nearby Toronto Observatory, Lindsay was able to check the accuracy of the group's efforts. It is further noted that he mentioned that women were participating in these activities. This is consistent with some of the photographs in the RASC archives showing both men and women participating in social observing sessions during this period.

In 1900 May 28, Lindsay travelled to Wadesboro, North Carolina, to view the total solar eclipse. This was a site selected by prominent institutions for their eclipse expeditions, including Yerkes Observatory, the Smithsonian Institute, and the British Astronomical Association. A literal temporary tent city was built around a large number of heliostat telescopes, cameras, and other scientific apparatus in the small Carolinian town. Lindsay travelled to Wadesboro, probably by rail with the then-president of the TAS, George Lumsden. Did Lindsay and Lumsden get to meet and chat with some of the more prominent names in astronomy? E.E. Barnard, the legendary observer and imager was there. Walter and Annie Maunder, very authoritative solar observers were also on scene. It is reasonable to assume that both men would have met these people and a lot of other prominent men and women in astronomy.

A photograph exists of Lindsay at his rather make-shift observing station at the eclipse site. The picture is particularly endearing in retrospect. While he was concentrating on specific observations for scientific purposes, he naturally allowed some time to enjoy the spectacle. A report of the eclipse by Lindsay was read at the TAS meeting of 1900 June 12.

> "… An excessively bright but small portion of the Sun's disc seen for one moment and gone the next! No tangible thing had touched them, and yet he felt conscious of a distinct physical change of some sort. To his mind, the sensation experienced at the moment of totality is a real sensation. It might be due entirely to shock to the optic nerve, as when a very bright object suddenly disappears, or it might be attributable to a change of temperature, supposed or real, as the gloom due to the sudden fall of darkness settled down upon one…"

On the evening of 1901 January 22, the TAS presented Lindsay with a pocket watch for 10 years of service at their monthly meeting. For this gift, he was genuinely humbled.

At the commencement of this meeting, word was received that the Queen had died. Queen Victoria's death occurred just a few hours earlier, and the news had just reached Toronto. Out of respect for the guest speaker, the meeting was not cancelled, but condolences on the death of the monarch were acknowledged into the official minutes.

Lindsay tragically died a few months later on 1901 September 20. His death was described in his obituary as an "illness of

Figure 3 — Thomas Lindsay in Wadesboro, North Carolina. A charming photograph showing Lindsay at his telescope for the total solar eclipse of 1900 May 28. Courtesy Will Caldwell.

the brain." Further in his obituary, it is claimed that the eclipse adventure brought some of the happiest hours of his life. Witnessing a total solar eclipse for many is not just about the extraordinarily beautiful and surreal physical properties, it is a deeply personal experience. He was 46.

At the time of his death, Thomas Lindsay's wife was pregnant with their fifth daughter and seventh child.

To Thomas Lindsay, astronomy was more than just a hobby. Lindsay, we can infer, needed to see comfort in what was obviously the darkest experience of his life. The kindness of a stranger sharing the night sky with him just days before the stranger's murder in part nurtured his passion for astronomy. It is as if there was a reprieve from the madness. Lindsay found it in the sky.

Years later, just before his untimely death, we see the role astronomy played throughout his life. We learn how significant the deeply moving experience of witnessing a total solar eclipse was to him.

For Thomas Lindsay, astronomy brought solace at the darkest time of his life. It also brought great joy near its end. ✶

Clark Muir has had a lifelong interest in astronomy as an amateur. He particularly enjoys observing, history of astronomy, and telescope making. He is currently Vice Chair of the RASC History Committee.

Figure 4 (a,b) — Pocket watch presented to Lindsay on 1901 January 22 for 10 years of service to the Toronto Astronomical Society. Inscription reads: "Presented to Mr. T. Lindsay by the TAS Jan 1901." Courtesy Will Caldwell.

Endnotes

1 The author wishes to express his gratitude to Will Caldwell 2 (great-great grandson of Thomas Lindsay) and his family. Their full cooperation in sharing information and material for this article was essential.

2 *Harper's Weekly* magazine published several sketches depicting the executions 1874 January 10.

3 Bahia Honda is the next key east, only 5 km away from West Sutherland Key, the home of the famous annual Winter Star Party.

4 Excerpt of Lindsay's remarks on the solar eclipse from a meeting of the TAS held on 1900 June 12.

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The Osseo, Ontario, IAB Complex Iron Meteorite Revisited

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International Meteorite Collectors Association.

Abstract

The Osseo 46.3-kg iron meteorite was found in 1931 near the small northern Ontario village of Osseo. Its find, however, was not announced until four years later. To this date, no other fragments of the meteorite have been recovered. We decided to reinvestigate this meteorite as part of an ongoing program to revisit Canadian meteorite falls and finds. Our goals in this effort were to clear up, if possible, the controversial story of its discovery; to possibly recover additional fragments; to provide a description and analysis of this relatively understudied meteorite; and to list the locations of all known specimens.

The Meteorite's Discovery

The story of the discovery of the Osseo meteorite, a 46.3-kg IAB complex iron found in 1931 about 5 km from the small village of Osseo, some 200 km north of North Bay, Ontario, is controversial and troublesome. The initial details of the find are related in letters between Frank Johnston, an Osseo resident, and members of the scientific staff at the Smithsonian Institution in Washington, D.C., from early March to early May 1935.

In Johnston's first letter, he stated that he had first notified the National Geographic Society in Washington, D.C., of the meteorite's discovery, but they had referred him to William F. Foshag (1894–1956), the Smithsonian's Curator of the Division of Mineralogy and Petrology.

Johnston informed Foshag, "I have in my possession an object which I think is a meteor (sic)." He said it was "a solid piece of metal weighing about 104 pounds and was found several years ago in a swamp and was buried several feet below the surface of the ground" (Figure 1). Johnston asked Foshag if he was interested in this, and if so, he would like to receive an idea of its monetary value (Johnston 1935a).

Foshag replied that the Smithsonian would be very glad to examine a fragment of the specimen to determine if it was indeed a meteorite, and if it was, they would be happy to make an offer for its purchase. He went on to explain: "The value of meteorites varies considerably and depends in part upon its size and in part upon its character. Some types of meteorites are much rarer than others and consequently bring a higher price. The minimum usually offered is $1 a pound for common types of irons. Rarer types would, of course, bring much more." (Foshag 1935a).

Johnston quickly sent Foshag a small fragment that had projected from a corner of the iron.

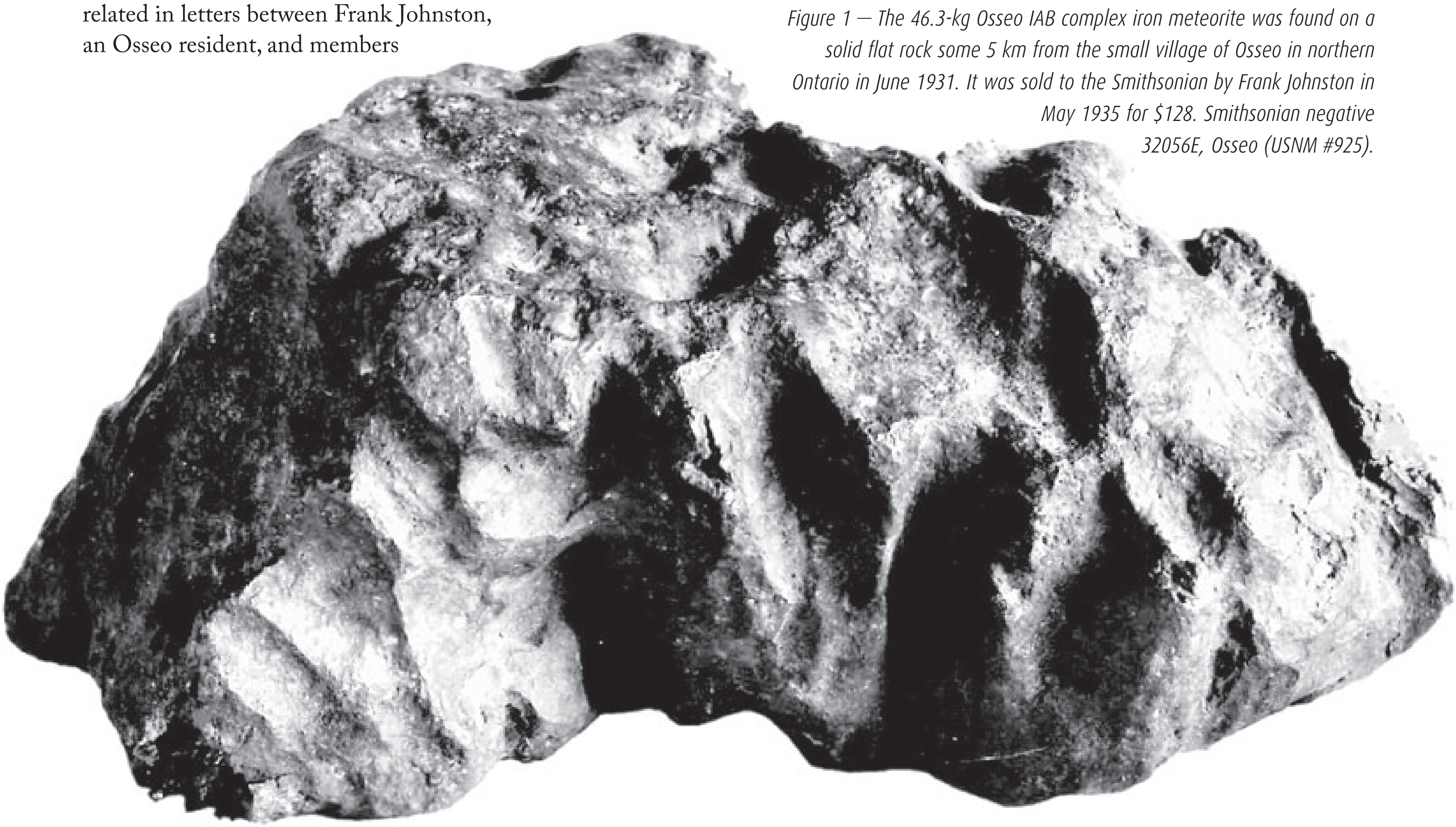

Figure 1 — The 46.3-kg Osseo IAB complex iron meteorite was found on a solid flat rock some 5 km from the small village of Osseo in northern Ontario in June 1931. It was sold to the Smithsonian by Frank Johnston in May 1935 for $128. Smithsonian negative 32056E, Osseo (USNM #925).

Due to Foshag's absence from Washington when the fragment arrived, the Smithsonian's examination of the fragment was undertaken by Edward P. Henderson (1898–1992), the Assistant Curator of the Division of Physical and Chemical Geology. Henderson told Johnston the fragment was indeed from an iron meteorite, and repeated Foshag's offer of $1 per pound, but informed him that if the large mass was in better condition than the fragment indicated, the Smithsonian would pay him a bonus.

He asked Johnston for more information concerning the meteorite's discovery, "whether or not it was a witnessed fall, if so, the time of day it fell; the depth at which it was buried, also the nature of the ground or rocks surrounding it" (Henderson 1935).

Johnston replied: "This meteorite was found accidentally by a farmer prospecting for silver. He found it on the edge of a swamp about two feet below the surface of the ground among some boulders." He stated that "one man claims to have seen it fall at about 10:30 p.m. in June 1925," but that he could not say if it was the same one or not.

Johnston then went on to say that he has a friend "who claims he knows where there is one [meteorite] weighing several tons. [It] was seen by his grandfather as it fell and was buried about twelve feet in the ground." Johnston asked if this could be possible (Johnston 1935b).

With information supplied by Foshag, Alexander Wetmore (1886–1978), the Assistant Secretary of the Smithsonian's U.S. National Museum (now the National Museum of Natural History) replied that "the largest [meteorite] known, the Hoba, in S.W. Africa weighs about 60 tons. There are 13 individual meteorites now known that weigh more than one ton" (Wetmore 1935). But neither Foshag nor Henderson pressed Johnston for further information, realizing that the likelihood of such a meteorite's existence was astronomically low.

Asked by Foshag to furnish as much information as possible as to the exact location where the meteorite was found, Johnston replied that the meteorite had been found four years earlier, in June 1931, "three miles from the village of Osseo, Temiskaming district, Northern Ontario." It had not been a witnessed fall and was "found by accident by a settler doing a little prospecting on his lot."

Johnston now changed the circumstances of its find location, however, and claimed that the meteorite "was lying on a flat rocky knoll when found and not in a swamp as I stated in a previous letter." Johnston had accompanied the meteorite's finder "to the actual spot just a few days ago," and asserted that "this meteorite was found lying on a solid flat rock which I have examined closely but cannot find the slightest mark where it fell" (Johnston 1935c).

In early May, Foshag informed Johnston that the meteorite he mailed had arrived at the Smithsonian, that it weighs "102 ½ pounds which at the offered price of $1 would be $102.50. We have, however, added an additional bonus of 25% to give you a total of $128" (Foshag 1935b). With this, the Johnston–Smithsonian correspondence came to an end.

Osseo, Ontario

One of us (Gary) lives only a few kilometres from Osseo and is very familiar with the place. It's so small, it's not even a village. It has a general store with a post office in it, but other than that, it's mostly made up of Mennonite farmers. Interestingly, it has somewhat of a dark history. Back in the old days, it was known as an outlaw hideout and the police would not go out there. As far as the meteorite is concerned, no one there knows anything about it, or even if there was one.

When Gary realized that he was essentially sitting on top of a meteorite fall zone, he decided to make a concerted effort to locate the site of the meteorite's discovery and look for possible fragments. Experience showed him that the best time to search was in April, just after the snow melted and before the bush started growing, which would obscure everything on the ground. May and June were not good times because the bugs were out then, including blackflies that take chunk-sized bites of you. July and August were also not good, because it was too hot then. And September was a bad time to be walking around because it was black bear and moose hunting season.

Recently, Gary tracked down one of Johnston's daughters, who passed along information she claimed to have about the meteorite's find location. She told him that "two old guys were blueberry picking when they came across the iron and the dent it made in the rock it hit." She went on to say that "The two guys dragged it to the Osseo general store and that's where [Johnston] found it being used as a door stop" (Mckerracher 2015).

Even though her story runs counter to Johnston's discovery story, Gary has gone to the place where she said the meteorite was found and searched this and nearby areas, but so far has not found any visible sign of the fall location or any fragments.

Description and Analyses of the Meteorite

The earliest analysis of Osseo was done by John Putnam Marble (1897–1955), a gifted amateur scientist who was an Associate in Mineralogy at the Smithsonian. In 1938, three years after the meteorite arrived at the museum, Marble published the results of his analysis of a 25-gram fragment (Marble 1938). After briefly describing the history of the meteorite's discovery as related by Johnston, he gave a short description of it.

Marble remarked that its most striking features were its "flutings," or elongated grooves that were prominent on one face of the meteorite. The larger grooves, he noted, averaged about two centimetres in width, and were not in a parallel alignment, but inclined somewhat to each other (Figure 1). Marble further described the meteorite as being covered by the "usual oxidized crust, which is not of any great depth," and that it exhibited the "usual pitted surfaces" (Marble, p. 282).

A cut and polished slice revealed that the meteorite was a coarse octahedrite, "a kamacitic iron, carrying a few troilite nodules and rather rare schreibersite" (Marble, p. 283). A chemical analysis yielded a nickel content of 6.51%, well within the average range of coarse octahedrites. All in all, the results of his analysis showed "no striking peculiarities" (Marble, p. 284).

Speculating on the absence of any markings on the solid flat rock that the meteorite had been found on, Marble discounted the idea that the meteorite could have been transported to its find site by glacial action, since it had a relatively thin weathered crust and didn't show any glacial striae. Instead, he thought that perhaps this could be accounted for if the fall had occurred in the winter, when the flat rock could have been covered by a heavy layer of snow and ice.

A more detailed, comprehensive description and analysis of the meteorite did not appear until nearly four decades later, when Vagn Buchwald published his three-volume *Handbook of Iron Meteorites. Their History, Distribution, Composition and Structure* (Buchwald 1975).

Examining the main mass at the Smithsonian, Buchwald observed that the meteorite's average dimensions were 38 × 18 × 17 cm. The elongated grooves noted by Marble were 9 × 2.5 cm in aperture, and 2–3 cm deep. The mass also displayed numerous coarse regmaglypts 15–25 mm in diameter up to 20 mm deep.

The meteorite's fusion crust, averaging 0.5 mm in thickness, showed that only a minor part of its surface had been removed by corrosion. This led Buchwald to believe that the grooves were not due to terrestrial weathering, but to "the dislodging during [atmospheric] flight of finger-shaped fragments that became separated along mineral-filled Widmanstätten boundaries" (Buchwald, p. 953).

Etched sections of the meteorite revealed straight, irregular kamacite lamellae with bandwidths of 2.8 mm. Taenite and plessite covered two to three percent of the meteorite's area,

Figure 2 — The Osseo fragment in the collection of the Royal Ontario Museum, Toronto, Ontario. The 490-g specimen, measuring 18 × 13 × 0.4 cm, is currently on display in the Museum's Teck Suite of Galleries: Earth's Treasures. Museum ID No. M25420, Image ROM2008_10166_18.

and schreibersite was common as 1.5 mm skeleton crystals (Figure 2).

Buchwald's analyses yielded the following results for nickel, gallium, germanium, and iridium, which have become key elements in the chemical classification of iron meteorites (Buchwald, p. 953):

Nickel	6.56 percent
Ga	91 ppm
Ge	450 ppm
Ir	5.4 ppm

On the basis of his analyses, he concluded that Osseo is a group I typical coarse octahedrite, but with its fusion crust in a better state of preservation than most.

The most recent chemical analyses of Osseo have been carried out by John T. Wasson and G.W. Kallemeyn. Their new and revised data yielded the following results (Wasson 1970, p. 410; and Wasson and Kallemeyn 2002, p. 2471):

Nickel	6.44 percent
Ga	92.4 ppm
Ge	463 ppm
Ir	6.04 ppm

They place Osseo in the IAB complex group. On the basis of their investigations, they conclude (p. 2445) that the meteorites in this group formed as impact-generated melts, with only minor solid/liquid partitioning effects superposed. But other meteorite scientists endorse different models, involving the fractional crystallization of magmas (e.g. Benedix, McCoy, Keil, and Love 2000). This topic, however, goes well beyond the scope of this paper.

Conclusion

Osseo is a coarse octahedrite with kamacite bandwidths of 2.8 mm, a normal member of the IAB complex group. This is the most populous group of iron meteorites. According to the on-line *Meteoritical Bulletin Database* (2019 July 11), IAB complex irons total 325 meteorites, 26.8 percent of 1,214 approved irons, just ahead of the populous IIIAB group with 316 members.

Johnston's account of the meteorite's discovery raises many important questions. Why did he change his story about the discovery? Is his final account of the discovery in which a single person found the meteorite while prospecting correct, or is his daughter's, in which two persons found it while blueberry picking? It seems to us that more credence should be given to Johnston's account, which was given at the time of the meteorite's discovery, rather than his daughter's, related more than three-quarters of a century later.

What were the circumstances of the meteorite's find location? Did it land on a solid flat rock and not leave any visible mark on it, as related by Johnston, or did it make a noticeable indentation, as related by his daughter? Similarly, we believe that more credence should be given to Johnston's own account, given at the actual time of discovery.

If Johnston's account is correct, we think there is a more plausible explanation for why no mark was made on a rock than the one given by Marble—that the meteorite might have fallen in winter, and the rock could have been covered by a thick layer of snow and ice. Noting that the meteorite had been found by a settler while prospecting on his lot, geologist Stephen A. Kissin of Lakehead University raises "the possibility that it was transported [there] by humans, possibly during the early 20th century silver rush in the area" (Kissin 2015).

Who was the meteorite's actual finder? Who was the landowner of this location? By Canadian law, meteorites belong to the owner of the land on which they are found.

Where had the meteorite been between its find in June 1931 and Johnston's initial letter to the Smithsonian in March 1935? How did it come into Johnston's possession? What led him to suspect that it might be a meteorite? Unfortunately, the historical record as it now stands does not allow a definitive answer to these interesting and important questions. ✶

Acknowledgments

We thank Phil McCausland of Western University and Brock University for his helpful comments on a draft of this paper. We thank Julie Hoskin, the Collection Manager of the Smithsonian's Department of Mineral Sciences, for providing the photograph of the main mass of the Osseo meteorite in its collection.

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Appendix

The following list of all known specimens of the Osseo meteorite is given in order of decreasing total mass. This compilation is based on the current (fifth) edition of the *Catalogue of Meteorites* (Grady 2000), with additional entries marked with an asterisk. All of the specimens are from the main mass.

Location	Mass (Total)
Smithsonian Institution, Washington, D.C. (main mass)	33,800 g
Geological Survey of Canada, Ottawa	2,000 g
Academy of Sciences, Moscow	1,230 g
Museum of Natural History, Denver	774.5 g
University of Michigan, Ann Arbor	750 g
Geological Survey of India, Kolkata	506 g
*Royal Ontario Museum, Toronto	490 g
*IMPACTIKA, Denver	230 g
Natural History Museum, London	200.5 g
Arizona State University, Tempe	173 g
Field Museum of Natural History, Chicago	156 g
University of California, Los Angeles	133 g
*Gary Mckerracher, Earlton, Ontario	35.5 g
*Corey Kuo, Taiwan	3.2 g
*Chris Spratt, Victoria, British Columbia	2.8 g
Total accounted for:	**40,484.5 g**

Skyward

California and the Universe

by David Levy, Kingston & Montréal Centres

Since early in the last century, astronomers dreamed of the clear sky over California as a place to unlock our imaginations and study the Universe. In 1917, the 100-inch Hooker Telescope was opened to the poetry of Alfred Noyes, who wrote:

We creep to power by inches.…Even to-night
Our own old sixty has its work to do;
And now our hundred-inch: I hardly dare
To think what this new muzzle of ours may find

And just think what the telescope did find: among many other things, it revealed that our Universe was double the size we thought it was.

Despite the fact that I have visited Mount Wilson many times, my most recent visit in September gave me an insight I hadn't experienced before. I was a guest of Scott Roberts, whose Explore Scientific telescope company had organized an observing party there. The place literally oozes history through every stone, piece of wood, and gear revealing the progress of our understanding of the Universe as it increased during the 112 years since the observatory's founding in 1907.

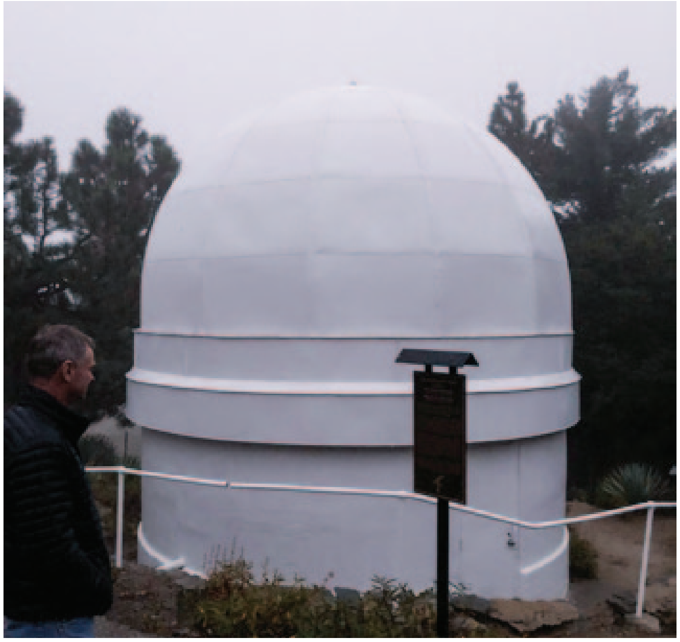


Figure 2 — This Seth Nicholson dome once housed the 12-inch Schmidt camera that now resides at Jarnac Observatory.

During my visit I felt as though I was standing next to some of these great astronomers, now long gone. I was standing next to George Ellery Hale as he struggled to build the Snow Solar Telescope, the mighty 60-inch, and the 100-inch Hooker Telescope. I was standing next to Fritz Zwicky as he used the 100-inch on so many nights. Zwicky had quite the reputation as a curmudgeon. He might have included me among the many colleagues he called "spherical bastards"—meaning a bastard no matter which angle or prism you choose to look through.

I was standing next to Walter Baade. There is a story that, at the outbreak of World War II, he was declared an enemy alien and ordered to stay near his Pasadena home. Since he, or someone, allowed the vicinity of Pasadena to include Mount Wilson, Baade essentially enjoyed three years of uninterrupted observing time on the 100-inch. With Los Angeles under occasional blackout conditions that darkened the Mount Wilson sky still further, Baade made his crucial observations of individual variable stars in the Andromeda Galaxy that he, and Bart Bok, later used to determine the size and shape of our own Milky Way Galaxy.

George Ellery Hale was unsatisfied with the size and abilities of the big 100-inch telescope, and he longed for a much larger one. He hired Russell Porter, the amateur astronomer who had founded the Stellafane telescope-makers meeting in 1925, to work on a 300-inch telescope. When that was deemed impractical, a 200-inch telescope was built instead. Porter's

Figure 1 — The venerable 100-inch telescope points toward the zenith inside its enormous dome at Mount Wilson.

drawings of the 200-inch were stupendous. Realizing that the 100-inch was unable to reach the north celestial pole due to its English double-yoke mount design, he envisaged a beautiful and elegant horseshoe design so that the 200-inch could point right at the pole if needed. Even the lowly 18-inch Schmidt camera telescope, the first telescope at Palomar, made history as the instrument Zwicky uased to discover 100 supernovae in distant galaxies, and, near the end of its useful life, it was the telescope used in the discovery of Comet Shoemaker-Levy 9.

The AAR Lives On!

About a year ago in this column, I wrote about the final Adirondack Astronomy Retreat (AAR) that Wendee and I held in the Adirondack Mountains near Lewis, New York. We had a special program with lectures, a banquet featuring, among other VIPs, my brother Gerry and his partner Duane, and President John Ettling of SUNY Plattsburgh. We even presented to Dr. Ettling the first Starlight Night Prize to celebrate the university's commitment to keep this wonderful place as dark as possible. We concluded the week by burying a time capsule.

Much as we tried, the enthusiasm for the event was too strong just to end it. Now, under the direction of Patrice Scattolin and his family from Montréal, AAR is continuing. With his high intelligence and brilliant sense of humour, Patrice ran the event with an efficiency and alacrity rarely seen. Laurie Williams, Patrice's wife, with the assistance of daughters Clara and Sophie and son Marc, kept the indoor portion running smoothly. And this year the weather helped big time. We had four beautiful nights, and good portions of two others. Using the camp's Meade 14-inch Schmidt-Cassegrain called Aart, a 26-inch reflector dubbed Enterprise, and Carl Jorgensen's 8-inch reflector named Pegasus, I did almost 25 hours of visual comet hunting. This total is possibly a record for this site. When the sky is at its best here, I can glimpse Messier 33 with the naked eye and I did that almost every night. The *International Space Station* made a nice pass, and we saw several bright meteors heralding the onset of the Perseid meteor shower.

The purpose of this particular retreat was and still is to recharge our astronomical batteries, and to remind us why we became amateur astronomers in the first place. While last year we had plenty of down time to enjoy movies and sing-alongs, this year the night sky occupied pretty much all our time. It was truly spectacular.

While the site may be superb now, we chose it for our star party because of the memories that flood back every time I revisit it. It provided my first serious dark-sky experience decades ago, during the summers of 1964, 1965, and 1966. I loved it so much back then that I asked Dad if I could attend SUNY Plattsburgh the rest of the year. In one of the few mistakes Dad ever made, he resisted, preferring that I attend

Figure 3 — The picture is of our site, focusing on the post office building that was built in 1966. This summer, Carl Jorgensen and the author set their telescopes up there, by the porch, in order to get a better view of the northern sky. Photographs by the author.

Montréal's McGill University instead. I flunked out of McGill twice. But I have never forgotten the pristine beauty of SUNY Plattsburgh's Twin Valleys campsite, with its unparalleled views of the "forever wild" Adirondack mountains. May this priceless spot continue to remind future generations of how beautiful the mountains are, and how beautiful the night sky remains far above their lofty peaks.

I close with a variation of a quotation by Sir Kenneth Clark. What defines the great observatories that look to the stars and revolutionize our understanding of them? I don't know. But I know them when I see them. And the observatories at Mounts Wilson and Palomar are them. ✶

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

Observing

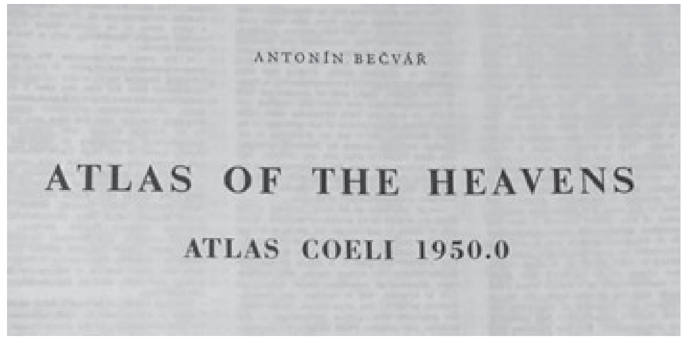
Antonín Bečvář's Atlas of The Heavens 1950.0

by Chris Beckett, Unattached

Between 1946 and 1966, former National President Helen Sawyer Hogg authored a column for the RASC *Journal* titled "Out of Old Books," where, in 1947 and 1948, she helped add several additional Messier objects to the famous list. To read her columns in their entirety, please see www.rasc.ca/outofoldbooks. I never met Helen, though I share her love for old books, rare amongst my generation who grew up during the rise of the internet. So, I have long thought it would be interesting to "reboot" this idea and write about my own divining for knowledge "Out of old Books," both those saved from the recycler, as well as those now digitally available to anyone with a high-speed internet connection.

At last, a like-new copy of Antonín Bečvář's *Atlas of the Heavens*! To the bewilderment of other attendees at the Saskatchewan Summer Star Party swap table, I made the first purchase of the day when I excitedly forked over a rubbery $20 bill and walked away with the 70-year-old atlas. I had this chart on my "to find" list for some time. But why? Well, for those following this column's narrative closely, you will recall the mid-century *Classic RASC Observing List* from the last edition the of the *Journal*, and Bečvář's chart would have served as *the* field chart for those pursuing the objects in that list. In fact, it was among the suggested readings in the *Observer's Handbook* during the time. *Atlas of the Heavens* is also the predecessor to Tirion's *Sky Atlas 2000* and many other "modern" astronomical star charts that I own. The fold-out colour charts of *Sky Atlas* are beautiful works, and *Atlas of the Heavens* offers the original inspiration in all its hand-drawn splendour. Writing in his *Celestial Handbook*, another cornerstone work for amateur astronomers, Robert Burnham mentions the *Atlas of the Heavens* is the most complete atlas available, and Burnham intended serious observers to use the Atlas in conjunction with his Handbook.

Dr. Antonín Bečvář's (*pronounced Betch-varzh*), 1901–1965, was a Czechoslovakian astronomer whose poor health had led delaying the start of a professional career until his mid-30s, when he accepted a government climatologist position in the High Tatra Mountains. During the challenging pre-WWII era, he convinced the Slovak government to relocate its 24-inch Zeiss to Skalnaté Pleso (Rocky Lake), where he became the founder of the Skalnaté Pleso Astronomical Observatory and served as its director from 1943–1950. In 1945, he also convinced a German dynamite squad to bypass the site saving the instruments and buildings from the Nazi scorched-earth policy. He discovered two comets, 1942 IV and 1947 III, and his uranography led to a lunar crater being named for him by the IAU.


ANTONÍN BEČVÁŘ

ATLAS OF THE HEAVENS

ATLAS COELI 1950.0

Figure 1 — Title Page of Bečvář's Atlas of The Heavens

Atlas Colei Skalnaté Pleso, or *Atlas of the Heavens* as it became known in the English-speaking world, was named after the Skalnaté Pleso Observatory in Slovakia. The charts were drafted by the observatory's graduate students who had stayed on during their holidays over 1947 to 1948, contributing more than 3,000 collective hours along with Bečvář, who plotted the objects spread across the chart pages. First published in 1948 by the Czechoslovak Astronomical Society, Sky Publishing, of *Sky & Telescope* magazine fame, making it the "go to" star atlas until 1981, when Tirion's *Sky Atlas 2000* debuted dethroning the 1950.0 epoch atlas. Charts were issued in both bound and unbound formats as well as in field, white stars on black background, black stars on white, and colour desk editions. My desk edition copy appears with the 1962 copyright though the excellent condition and mention of Bečvář's passing in 1965 indicate it is among the more recent vintages. The atlas contains 16 hand-drawn charts, 16″ x 22″, 3.3° to the inch, with 32,571 stars from the Boss and Henry Draper Catalogues covering the entire sky. But what made the *Atlas of the Heavens* unique was that, in addition to all stars 7.75 magnitude and brighter, it contained virtually all deep-sky objects down to 13th magnitude, including 1,300 nebulae, clusters, and extragalactic nebulae (galaxies) from Herschel and other catalogues essentially creating a compendium for all objects visible in an 8-inch telescope.

As seen in Figure 2, the charts are stunning, each a work of art. Keep in mind, these were all hand-drawn and compiled not from a computer database but plotted by Bečvář and his students working long into the night. Deep-sky objects stand out on the pages with their magnificent colours, creating a near three-dimensional perspective, from the brilliant yellow star clusters to the iridescent green nebulae and scarlet galaxies. However, of greatest interest to this observer are the detailed renderings of the Milky Way, shown in several isophotes, from pale blue to a deep turquoise. *Atlas of the Heavens* also includes detailed shapes of diffuse nebulae larger than 10′ as well as dark nebulae from E.E. Barnard's *Photographic Atlas of Selected Regions of the Milky Way*, among

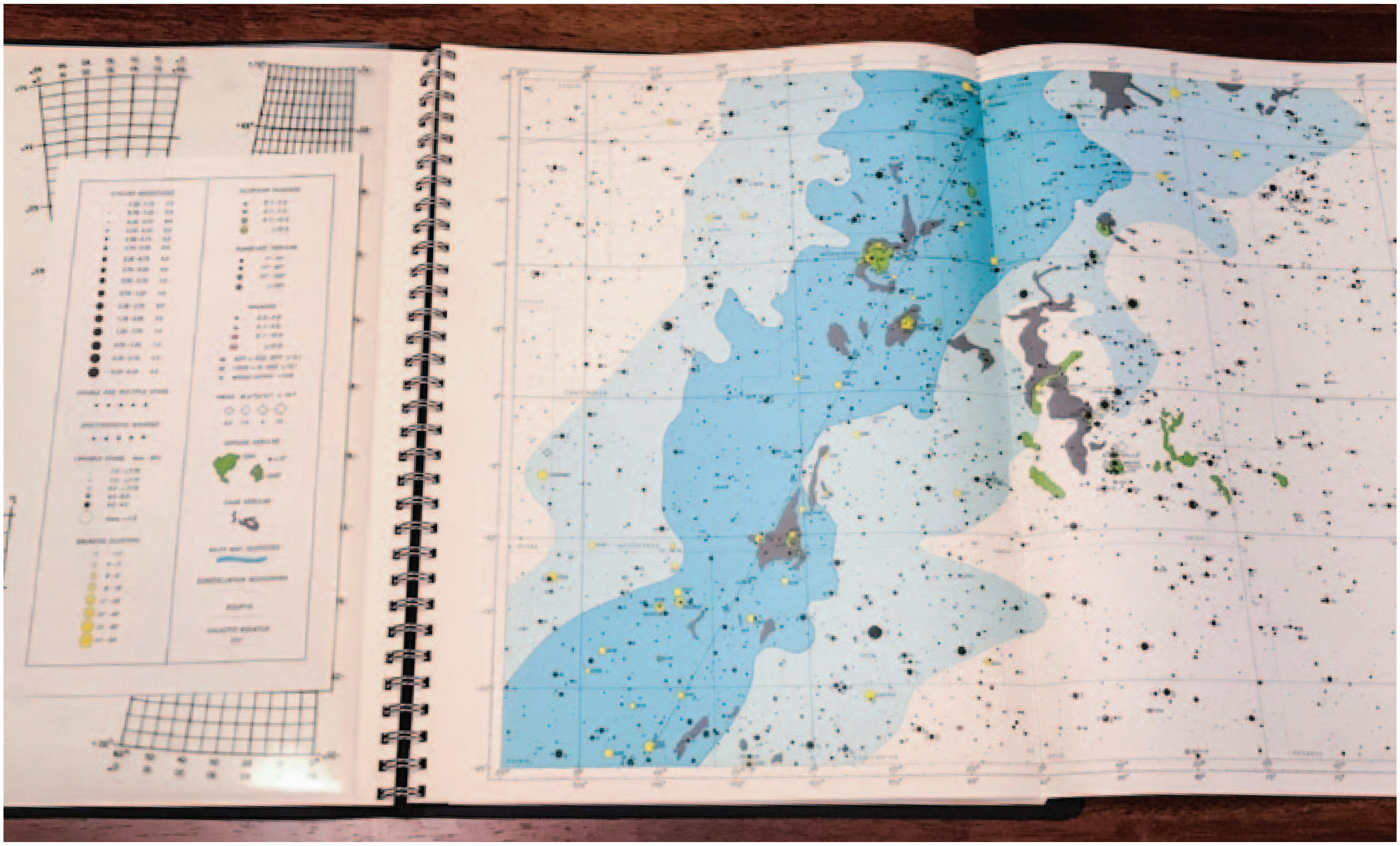


Figure 2 — Orion Nebula and chart legend from Bečvář's *Atlas of The Heavens*

others, all marked in gray scale. While beautiful, my hope is to plumb the depths with this work and attempt to understand the nature of many large objects, such as the dark nebula that appears to cover much of the central region of the Hunter asterism in Orion. As the introduction to the *Atlas of the Heavens* puts it, "the larger of which are indicated by their characteristic shapes as revealed on actual photographs."

Planetarium software and current charts owe a debt to Bečvář and his team, since nearly everything from the outlines of the Milky Way to the depictions of deep-sky objects are all offshoots of his *Atlas of The Heavens*. Now, if I could only find some of those clear 1950's *Skalnaté Pleso* skies! ✶

References:

Bečvář, A. (1962). *Atlas of the Heavens*. Cambridge: Sky Publishing.

Burnham, R. ( ). *Burnham's Celestial Handbook*. New York: Dover Publications.

Kopal, Z. (1965). Dr. Antonin Bečvář. *Nature.J.*, *4983*, 449.

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.*

Is it a 'Scope Night? Should I Get Ready?

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

I've said it before: amateur astronomers are part-time meteorologists. We need to predict the weather, particularly if we are making a long trip or we have a complex telescope setup.

For people wanting to see or image a fast-moving comet, record an occultation, or catch some elusive aurora, it's all about location. Get thee to a dark site free from infernal clouds. But which site? Which direction should we travel?

For dark sky chasers with iOS mobile devices, the Scope Nights app that may prove very useful.

https://eggmoonstudio.com/app/astronomy-weather-forecast/

Scope Nights is a prediction tool for the iPhone, iPad, and iTouch. It can tell you whether you should set up your telescope, pack the car, or open the observatory. You can configure preferred locations or search for clear skies to drive to. It can give you long range advice as well as help with last-minute decisions.

The Next Few Days

For long-range planning, the app offers the main display called Scope Nights. This shows what is expected for the next ten days. There's a plethora of information on this screen including weather indicators, temperature, and the Moon phase. Perhaps the most important nugget of information for each day is the assessment. The app takes into consideration a number of factors and tells you whether it will be a good telescope night or not.

Green is good! The red-amber-green (RAG) colour scheme is used throughout the SN app as a rapid visual indicator of conditions. You also see these colours used in the Forecast screen for a single day and on the location map. In addition, there's a verbal remark beside the date.

The February *Journal* deadline for submissions is 2019 December 1.

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

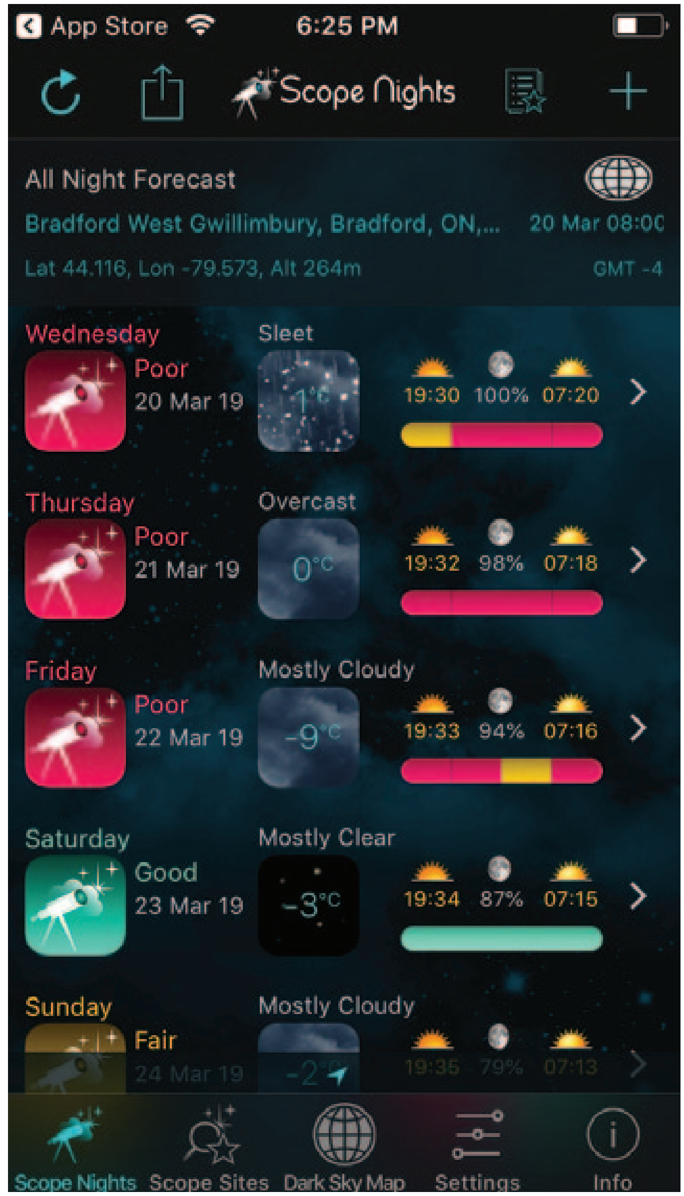


Figure 1 — The main screen of Scope Nights listing predictions for ten days.

We can see (in Figure 1) the conditions are not looking good for the next couple of days. That's OK. The Moon is full and these are "school" nights. But Saturday is looking very promising with clear skies all day. It is also not as cold as Friday. SN says Saturday looks "good" and Sunday should be "fair."

A small weather tile (sometimes animated) visually indicates the anticipated sky conditions. The predicted air temperature shows here, too. A brief text entry (e.g. overcast, mostly clear, and, yes, sleet) echoes the projected conditions.

On the right is a bar with the four segments possibly showing different colours. Above the bar you will see the sunset and sunrise times along with a rendered Moon with percentage of illumination. If the Moon text is red, the brightness exceeds your maximum threshold.

Figure 2 — The All Night panel with expected conditions including humidity.

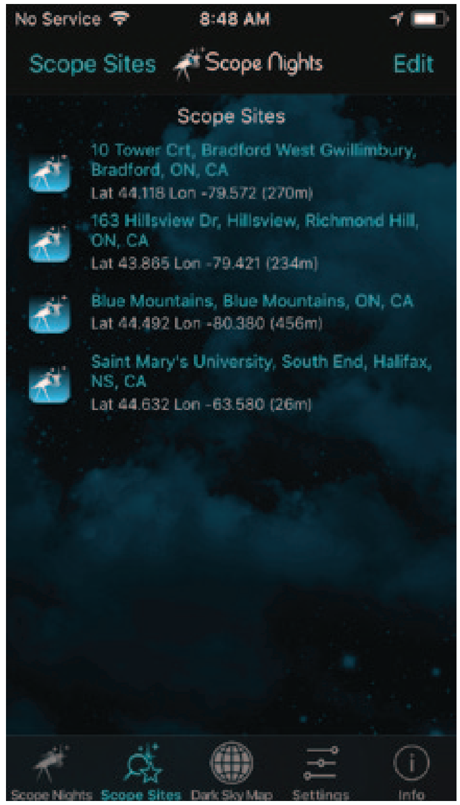


Figure 3 — Stored locations in the Scope Sites screen.

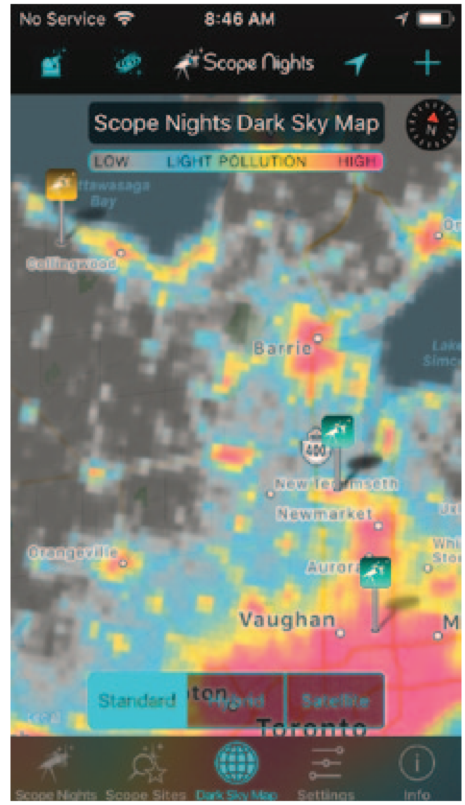


Figure 4 — The Dark Sky Map shows light pollution and weather predictions.

When you tap on a specific day from the main Scope Nights display, an evening panel appears. This is your short-range or immediate weather predictor screen. Now you're focused on one particular night at the designated location.

One can see the evening forecast is broken into four periods with predictions or indicators of each three-hour period.

Like the 10-day display, there's lots of information here: the RAG indications, verbal assessments, the weather conditions visually noted with air temperature, along with the Sun and Moon times. In addition, we see predicted wind speed and direction, percentage cloud cover, and the relative humidity. Values exceeding your specified thresholds will trigger red text and red markers.

What's your take on this display (Figure 2)? The early evening outlook is good while warm at 25°. The Sun will be gone at 9:05. It doesn't seem like we'll need the dew heaters unless we push into the early morning when the humidity climbs above 80%. The wind speed drops around midnight. It seems we should start packing up around 2 a.m. before the clouds arrive.

These two screens, the 10-day, the "all night," can be shared. If you like the assessment and decide to pull the trigger for an observing session, you can quickly relay this information to others via social media or email. Don't star party alone.

Preferred Locations

The Scope Sites panel is simply an editable and sortable listing of your favourite observing locations.

Unless I'm missing something, you cannot directly add a new spot to the Site list (you have to use the map screen). You also can't change the clunky description for the location as far as I can tell, but that's not a big deal.

Regardless, once you have configured your sites, you can easily switch locations in the app.

Big Picture

The Dark Sky Map panel (Figure 4) serves many purposes.

With the high-resolution light pollution overlay from NASA, you can gauge a location's darkness. So, if you plan to travel to darker skies for noctilucent clouds or faint fuzzies, this can help you decide where to go.

Again, this is where you add your preferred stored locations. Move about the map, zoom in as needed, then do a long press. Now you can append this site to your favourites.

Continued on page 244

Pen & Pixel

Figure 1 — STEVE is seen here near Lucky Lake, Saskatchewan on September 5 taken by Tenho Tuomi. Tenho used a Canon T5i camera with a 10-mm lens at ƒ/3.5. Total exposure was 15 seconds at ISO 3200.

Figure 2 — The thin crescent Moon was imaged by Dave Chapman just 28 hours after new Moon using a Canon SL1 with a 300-mm lens.

Figure 3 — The Milky Way stretches above the Bowron Lakes canoeing circuit just east of Quesnel, B.C. Tom Burbee used a Canon 70D with a Sigma Art 18-35 ƒ/1.8 lens. Tom took a 20-second exposure at 1.8 and 2500 ISO. The final image was edited in Lightroom.

Figure 4 — The magnificent Pleiades was photographed by Stephanie Harron from Buchannan Summit, Kaslo, B.C., at an altitude of 1,912 metres. Stephanie used a Canon Mark IV with 500-mm lens and a 1.4X converter that was tracked with Celestron AVX and an Orion autoguider.

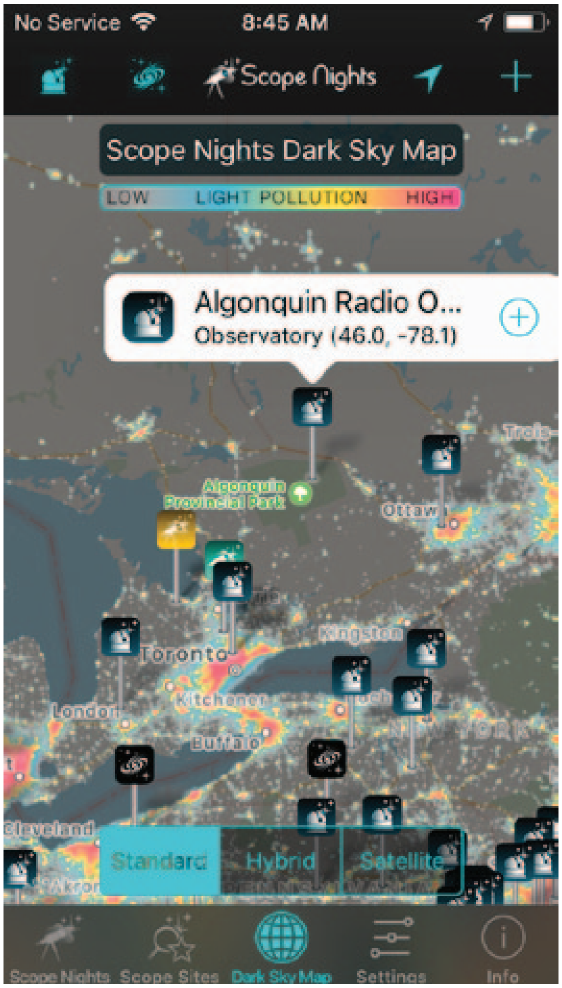


Figure 5 — The map can also show observatories and dark sky preserves.

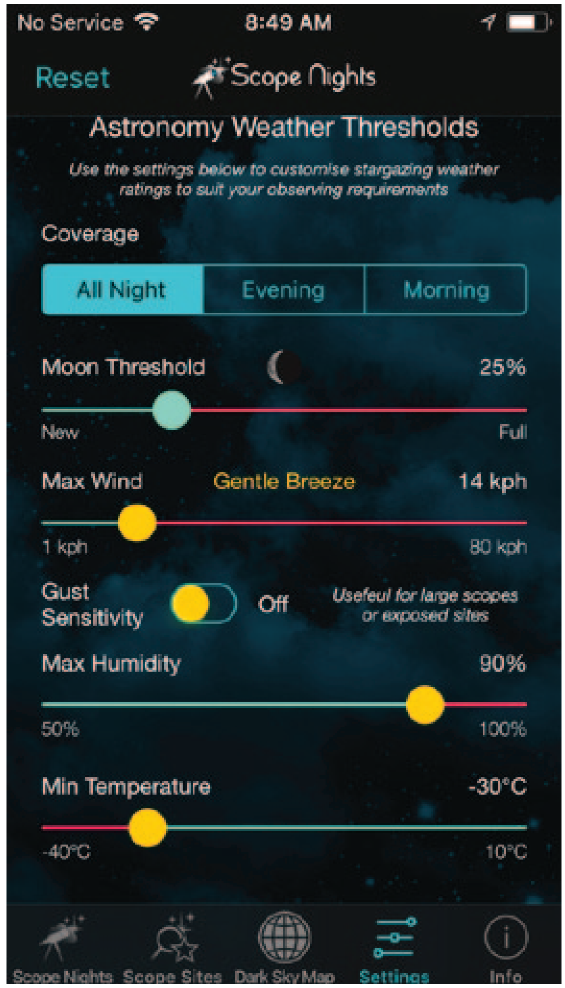


Figure 6 — The Settings screen to configure various thresholds.

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When you have some frequently used sites on file, you'll see pins appear on the map. Note that the RAG colour scheme at the pin tells the weather conditions at that site. If you see a green flag in a dark zone, start the car!

There are rather interesting little icons above the map display.

The first button, the dome, might be helpful for when you are travelling about—doing some astro-tourism—and hope to visit an observatory. The map (Figure 5) will show dome markers for notable locations. I was a little surprised to see the Algonquin Radio Observatory tagged! Been there (but didn't get the shirt).

The spiral galaxy button toggles the display of attractive sites such as International Dark-Sky Preserves. Many such locations around the world are noted if your budget includes jet fuel. I was expecting many more locations to pop up in Canada, yet I only found Bon Accord in Alberta.

Your Constraints

The Settings panel (Figure 6) allows you to control your preferred units for temperature and wind speed.

More importantly, you can set thresholds. How much moonlight will you tolerate? What is the maximum wind your telescope can withstand? You can also specify a ceiling for humidity. This makes the predictive screen text and markers turn red when a limit is passed.

What's the Best of the Best?

One final screen merits your attention. From the main screen, you can tap the icon near the top right, the one that shows a bullet list with a star. This produces the Best Scopes Sites list.

Now the SN app takes everything into account. Using algorithms, it evaluates all your stored locations, the weather data, and your constraints to find the best conditions. That's cool. But this might mean you're racking up the klicks.

You'll note in Figure 7 that conditions should be good in Richmond Hill on Thursday. Maybe we can have a parking lot session at the David Dunlap Observatory. Since Friday night should be fair in Halifax, we could load a job or two into the Burke-Gaffney Observatory queue. You can just make out that fair prediction for Bradford. If not exhausted, I could make the sojourn to the backyard with the little grab-and-go.

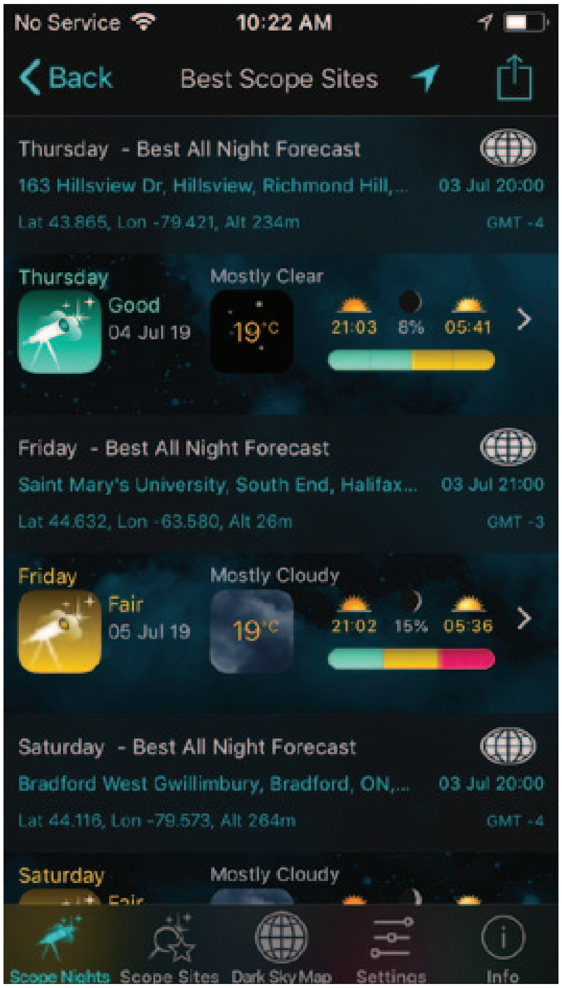


Figure 7 — The Best Scopes Sites lists the very best conditions by site.

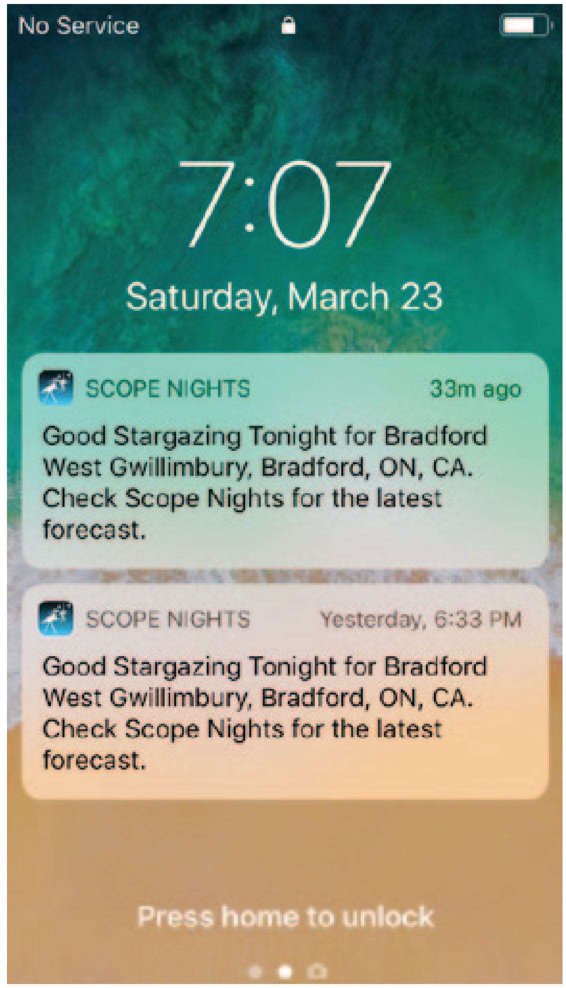


Figure 8 — Alerts tell you that good conditions are expected soon.

up in the Canadian Clear Sky Charts of late. The SN website proclaims the app provides accurate stargazing weather forecasts worldwide and has done so for many years. During my testing, it correctly anticipated my local weather.

Some of the text is very small and there's no red-light mode, but these are minor issues.

The app has accumulated a very high rating online with many responses. *Sky at Night Magazine* praised Scope Nights. It received a big thumbs up from Uncle Rod Mollise in *Sky & Telescope*. I tested version 2.5.1 of the app on an iPhone, and it worked well for me. It is compatible with iOS 11. Purportedly it has backward compatibility with older devices.

Hey, Human, it's Good!

Of course, all these predictive screens are wonderful if you're proactively planning an excursion or checking conditions for the next Moon-free weekend. So, to nudge you while you're busy with life, Scope Nights issues alerts.

When good weather is around the corner, messages will appear on the device wakeup screen. Mind you, it might be short notice: you'll be informed three to six hours ahead of clear skies.

Summary

Scope Nights is a very good app. Simple, to the point, with some clever features. It summarizes weather conditions at different observing locations. It can help you make informed decisions before hittin' the road. Should I get out the telescope? Should I open the observatory? Should I fill up the gas tank? How far am I willing to travel?

Weather information is collated from trusted sources in the U.S. and Europe, both in the long and short term. In fact, it uses the European Centre for Medium-Range Weather Forecasts (ECMWF), which you may have noticed showing

The author Martin Dodd provided me an evaluation copy of the Scope Nights app. He said that he hadn't worked on it in a while but wanted to get back at it. He's planning to add seeing and transparency predictions and short-range local forecasts for Canada. That'll just make it better.

The app costs CAD $4.99. It's worth it.

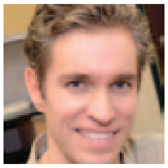
Bits and Bytes

I was a little disappointed to learn that some versions of SkySafari do not show local sidereal time. For example, the free basic Android version 6 does not show LST. I think you need the Plus level or higher. ✶

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.

Dish on the Cosmos

Big Pulsars make Bigger Problems



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

Since their discovery in 1967, neutron stars have been one of the great mysteries in modern astrophysics. To the present day, astronomers continue to grapple with the nature of these extreme objects. Work so far has led to the conclusion that these stars are fantastically dense with 1.5–2 solar masses worth of material packed into a sphere with a diameter of approximately 25 km. The density of this material exceeds that of atomic nuclei and the star is only barely supported against its own gravity, teetering on the edge of collapse into a black hole. Since the physics requires going beyond what we can probe here in terrestrial laboratories, we must use our astronomical observations of neutron stars to discover how they work.

Neutron stars were first discovered as pulsars, based on observations made by Jocelyn Bell Burnell, who was a graduate student studying under the guidance of Anthony Hewish at Cambridge. She noted that some "scruff" (her phrasing) on some radio observations corresponded to a regular pulsed signal from the source they were studying, with a regular period of 1.3 seconds. The signal was originally termed LGM-1 for "Little Green Men," referring to the potentially artificial nature of the radio blips. The sources have been rebranded as pulsars for the pulsed nature of their radio emission.

Diving into the theoretical literature of the time showed that a hypothetical type of star called a neutron star was able to explain many properties of the pulsar data. The hardest thing to explain was the frequency of pulses—a sharp signal with only a 1.3-second period required a small object. The

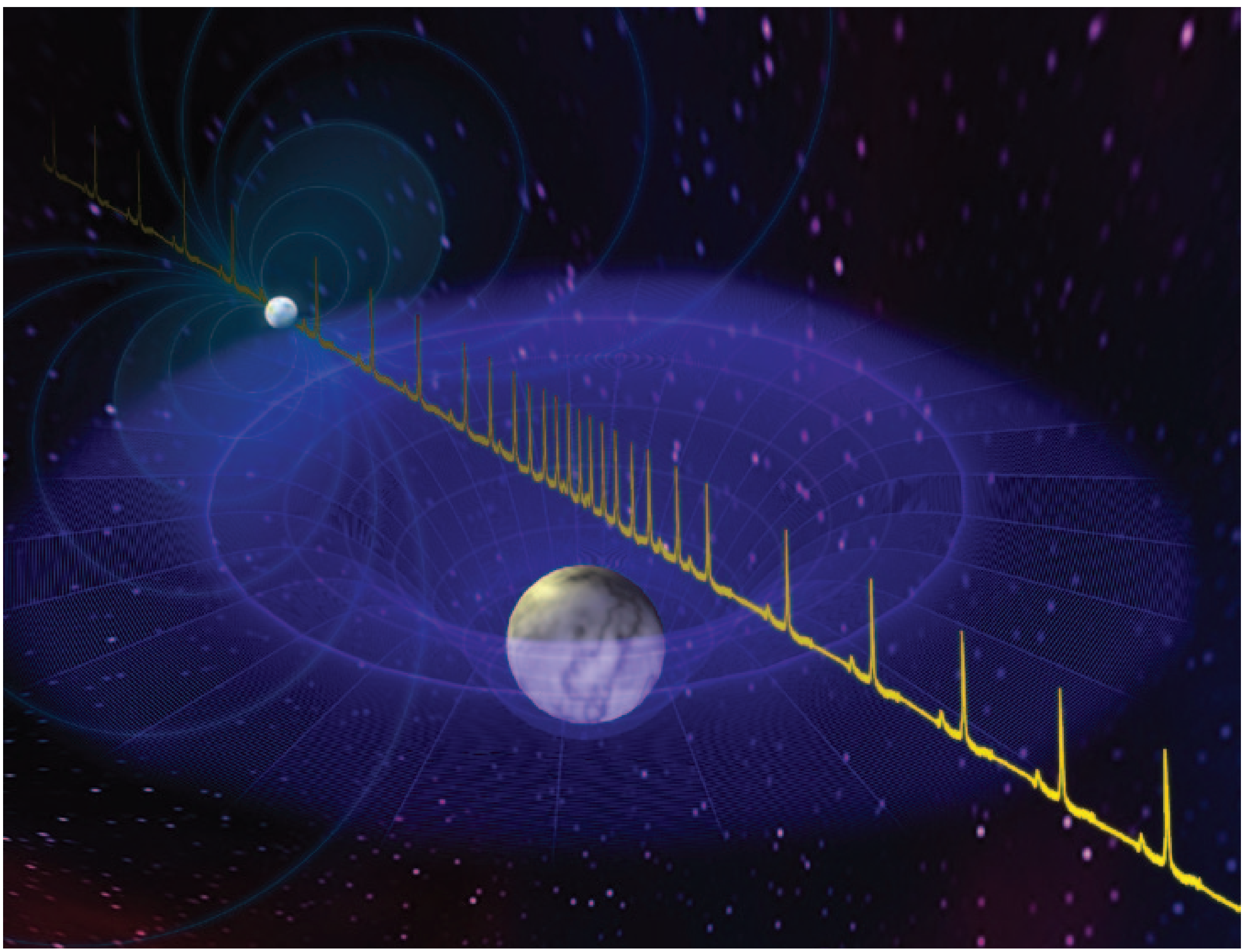


Figure 1 — Artistic rendering of the system J0740+6620 showing the pulse train from the neutron star being delayed by gravitational effects as it passes near the white dwarf. This delay is then used to measure the mass of the two stars in the system. Credit: B. Saxton, NRAO/AUI/NSF

rate at which a signal can change is limited by the time it takes for light to cross the object. The maximum size for the emitting region would be 1.3 light-seconds for this signal, but other pulsars have even shorter times between their pulses, some reaching down to shorter than a millisecond. A light-millisecond is only 300 km, by far the most compact objects known. Studying objects in orbit with pulsars has showed that the neutron stars have masses close to that of regular stars. Combined with the radius measurements, this mass implied the extreme densities. We have since concluded that pulsar emission comes from neutron stars using what is called the lighthouse model—the pulsar sends a beam of radio emission out into space. Because the pulsar is rotating quickly, the beam projects across the sky and systems in the path of the beam see a brief pulse of radio emission as the beam sweeps past.

The next mystery is how the neutron stars are able to support themselves against gravity. There must be an incredibly strong form of pressure to provide this support. Inspired by the study of white dwarfs, we believe that part of this pressure comes from degeneracy pressure. Degeneracy pressure arises as a consequence of quantum mechanics applied to the neutrons that make up the star. The rules of quantum mechanics state that no two neutrons can be in the exact same quantum state, which is one way to phrase the Pauli exclusion principle. If two neutrons are too close together and travelling in the same direction they would be in the same state and thus violate this principle. Consequently, if many neutrons are crammed into the same volume of space, some must be travelling quickly otherwise they will violate the rules. These fast neutrons are able to provide the pressure support and they are unable to slow down or else they would enter the same state as another neutron. Degeneracy pressure and the consequences of quantum mechanics cannot be the whole story—when neutrons are this close together, the forces that govern the dynamics of atomic nuclei become important. In particular, the strong nuclear force starts to bind the neutrons together. In fact, neutron star densities are so high that the neutrons are pressed into each other and the quarks that make up neutrons start to blend together. Since the conditions are more extreme than those found in atomic nuclei and of higher density than we can make in our particle accelerators, we have no idea what matter will actually do in this state. Instead, we must rely on theoretical predictions for how this ultra-dense matter will behave.

Theoretical physicists are prolific and are able to generate many different possible ideas for what could happen inside neutron stars. Without any observational limits on their imaginations, several strange scenarios have been predicted. We need to use new observations to determine which ones are right, or more specifically, which theories are not wrong. To help with this assessment, the theoretical models are used to predict the "equation of state" that describes how the pressure exerted by the material depends on its other properties. You may be familiar with the equation of state for a gas, which predicts the pressure in terms of the temperature and volume of an ideal gas. The equations of state for ultra-dense matter do much the same thing, predicting the pressure inside neutron stars. These predictions can be used to calculate the maximum mass that a neutron star can have before it collapses into a black hole. We can then measure the masses of different neutron stars and rule out equations of state that cannot reach the observed maximum mass.

Pursuing this effort, recent observations have just found the most massive neutron star known to date, with a mass of 2.17 solar masses. The system is called J0740+6620, where the name encodes the right ascension and declination coordinates of the source. The observers used the Green Bank Telescope (GBT) in West Virginia, USA, to measure the pulsar signal from J0740+6620 in several different studies over many years. Each time the pulsar is observed by the GBT, astronomers measured the regular chain of pulses and compared the times of arrival for the pulsars to what is expected from a model of the system. Small deviations from the model showed that the pulsar was actually in a binary star system with a white-dwarf star. By accounting for the orbital motions, the model for the pulsar timing was adjusted to solve for the total mass of the two stars. However, determining the masses of the individual objects requires a separate measurement. Subsequent observations also revealed that the orbital motion model was unable to explain all the timing delays and one additional component is needed. The orbit of the system is close to edge on, so the pulses from the neutron star pass close to the white dwarf on their way to the telescope. As they do, they experience a delay from the gravitational field of the white dwarf. By modelling this delay, the astronomers were able to determine the masses of the white dwarf and the neutron star separately, revealing the new record-setting neutron star mass.

This new mass rules out ever more of the equations of state, slowly leading to some convergence of a few different models. The next steps forward will come from measuring the radius of the neutron stars, which is also predicted from the equation of state. This measurement will be challenging: distinguishing between these models requires determining whether an object is 22 vs 25 km in diameter at interstellar distances. This result is still thought to be attainable using novel methods, requiring new approaches in X-ray astronomy and gravitational-wave detection to move forward. ✶

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.

CFHT Chronicles

Icy Worlds and Cannibal Galaxies

by Mary Beth Laychak, Director of Strategic Communications, Canada-France-Hawaii Telescope

Late summer and early fall brought several interesting science results to CFHT. Two of the new releases came from CFHT large programs—OSSOS and PAndAS, and the third revolves around everyone's favourite interstellar comet, 'Oumuamua. I have taken the CFHT news stories about these discoveries and added some additional information.

A Search for Distant Collisional Remnants

The distant Solar System contains a large reservoir of objects beyond the orbit of Neptune, which are the icy remnants of planetary formation. These small icy bodies are challenging to discover, but their orbital properties and surface composition provide critical information about the formation and evolution of the Solar System. The Outer Solar System Origins Survey (OSSOS) and its companion surveys (CFEPS, HiLat, Alexandersen) covered 1,209 square degrees and discovered more than 1,000 trans-Neptunian objects (TNOs). The main surveys were conducted using the Canada-France-Hawaii Telescope on Maunakea.

The OSSOS survey, led by principal investigator Brett Gladman from the University of British Columbia, was allocated 560 hours of observing time at CFHT from 2013–2016. The team used our wide-field imager Megacam to track 8 patches of the sky in the r band (640 nm), over the course of the survey. Each 21-degree-square patch was chosen to target populations in resonance with Neptune. One of the science goals was to explore these resonant populations of the Kuiper belt to test models of how the Solar System evolved. The astrometric precision of the survey along with the regular observing cadence allowed the team to accurately determine the orbits of these distant, icy worlds in one percent of the time it takes the objects to orbit the Sun.

Figure 1 — The summit of Maunakea includes many telescopes, including the Canada-France-Hawaii Telescope (CFHT, centre, white) and Gemini Observatory (closest, silver). These distant icy objects, marked in white rectangles, were discovered in the Outer Solar System Origins Survey (OSSOS) on CFHT. Half of the OSSOS survey fields are visible in the photo. Photo credit: Joy Pollard

Hidden among the more than 1,000 objects discovered by the team are three large objects, which may belong to the Haumea family. Named after the dwarf planet of the same name, the Haumea family of objects are thought to have formed as the result of a collision several billion years ago. Called a collision family by astronomers, the family members are identified by their similar orbital elements and surfaces, which display water-ice. The namesake object, Haumea, was named after the Hawaiian goddess of childbirth, an homage to Maunakea where Haumea's moons were discovered.

While the asteroid belt contains more than 100 collisional families, only one family has been identified in the Kuiper belt, which is a region of our Solar System located 30 to 50 times more distant than the Earth is from the sun. Understanding the collision that created the Haumea family provides critical information about the types of collisions that have occurred in the Kuiper belt, and potential insight into how to best search for additional families of objects beyond Neptune.

A recent paper in *Nature Astronomy* written by Rosemary Pike from ASIAA and the OSSOS team, shows surprising results for the Haumea family. The OSSOS team discovered three potential Haumea family members significantly brighter than the survey limits.

"Based on our discovery of these three large objects, we expected to find 10 to 30 smaller Haumea family TNOs," said Pike, lead author of the paper. "We didn't find the smaller objects, which gives us important clues about the formation of the Haumea family."

Pike and the team carefully tested the survey sensitivity and models of the orbital distribution of the Haumea family, and determined conclusively that the Haumea family has significantly fewer small objects than the other TNO populations. They describe this result as a shallow size distribution in their model. The OSSOS survey has well understood discovery bias, so the team conducted the first statistically rigorous testing of the Haumea family size distribution, which provides the first robust constraints on how many small and large Haumea family members exist in the Kuiper belt.

Pike and the OSSOS team determined that the shallow size distribution of the Haumea family members is different from the size distribution of all other TNOs, important implications for the formation of this family. A shallow size distribution like the one seen with the Haumea family is produced by graze and merge simulations, where the impacting object grazed the proto-Haumea, slowed, and returned to collide again

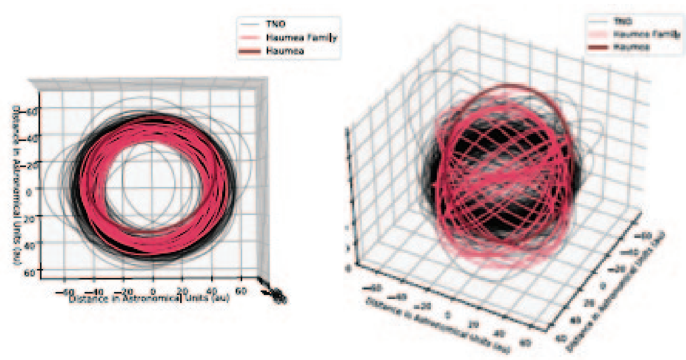


Figure 2 — Haumea and its family members (red/pink) have orbits that are different from the majority of classical TNOs (gray). The Haumea family members have higher inclinations, so their orbits extend further from the ecliptic plane where the classical TNOs cluster.

and merge with Haumea. The newly merged objects rotate quickly and shed material forming the other family members. However, the orbital distribution expected by a graze and merge collision does not match the known orbital distribution of Haumea family members; rather the Haumea family has an isotropic orbital distribution. An isotropic orbital distribution results from a catastrophic collision, where the impactor is immediately destroyed. Catastrophic collisions produce a steep size distribution conflicting with the team's results. This conflict inspires future work on the Haumea family, which will focus on understanding possible formation scenarios, which reproduce both the observed orbital and size distributions.

"The OSSOS team's long history of observations with Megacam here at CFHT and coordinated observations with Gemini Observatory means they really understand how their discovery of these three reflects the number of Haumea members in Kuiper Belt," said Todd Burdullis, QSO operations specialist at CFHT. "Their discovery about the formation of the Haumea family add to the long string of great discoveries about the outer Solar System from CFHT."

New Insights into 'Oumuamua

While amateur astronomer Gennady Borisov discovered a second interstellar comet earlier this year, our hearts still belong to 'Oumuamua. Using hundreds of millions of physcial models, Sergey Mashchenko of McMaster University published the first detailed kinematic model of 'Oumuamua.

'Oumuamua is the first interstellar minor body detected to pass through the Solar System. It was detected by Pan-STARRS1 survey on 2017 October 19 as an extremely faint unresolved dot moving very fast across the plane of the sky. Soon many large telescopes, including CFHT, began tracking this object. From the very beginning, researchers were puzzled by its strange and unique properties. To start with, the expectation (based on current theories of how planets form) was that the first interstellar visitor would be a classical comet—an icy body quickly developing a large and bright coma and tail due to outgassing (evaporation of the surface ices driven by solar radiation). Instead, the object remained point-like and unresolved, as if it were a rocky asteroid.
The second puzzle was the extreme brightness variations of 'Oumuamua (by more than a factor of ten—more than any known minor body in the Solar System). The popular explanation is that 'Oumuamua is a strongly elongated cigar-shaped object spinning about its smaller axis, though a thin disk (pancake) rotating about its larger axis would produce the same effect. The latest puzzle was the discovery of non-gravitational acceleration exhibited by this object—an effect normally associated with strong outgassing in comets—combined with the fact that 'Oumuamua never showed any signs of outgassing. This conundrum led some researchers to suggest that 'Oumuamua is a solar sail from an advanced civilization, experiencing non-gravitational acceleration due to solar radiation pressure.

Sergey Mashchenko's paper in the *Monthly Notices of Royal Astronomical Society* shed some more light on the nature of 'Oumuamua. The researcher wrote a GPU-accelerated code, which was used to generate hundreds of millions of physical models of the asteroid. By comparing the simulated light curves from the models with the observed light curve of 'Oumuamua, two important conclusions were made.

First, it was discovered that to reproduce the specific timings of the most conspicuous features of the observed light curve—deep brightness minima—some torque (non-gravitational spin-up or spin-down) was required. This seems to have given more credibility to the idea that 'Oumuamua is a comet, as there are a few Solar System comets that exhibit both non-gravitational acceleration and non-gravitational torque (both driven by the same mechanism—strong outgassing from the surface). On the other hand, the lack of any outgassing detections from 'Oumuamua remains unexplained. One possible way out of this dilemma is to assume that the object is a solar sail with some parts brighter (more reflective) than others. Solar radiation would push the object as a whole, reproducing the observed non-gravitational acceleration, while the variable reflectivity would result in some spin-up or spin-down (torque) of the sail.

Second, it was shown that the popular cigar shape is very unlikely, as it would require an extreme fine-tuning of the object's orientation. Specifically, the observer would only see large brightness variations if the cigar was repeatedly pointing at the Earth with a high accuracy. The disk (pancake) shape has no such issue and hence is much more likely. Mashchenko showed that the disk can be potentially as thin as the solar sail requirement (less than 1 mm), though the best quality fit was obtained for a disk with 6:1 aspect ratio. Assuming albedo 10 percent, this would correspond to the physical size of 115 × 111 × 19 metres.

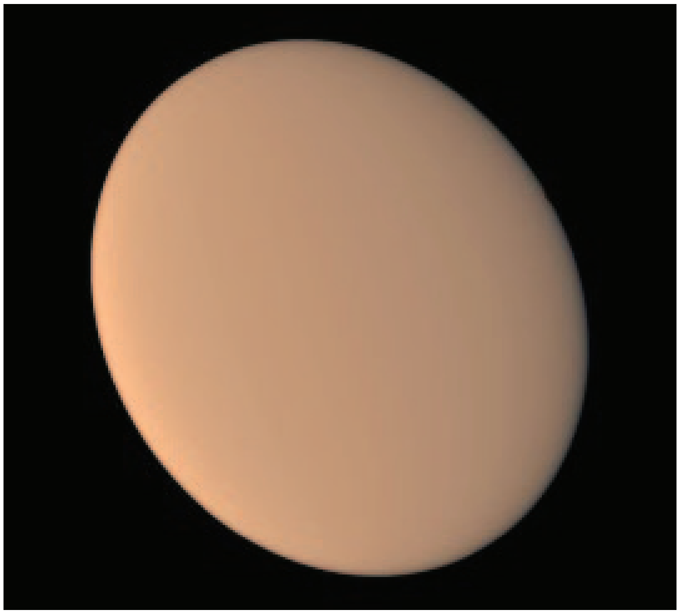


Figure 3 — Visualization of the disk model for 'Oumuamua. image Credit: Sergey Mashchenko

"Our model implies that 'Omuamua is a pancake shaped comet that experienced some outgassing as it passed through the inner Solar System," said Sergey Mashchenko, author of the paper. "Too bad the comet is no longer observable. So I am afraid the lack of any signs of outgassing will remain an unsolved puzzle."

Cannibalistic Andromeda

Moving way out of our Solar System, our final science news concerns the violent history of our nearest big neighbour, Andromeda. The team, led by Dougal Mackey from the Australian National University and Geraint Lewis from the University of Sydney, used data from another CFHT large program, the Pan-Andromeda Archaeological Survey or PAndAS.

Astronomers have pieced together the cannibalistic past of the neighbouring large galaxy Andromeda, which has set its sights on our Milky Way as the main course.

The galactic detective work found that Andromeda has eaten several smaller galaxies, likely within the last few billion years, with leftovers found in large streams of stars.

Dr. Mackey said the international research team also found very faint traces of more small galaxies that Andromeda gobbled up even earlier, perhaps as far back as during its first phases of formation about 10 billion years ago.

"The Milky Way is on a collision course with Andromeda in about four billion years, so knowing what kind of a monster our galaxy is up against is useful in finding out its ultimate fate," said Dr. Mackey of the ANU Research School of Astronomy and Astrophysics.

"Andromeda has a much bigger and more complex stellar halo than the Milky Way, which indicates that it has cannibalized many more galaxies, possibly larger ones."

The signs of ancient feasting are written in the stars orbiting Andromeda, with the team studying dense groups of stars, known as globular clusters, to reveal the ancient mealtimes.

"By tracing the faint remains of these smaller galaxies with embedded star clusters, we've been able to recreate the way Andromeda drew them in and ultimately enveloped them at the different times," Dr. Mackey said.

The discovery presents several new mysteries, with the two bouts of galactic feeding coming from completely different directions.

"This is very weird and suggests that the extragalactic meals are fed from what's known as the 'cosmic web' of matter that threads the Universe," said Professor Lewis from the Sydney Institute for Astronomy and University of Sydney School of Physics. "More surprising is the discovery that the direction of the ancient feeding is the same as the bizarre 'plane of satellites,' an unexpected alignment of dwarf galaxies orbiting Andromeda."

Dr. Mackey and Professor Lewis were part of a team that previously discovered such planes were fragile and rapidly destroyed by Andromeda's gravity within a few billion years.

"This deepens the mystery, as the plane must be young, but it appears to be aligned with ancient feeding of dwarf galaxies. Maybe this is because of the cosmic web, but really, this is only speculation," Professor Lewis said.

"We're going to have to think quite hard to unravel what this is telling us," he said.

Dr. Mackey said studying Andromeda also informed understanding about the way our galaxy has grown and evolved over many billions of years.

"One of our main motivations in studying astronomy is to understand our place in the Universe. A way of learning about our galaxy is to study others that are similar to it and try to understand how these systems formed and evolved. Sometimes this can actually be easier than looking at the Milky Way, because we live inside it, and that can make certain types of observations quite difficult."

The study, published in *Nature*, analyzed data from PAndAS. The CFHT observed the PAndAS program from 2008–2010 as part of CFHT's large program observations. [Ed: See Leslie Sage's article and image on pp. 257.]

PAndAS used CFHT's wide-field optical imager MegaCam for 226 hours spread out over the 2-year period. The goal of the program was to provide the deepest and most complete panorama of galactic halos for the Milky Way's nearest neighbours, M33, the Triangulum Galaxy, and M31, the

Andromeda Galaxy. The PAndAS team intended to create the primary reference dataset for all subsequent studies of the stellar populations of M31 and M33.

"CFHT and the PAndAS team spent considerable time crafting the observing strategy for the program with the hope that the survey would lead to discoveries like those made by Dr. Mackey's team," said Todd Burdullis, queue observations specialist at CFHT. "We are incredibly proud of the dataset and its continuing impact on astronomy's understanding of the histories of our nearest neighbours."

"We are cosmic archaeologists, except we are digging through the fossils of long-dead galaxies rather than human history," said Professor Lewis, who is a leading member of the survey.

Figure 4 — CFHT birthday cake donated by KTA.

A Birthday Blow Out

As regular readers of this column hopefully have realized by now, 2019 is CFHT's 40th birthday. We have spent the year celebrating (not quite done yet, I am writing this column in October), but one of the highlights was our community birthday party held on September 28.

We hold an annual Solar System Walk every October, where we turn Waimea into a scale model of the Solar System between our headquarters and the Keck Observatory offices about a mile away. With that event on the horizon, we decided to just throw a fun party. And that we did! More than 400 people attended. We rented a dunk tank and bounce castle slide, had a complimentary BBQ, face painting, music, and a birthday cake donated by a local grocery store, KTA. The dunk tank raised money for our Maunakea Scholars program and Waimea Elementary School.

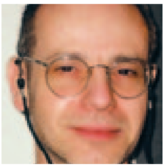
The party capped off over a week of activities. CFHT's director Doug Simons kicked the celebrations off with a talk on September 20th at Imiloa Astronomy Center in Hilo. He covered the discoveries, instruments, and people of CFHT over the past 40 years. CFHT staff marched in the 44th Annual Paniolo Parade in Waimea. The parade, chaired by one of our retired staff members, Moani Akana, celebrates the cowboy culture and history of Waimea. CFHT also donated books to our local public library and a few local schools, sponsored and volunteered at the weekly Waimea Community Meal, and treated our local teachers to chocolate-covered macadamia nuts. We also bought our local crossing guard breakfast and learned she went to Waimea school with the daughter of one of our early directors, René Racine. That pretty much sums up Waimea.

Eagle-eyed readers may notice that my biography changed since the October issue. I am now the Director of Strategic Communications at CFHT. While the new position changes some of my responsibilities, it does not change my core job at CFHT—communicating astronomy to people. ✶

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

Astronomical Art & Artifact

Requirements for a Good Astronomical Drawing: An Evolving Landscape of Purpose?



by R.A. Rosenfeld
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Abstract

In our time amateur astronomy offers several approaches to imaging, each defined by its own technology, and each with its own community of practice. Astrosketching, the drawing of celestial phenomena in which the eye is the light detector, the brain the image processor, and the hand the means of "mechanically" reproducing the image, is the oldest among the imaging technologies still in use. As is the case for many venerable technologies in the sciences, its purpose, techniques, and role have changed as science has developed. This paper will look at transformations in the requirements for a good astronomical drawing, by considering direct statements of the purpose of drawing in observational astronomy.

What is the Artist Trying to Achieve?

When the group ancestral to the RASC came together in 1868 it quite naturally included people whose mode of imaging was to sketch at the eyepiece (*e.g.*, Andrew Elvins). The Society was formed in a "golden age" of visual observation, when the best way to image through a telescope was by drawing what one observed.[1] The technical periodical literature on astronomical sketching has never been extensive.[2] The sparseness of the published record aside, the previous literature is of value both as source of potential technical advice for astrosketchers now, and as a quarry for historical attitudes towards sketching. In addition to the relevant periodical literature, the general observing guidebooks of the period may also be informative on attitudes to sketching. Some representative examples of each appear below.

In 1843 Charles Piazzi Smyth (1819–1900), while serving his astronomical apprenticeship at the Cape, published through the intermediary of his father a "A Memoir on Astronomical Drawing," in which he states that:

"One of the great objects to be attained in astronomical drawing is the absolute fidelity of the details, and in this it differs materially from ordinary drawing from nature, where the accuracy of the *general* resemblance is the great point to be aimed at;" (Smyth 1843, 278).

Figure 1 — Andrew Elvins (1823-1918), one of the original founding members of the RASC, in a photographic portrait of 1893. Elvins, like many astronomers (amateur and professional) of his generation, imaged celestial objects by sketching them at the eyepiece. Present-day RASC astrosketchers stand in a long tradition. Reproduced courtesy of the RASC Archives.

Three years later a fuller version of his paper appeared:

"In ordinary drawing, the reduction of the natural objects is so great as to preclude the possibility of exactness of detail; nor would it be worth while to spend much time in any serious endeavour to produce this sort of perfection, even if it were possible. In representing, therefore, such an object as a tree, a certain mode of imitation is adopted, expressive of the general configuration of the foliage, and the effects superinduced by light and shade; and though such a production is not very like the original, still it is so generally understood that it may be considered a successful example of a conventional arrangement. No astronomical drawing ought, however, to be invaded by any such device for procuring a general effect; no vague expression or semblance of that which exists must be allowed to take the place of painstaking, accurate, and detailed delineation; for the passage of a celestial object from one state to another, which it is our prime object to ascertain, can only be established by a comparison of very exact and faithful representations;" (Smyth 1846, 74–75).

Smyth is unequivocal about the purpose of observational drawing; it is "absolute fidelity of the details," and "painstaking, accurate, and detailed delineation…very exact and faithful representations."

A very popular and long-lived guidebook to amateur observing was the Rev'd Thomas William Webb's (1807–1885) *Celestial Objects for the Common Telescope* (the first edition appeared in

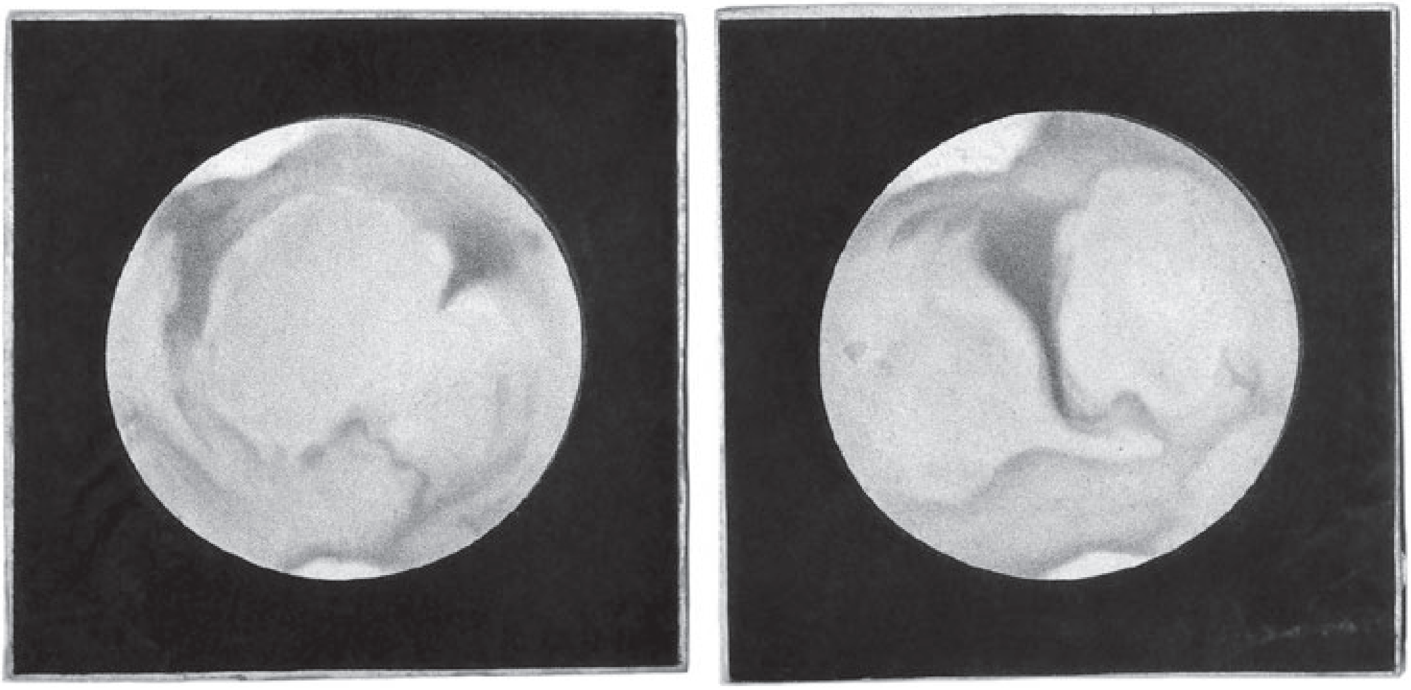

Figure 2 — Elvin's best surviving astrosketches of Mars at its 1892 opposition. If Elvins followed the prevailing practice, he most likely sketched with the purpose of making as accurate a record as possible of what he saw at the eyepiece. Other examples of his work can be found at www.rasc.ca/sketch-galleries. Reproduced courtesy of the RASC Archives.

1859, and a revised version of the 5th edition was available for decades after 1962). Prebendary Webb's recommendation of an approach to astrosketching is brief:

"Do not avoid the trouble of recording regularly all you see, under the impression that it is of no use. If it has no other good effect, it tends to a valuable habit of accuracy: and you might find it of unexpected importance…Everybody ought to be able to draw; it is the education of the eye, and greatly increases its capacity and correctness;" (Webb 1859, 15–16).

In the five subsequent editions of Webb's book, up to the sixth of 1962, the wording remains the same. Neither he, nor the later editors of his handbook, the Rev'd T.H.E.C. Espin (1858–1934) and Margaret Mayall (1902–1995—both were RASC members), thought it required updating.

Even more succinct is the statement of Lady Huggins (1848–1915) on the purpose of astrosketching:

"In all drawings for scientific purposes nature must be studied with line-by-line faithfulness;" (Huggins, 1882, 359).

In the same year Lady Huggins's paper appeared, strikingly stylized versions of some of E.L. Trouvelot's (1827–1895) accurate observational drawings were issued as a set of luxury chromolithographs. In the accompanying "manual" for the album, Trouvelot gave an account of his approach to observational art:

"DURING a study of the heavens, which has now been continued for more than fifteen years, I have made a large number of observations pertaining to physical astronomy, together with many original drawings representing the most interesting celestial objects and phenomena. With a view to making these observations more generally useful, I was led, some years ago, to prepare, from this collection of drawings, a series of astronomical pictures, which were intended to represent the celestial phenomena as they appear to a trained eye and to an experienced draughtsman through the great modern telescopes, provided with the most delicate instrumental appliances…While my aim in this work has been to combine scrupulous fidelity and accuracy in the details, I have also endeavored to preserve the natural elegance and the delicate outlines peculiar to the objects depicted; but in this, only a little more than a suggestion is possible, since no human skill can reproduce upon paper the majestic beauty and radiance of the celestial objects. The plates were prepared under my supervision, from the original pastel drawings, and great care has been taken to make the reproduction exact…A well-trained eye alone is capable of seizing the delicate details of structure and of configuration of the heavenly bodies, which are liable to be affected, and even rendered invisible, by the slightest changes in our atmosphere…The plate representing the November Meteors, or so-called "Leonids," may be called an ideal view, since the shooting stars delineated, were not observed at the same moment of time, but during the same night;" (Trouvelot 1882, v–vi).

There is much sense and nuance in Trouvelot's account, and his stated purpose of placing accuracy first accords with the opinions cited earlier.[3]

William Frederick Denning (1848–1931), an honorary RASC member, was a frequent contributor on meteoritical subjects to the Society's publications. He also wrote a classic manual on observing, *Telescopic Work for Starlight Evenings*, which is still worth reading. His is one of the strongest formulations on the need for disciplined accuracy in the drawing of astronomical phenomena:

"Few observers are good draughtsmen; but it is astonishing how seldom we meet with real endeavours to excel in this respect. Every amateur should practise drawing, however indifferent his efforts may be. Delineations, even if roughly executed, are often more effective than whole pages of description. Pictorial representations form the leading attraction of astronomical literature, and are capable of rendering it more interesting to the popular mind than any other influence. They induce a more apt conception of what celestial objects are really like than any amount of verbal matter can possibly do. For this reason it becomes the obvious duty of every observer to cultivate sketching and drawing, at least in a rudimentary way. He will frequently find it essential to illustrate his descriptions, so as to ensure their ready comprehension. In fact, a thoroughly efficient observer must of necessity become a draughtsman. It should, however, be his invariable aim to depict just what he sees and in precisely the form in which it impresses his eye. Mere pictorial embellishments must be disregarded, and he should be careful not to include doubtful features, possibly existing in the imagination alone, unless he intends them simply for his own guidance in future investigations. If he sees but little, and it is faithfully delineated, it will be of more real value than a most elaborate drawing in which the eye and imagination have each played a part. It is an undoubted fact that some of the most striking illustrations in astronomical handbooks are disfigured by features either wrongly depicted or having no existence whatever;" (Denning 1891, 73–74).

Incidentally, Denning's words on the power of images of astronomical phenomena seem remarkably contemporary.

The professional artist Nathaniel Everett Green (1823–1899), a great aereographer and a very sane observational artist who witnessed the rise of the canalists, placed accuracy above all else in one of the cleverest statements on the purpose of observational art:

"A remark has been made in this room [Barnard's Inn Hall, Holborn] to the effect that I prefer an artistic drawing to a correct one; but I know no difference between the two. Especially in drawing astronomical objects the highest accuracy belongs inseparably to the highest art" (Green 1892–1893, 367).[4]

The point Green made, that accuracy *is* an integral part of observational art as an *art*, was frequently missed by his contemporaries and successors, who preferred to set up a

Figure 3 — Saturn by Alan F. Miller, based on E.L. Trouvelot's drawings of the planet. This image dates from the end of the 19th or the very beginning of the 20th century, and serves to illustrate the popularity of Trouvelot's images among some dedicated amateur observers. Reproduced courtesy of the RASC Archives.

simplistic dichotomy between disciplined accurate representations of observations no matter how aesthetically rough, and undisciplined "artistically pleasing" representations of things of the imagination.

One can argue that much was lost by not thinking like Green. It is striking how little impact his neat statement seemed to have, at least in print. Even British Astronomical Association members, whom one imagines must have had access to his paper in their Journal, choose to ignore his message:

"An observer should not aim at picture making, but rather at showing just what he sees and no more. It is of infinitely greater value to science and to one's own reputation to be able to assert that whatever little one's drawing of Jupiter or Mars shows, it is nevertheless a true telescopic view;" (Cobham 1904, 102).

That aside, Green and Cobham are in agreement on the desirability of accuracy in astronomical drawings.

The pioneer space artist, astrophotographer, and observational artist, Lucien Rudaux, also emphasized the primacy of accuracy in observational art:

"After acquiring skill and judgement in the practice of observation, you must be able to reproduce what you see, by means of sketching—if not "artistically", at least conscientiously…for it is essential to be able to represent the relative proportions, and the exact forms of the details which you observe. And you have to know how to depict the relative prominence of features according to their degree of visibility… an image which is artistically charming, if it is wrong in its proportions, will possess a lesser degree of interest than a sketch which is coarse in execution, but accurate in depiction;" (Rudaux 1908, 83, translation by R.A. Rosenfeld).

All of these views are substantially in agreement. Up to the beginning of the 21st century I could not find any dissenting opinions. This is largely because the goal of the serious, or advanced amateur astronomer in the nineteenth to the mid or late twentieth century was to add to science, to *do* science by gathering reliable data, within organized programs, and to make it available to professionals. For the majority of that period visual observation was superior to photography for some sorts of astronomical work, such as monitoring of planetary atmospheres in visible wavelengths, and astroketching was the best and only way to make graphic records of the observations. When the prime goal of "real" astronomy for amateurs is participation in a scientific program, and accurate data is at stake, then accurate observational drawings are what are wanted.

Advice about astrosketching in this context is prescriptive. And there is a moral dimension in the considerations of the purpose of astronomical drawing. One's reputation as an observer is intimately tied to one's reputation for accuracy as an astronomical draftsman. It is a world I am at home in.

This tradition continued (and continues) into the period when astrophotography, even amateur astrophotography, is capable of at least as much as visual planetary observation:

"Drawing at the Telescope…The drawings require care; this does not mean that they should of necessity be works of art, but they should be clear, objective reproductions of what the observer has seen through his telescope;" (Roth 1970, 58),

and

"What the observer sees in his telescope should be recorded by graphic means…Planetary drawings ought not to be "imaginative paintings," nor "works of art," but on the contrary they should be purely naturalistic, objective representations of the view in the eyepiece;" (Roth 2002, 63, translation by R.A. Rosenfeld).

In this world there is no evolving landscape of purpose, merely an evolution in ways to better the accuracy of the observer, and the drawing.

In the 2000s, Springer embarked on an ambitious plan to publish a number of books on astrosketching; *Astronomical Sketching: A Step-by-Step Introduction* (Handy *et al*. 2007), *Astronomical Cybersketching: Observational Drawing with PDAs and Tablet PCs* (Grego 2009), *Sketching the Moon: An Astronomical Artist's Guide* (Handy *et al*. 2012), and *Solar Sketching: A Comprehensive Guide to Drawing the Sun* (Rix *et al*. 2015).[5] These all offer generally useful treatments, but in light of the earlier literature on astrosketching they lack a clear statement on the purpose of astrosketching, a broad discussion of accuracy in depiction, and any connection to astrosketching as part of a scientific program (such as is run by the planetary sections of the British Astronomical Association, or the Association of Lunar and Planetary Observers).[6] Against the background of what went before, the silences are interesting.

While Springer was producing its series of books, the most comprehensive multivolume work ever to appear on astrosketching was published by another firm, *Astrodessin: Observation et dessin en astronomie* (Vieillard *et al.*, 2013). This work is much more sophisticated than anything which has previously appeared. For instance, it contains a whole chapter examining the question "Why draw?"

In answer to that question, which is the same as the question "what is the purpose of drawing in observational astronomy?" asked here, the authors write:

"*Why draw?* To seek to define and characterize a unified philosophy of astrosketching would be a vain quest; there ought to exist as many philosophies as there are observers of the sky, who, each in their own manner, pursue different goals…;" (Pothier & Vieillard 2013, 30, translation by R.A. Rosenfeld).

The authors then proceed to give nine reasons in answer to the question "what is the purpose of astrosketching," listed deliberately without any hierarchical ranking. They are: 1. to learn to observe; 2. to accommodate to the idiom of "visual imagery;" 3. low cost (i.e. compared to astrophotography); 4. to preserve a record of observations; 5. to create an "artistic" work, to engage in self expression; 6. for comparative ends (e.g. comparing variations in equipment when observing the same objects, or to compare different observing sites, etc.); 7. to advance science; 8. for personal enjoyment; and 9. to consider if drawing can define itself. Astrosketching to accomplish science—or for any other end—with the sole purpose of achieving the greatest possible accuracy of representation has been dethroned. From being the sole purpose of astrosketching, it is now merely one of nine, with no special status (and the authors remark that providing nine reasons is an arbitrary decision; they could have offered more, or less).

Their final section well represents the point they are trying to make:

"Where does drawing begin and end?…Ought we to fix the limits, the barriers, as regards to practice? Is it necessary to impose rules?…To exclude a technique, a procedure, or a tool, risks handicapping the pursuit of the objectives which the astrosketcher has set. All goals are good to explore, and it is good to employ all interesting techniques, as long their use is sincere and coherent taken as a whole, and that the viewer is in no doubt as to which techniques have been used;" (Pothier & Vieillard 2013, 33, translation by R.A. Rosenfeld).

It is difficult to know how general this attitude is in amateur circles, and if it is, what the cause might be. One possibility is that with the increase in recreational "amateur astronomy," an astronomy which makes no attempt to do science, or even to be scientific, many people are taking up astrosketching for the same reason that they're taking up astrophrography—to produce pretty pictures, and no more.

There are places where the former general attitude to astro-skecthing's absolute commitment to accuracy as its sole purpose persists, namely among the serious observers in organizations such as the BAA, ALPO, and some Japanese organizations.

What do I think? I am sympathetic to the desire of MM. Vieillard, Pothier, and colleagues to foster an open-ended, non-restrictive, broad community of astroketchers. And it makes sense to encourage the use of any technique which may offer some graphic advantage. Why not? But the basic desire should be to develop the personal skills to produce as accurate an observational drawing as possible, in the first instance, and always to want to produce an accurate observational drawing. If there is a desire to produce a more imaginative work of any sort, then it should be based on that first generation accurate observational drawing. To abandon a first commitment to accuracy is to impose a very limiting liability on the astros-ketcher, and is a very short-sighted way of looking through an eyepiece. ✶

Acknowledgements

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Endnotes

1 The term is a flexible one, by its nature. Hewitt 2001, 126 uses it in a way similar to its use here.

2 The dearth was noted by Piazzi Smyth in 1843, 277.

3 That there is a discrepancy evident to some modern viewers between Trouvelot's stated intent and his graphic results will not be pursued here; see Rosenfeld & Sheehan 2011.

4 According to the official history of the British Astronomical Association, the BAA used Barnard's Inn Hall for its meetings from its inception to 1893; Kelly 2011, 9, 12. It is now the home of Gresham College.

5 For reasons of completeness, Hernández 2017 should also be cited.

6 Handy et al. 2012 is a partial exception here, for it does contain the advice "Drawing improves visual skills, increasing your aptitude for perception and interpretation, enabling you to become a more accurate observer" (181), and "One often-overlooked aspect of the sketching process is that the observational element is crucial! To be able to accurately draw what you are seeing, you have to really look at your subject first" (205).

Second Light

Two Distinct Populations of Globular Clusters Around M31

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

I believe that I have written previously about the odd distribution of dwarf galaxies orbiting the Andromeda Galaxy (M31). Most of them lie in a thin plane that is perpendicular to the disk of M31. How they ended up in that configuration has been the subject of much analysis and speculation. Now, Dougal Mackey of Australian National University and his worldwide set of collaborators have found a population of globular clusters that orbit in the same direction, perpendicular to the disk (see the October 3 issue of Nature). But these clusters are much more spread out—they are not located in a thin plane.

It has been known for a while that M31's globulars outside a radius of 25 kpc were moving in the same general direction that the disk is rotating, though they are well outside the visible disk, as are some of the centrally located clusters. They are located in halo, which is a remnant of all the stars and clusters accumulated through the in-fall of gas and the destruction of dwarf galaxies that used to orbit M31. So, the fact that they were orbiting in the same direction as the disk was an odd result—there is no reason to think that the destruction of dwarf galaxies should be connected to the stellar disk.

M31's stellar halo has two distinct components. One component is smooth, while the other contains prominent substructures. The structures arise from "splash effects" from the absorbed dwarf galaxies. Over time, the orbits of the stars from the destroyed dwarfs become randomized and smoothed out.

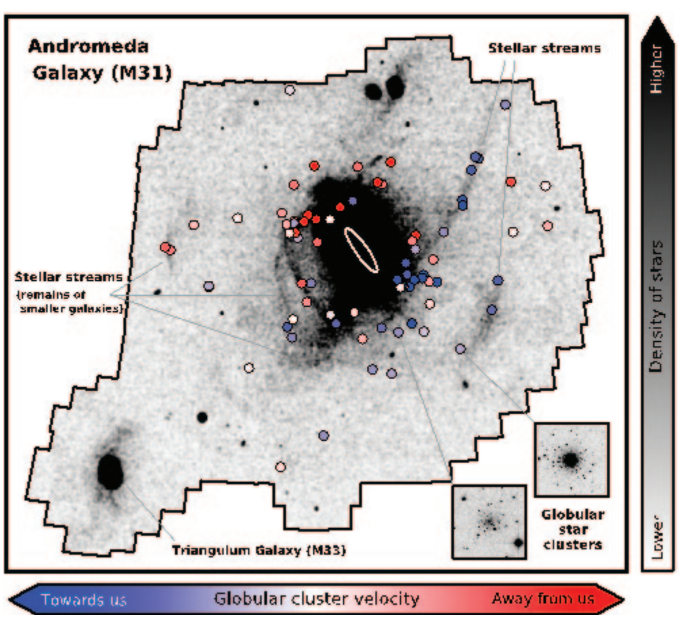

Figure 1 — M31, with stellar streams identified. Credit: Dougal Mackey

Many of the globulars outside of 25 kpc are associated with the most prominent structures, though some follow the smooth halo. So, Mackey and company decided to analyze the motions of the two populations. They found that the clusters associated with the smooth stellar halo are orbiting perpendicular to M31's disk, just as the dwarf galaxies are, while the ones associated with the structures are moving in the same direction as the stellar disk. Why would this be?

Now I have to back up a bit. Galaxies are thought to be assembled through the mergers of smaller components. In principle, it is possible to use the different populations of stars and/or clusters to tease out the history of how big galaxies were put together. This is an active area of research, especially in the Milky Way, using data from the Gaia spacecraft.

Mackey explains his populations as arising from two separate major merger events, probably separated by billions of years. The one that happened long ago produced the cluster population that is moving perpendicular to the disk. Any ripples have long since been erased, leaving the smooth halo. A more recent merger event (one to two billion years ago) left its mark on the halo in the form of the structures. One possibility is that the companion dwarf elliptical galaxy M32 is the stripped core of the more recent event. One curious fact about M32—it does not have a population of globulars, unlike most galaxies.

The clusters that are moving in the same general direction as the stars in M31's disk turn out to be somewhat misaligned, with the axis of rotation tilted about 30 degrees.

Globular clusters typically comprise about 3 × 10-5 of the mass of the parent galaxy. Using that, and the masses of the two populations, Mackey estimates that the mass of the first merger event was about 2 × 1011 solar masses, while the galaxy involved in the more recent one was about 1.5 × 1011 solar masses (he says these are lower limits). For comparison, the current estimate for the total mass of M31 is about 1 × 1012 solar masses. So, these really are major merger events, especially the first, as it happened before M31 was fully formed.

So, the next time you observe M31, think of those two populations of globular clusters, deposited in two separate mergers. ✶

Leslie J. Sage is Senior Editor, Physical Sciences, for Nature Magazine *and a visiting principal 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.*

John Percy's Universe

My Favourite Constellation: Delphinus

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

How could I resist a pretty little constellation that looks like its namesake—everyone's favourite sea mammal, the dolphin, leaping up out of the Milky Way. Even if its main asterism goes by the name of *Job's Coffin*! Delphinus contains some variable stars that have been important to my career as a researcher, and as an enthusiastic supporter of variable-star research by amateur astronomers and students.

1. Nova Delphini 1967

On 1967 July 1, I formally began my professorial career at the University of Toronto (Percy 2016a), while finishing up my doctoral thesis on the theory and observation of Beta Cephei stars (Percy 2016b). A week later, on July 8, G.E.D. Alcock of Peterborough, England, discovered Nova Delphini 1967. (To prove that it wasn't a fluke, he discovered Nova Vulpeculae 1968 a year later.) Nova Del 1967 was a highly unusual "slow" nova, in that it stayed at naked-eye brightness for most of a year. It actually peaked at magnitude 3 at Christmas 1967. Figure 1 shows its light curve. Nova Vul 1968 was a more typical "fast" nova; it rose quickly to fourth magnitude and faded within a few weeks.

My student and faculty colleagues immediately began systematic photometry of the nova using the small telescopes at the David Dunlap Observatory (Barnes *et al.* 1967, Barnes and Evans 1970). This impressed on me the value of having regular access to "local" observing facilities: they enable professionals and students to obtain systematic, sustained long-term photometry and spectroscopy of variable stars. Of course, most amateur astronomers have similar access to their "backyard telescopes." That's one reason why they can contribute so significantly to variable-star research.

One such contribution was by Herbert Lange of the RASC Toronto Centre, shown in Figure 1 (Lange 1970). In his paper on Nova Del 1967, he traced the origin of his interest in Nova Del 1967 and other variable stars—an RASC meeting in September 1967—as well as his evolution as a variable-star observer. His paper also made a strong impression on me because, at the time, I was becoming more active in the RASC and its publications and becoming even more aware of the significant contributions amateur astronomers could and did make to variable-star research and other areas of astronomy.

Slow novae are still something of an enigma, so the discovery and study of objects like Nova Del 1967 continues to be important. They are a "gift that keeps giving." Like other novae, slow novae are close binary stars consisting of a white dwarf and a cool main-sequence star. Gases stream from the main-sequence star onto the white dwarf, where they ignite in a runaway thermonuclear explosion. Slow novae seem to have low-mass carbon-oxygen white dwarfs, rather than the usual oxygen-neon ones, and may have thick layers of material that accreted on their surfaces before the explosion. These result in a massive ejected envelope, expanding at typically 200 km/sec. There may be multiple explosive events, which give rise to the multiple peaks in their light curve (Figure 1). Beyond that, there are several theories as to why some novae behave in this way and refuse to fade away — but no consensus.

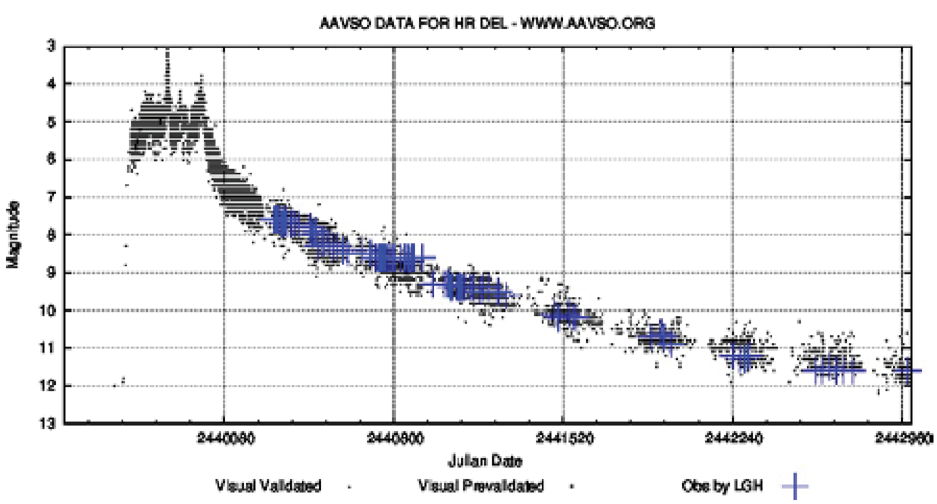

Figure 1 — The light curve of Nova Del 1967—visual magnitude versus Julian Date. About ten years of data is shown. Each point is a visual magnitude measurement. Note the multiple peaks in the first year of the light curve. The blue crosses are measurements by RASC Toronto Centre member Herbert Lange. See: Lange (1970). Source: AAVSO International Database.

2. Delta Delphini

Delta Delphini is a 40.58-day spectroscopic binary in which both components are Delta Scuti stars—short-period, small-amplitude, main-sequence pulsating stars of A-F spectral type. Their periods are 0.158 and 0.134 day. These stars are also *chemically peculiar* in that certain elements are more or less abundant than usual in the stars' spectra. This is because, in some stars, some elements sink preferentially in the atmosphere, whereas others are "levitated" by the stars' radiation. They require an atmosphere that is not convective, that is ideally slowly rotating, and is perhaps further stabilized by a strong magnetic field. Delta Del is the prototype of this particular type of star.

I never observed or studied Delta Del specifically, but I did observe many other Delta Scuti stars, including chemically peculiar ones, and also carried out theoretical studies as to whether and how these chemically peculiar stars could pulsate (Percy 1977). I evolved through these interesting stars on the way from Beta Cephei stars to my present interest in pulsating red giants.

3. EU Delphini and U Delphini

By 1980, I was active in the American Association of Variable Star Observers (AAVSO: www.aavso.org/vstar). AAVSO Director Janet Mattei was becoming a close colleague and friend. The amateur photoelectric photometry (PEP) "revolution" was beginning. Off-the-shelf photometers were available. Amateur PEP observers were organizing. Janet and I decided that the AAVSO needed a PEP observing program. She suggested that it should concentrate on pulsating red giants whose amplitudes were too small for easy visual observing. At the time, Mira stars, with amplitudes of many magnitudes, were the AAVSO's visual bread-and-butter, so to speak. The PEP program was therefore made up mostly of pulsating red-giant stars whose amplitudes were typically 0.5 to 1 magnitude—an order of magnitude larger than Beta Cephei or Delta Scuti stars, and an order of magnitude smaller than Mira stars.

This is where EU Del comes in. This fifth-magnitude star is a textbook example of a small-amplitude pulsating red giant (PRG). The AAVSO's first major PEP paper was about this star (Percy *et al.* 1989). EU Del has all the interesting properties that I now associate with pulsating red giants (Percy 2015). In addition to its basic pulsation period of 62.5 days, it has a mysterious "long secondary period" (LSP) of 626 days, of unknown nature and origin. Its pulsation amplitude varies on time scales of hundreds to thousands of days; we don't know why. Thousands of smaller-amplitude, pulsating red giants have now been observed by the AAVSO and by automated surveys such as ASAS-SN (1) but, to me, EU Del remains the prototype and "poster child."

U Del, at sixth magnitude, is a bit fainter, but equally interesting. Its pulsation period is 119 days, and its LSP is 1163 days. Its total magnitude range is 6.0 to 7.5, and EU Del's is 5.5 to 6.5, so visual observation of both stars is still possible, but PEP or CCD photometry is preferred. For both EU Del and U Del, you can find charts (2) with comparison stars, and also thousands of previous observations (3) on the AAVSO website. I highly recommend these stars to you.

4. Other Interesting Objects in Delphinus

Beta and Gamma Del are included in the *Observer's Handbook* table of notable double stars; the latter has a noticeable colour contrast. The more conspicuous variable stars in Delphinus are the usual grab-bag of Mira stars. W Del is interesting; it's a 4.8-day Algol-type eclipsing binary with a range of 9.69 to 12.33 (wow!), and a changing period. It's on the AAVSO Eclipsing Binary program (4), for regular monitoring.

Thanks to surveys such as ASAS-SN, there are *thousands* of known variable stars in Delphinus. You can generate a list of them in the AAVSO's VSX Catalogue (5). Unfortunately, a significant number of the ASAS-SN pulsating red-giant discoveries have been mis-analyzed and/or mis-classified (Percy and Fenaux 2019), so you could do useful "cloudy night" work by analyzing the ASAS-SN PRGs more carefully, and in more detail! There's lots of useful information on the AAVSO website on how to use its VSTAR time-series analysis software (6).

Otherwise, Delphinus is rather sparse. Not much for the deep-sky observer. But enough for variable star observers!

Acknowledgements

I thank Professor Ulisse Munari for his update about slow novae. ✶

Websites

1 www.astronomy.ohio-state.edu/asassn/index.shtml
2 www.aavso.org/variable-star-charts
3 www.aavso.org/LCGv2/
4 www.aavso.org/aavso-eclipsing-binary-section
5 www.aavso.org/vsx/
6 www.aavso.org/vstar

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Celestial Review

2019 Transits and Eclipses

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

2019 Transit of Mercury

A transit of Mercury across the face of the Sun is not a common sight. The last century had 15 transits of Mercury and this century will have only 14. The most recent transit occurred on 2019 November 11, and you won't have another chance to see a Mercury transit until 2032.

Why are Mercury transits so uncommon? Mercury orbits the Sun every 88 days and, due to its inclination, crosses the plane of Earth's orbit (ecliptic) every 44 days moving either northward or southward. These points where Mercury crosses the ecliptic are called ascending and descending nodes. For a transit to occur, there are certain necessary conditions: Mercury must be near inferior conjunction and, because Mercury has an inclination to the ecliptic of 7°, it must also be near an ascending or descending node. The requirement of Mercury being near a node during an inferior conjunction makes it an unusual event.

As Earth revolves around the Sun, these ascending and descending nodes line up between the Earth and the Sun twice per year, six months apart; the descending node in May and the ascending node in November. If Mercury happens to be at either node during these times, observers may see a transit.

The table below lists a few recent and some upcoming transits of Mercury. All occurring on the date of inferior conjunction.

Date	Node
2003 May 7	Descending
2006 Nov. 8	Ascending
2016 May 9	Descending
2019 Nov. 11	Ascending
2032 Nov. 13	Ascending
2039 Nov. 7	Ascending
2049 May 7	Descending
2049 May 7	Descending
2052 Nov 9	Ascending

You may guess from the abbreviated table above, that most transits seem to occur during the ascending node. This is attributed to the eccentricity of Mercury's orbit (e = 0.2), which is greater than any of the other major planets. At a May transit, Mercury is near the descending node and fairly close to the point of aphelion. At a November transit, Mercury is near the ascending node and is close to perihelion. When Mercury is closer to the Sun at perihelion you are more likely to view the transit, and therefore more likely in November.

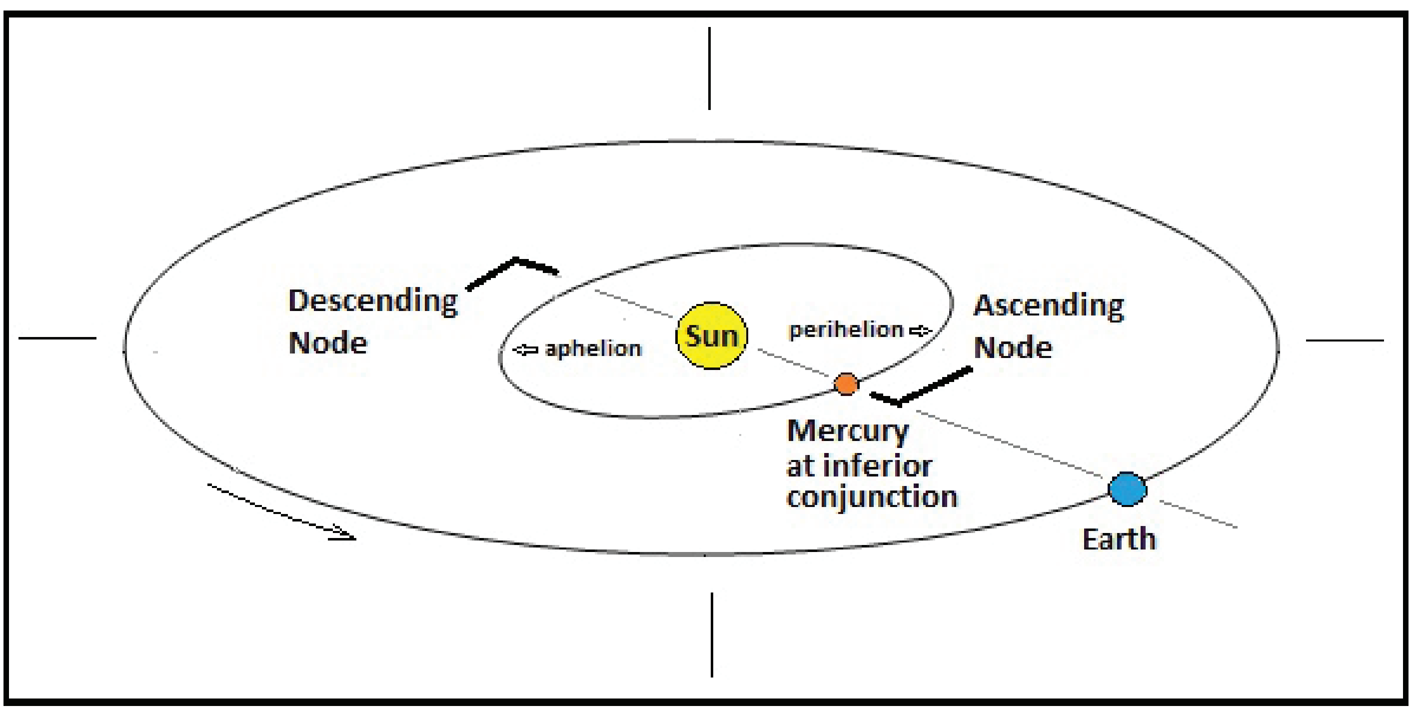


Figure 1 — The positions of Earth, Mercury, and the Sun 2019 November 11. Mercury is at the ascending node during the inferior conjunction.

2019 Eclipses

Solar eclipses have something in common with transits. Instead of a planet crossing the face of the Sun, it is the Moon. Not just any Moon, it must be a new Moon. A new Moon rises with the Sun, crosses the sky during the day, and sets with the Sun.

Now, we know the Moon orbits the Earth every 29.5 days, but since it is tilted to the ecliptic by about 5°, the Moon, just like Mercury, must be in the new phase and at either an ascending or descending node for a solar eclipse to occur. This December 26, some of us will be treated to a solar eclipse, and in this case, the new Moon will be at the descending node.

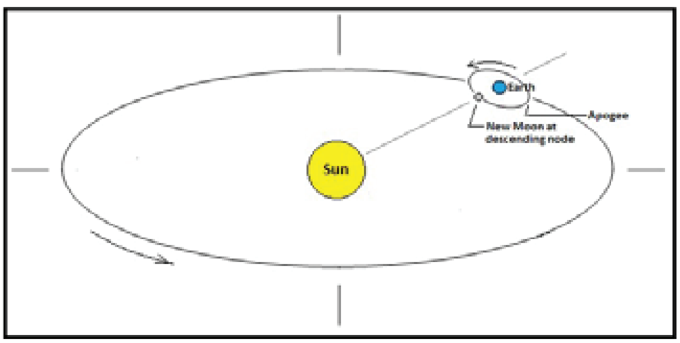


Figure 2 — The position of Sun, Earth, and Moon 2019 December 26. The new Moon is at the descending node and approaching apogee.

The upcoming solar eclipse will be an annular solar eclipse. The new Moon will cross the Sun at a node, but, will also be approaching the apogee of its orbit, where it is farther away from Earth. The Moon's apparent diameter in the sky will not be large enough to completely block the Sun as it would during a total solar eclipse when the Moon is closer to perigee. This smaller apparent diameter of the Moon causes the Sun to look like an annulus (ring).

A solar eclipse and a lunar eclipse typically occur around the same time within about two weeks before or after one another. The two weeks is simply due to the difference in time between new Moon and full Moon. For example, the lunar eclipse of January 21 this year was preceded by a partial solar eclipse two weeks earlier on January 6. The total solar eclipse of July 2 was followed two weeks later by a partial lunar eclipse on July 16. Similarly, the annular solar eclipse due to the new Moon of 2019 December 26 will be followed two weeks later by a penumbral lunar eclipse on 2020 January 10, the date of the full Moon.

Although there are many different Saros families or series, any Saros is a period of 18 years, 11 days, and 8 hours, and can be used to predict solar and lunar eclipses. One Saros period after an eclipse, the Sun, Moon, and Earth return to the same relative positions such that a similar eclipse will occur.

For just a half Saros (9 years and 5.5 days) the opposite eclipse will occur; lunar instead of solar, or solar instead of lunar, but with similar geometry. This means you can predict a lunar eclipse 9 years and 5.5 days after the solar eclipse of 2019 December 26, or in other words, in 2028 December 31.

After a full Saros cycle expect a similar solar eclipse on 2038 January 5, and indeed, it will be an annular eclipse with the new Moon at the descending node again. If you would like more information about this, refer to Fred Espanek's *Thousand Year Canon of Solar Eclipses*. This upcoming solar eclipse in December is part of Saros 132 and you can get more information about it from this website: *Catalog of Solar Eclipses of Saros 132* (https://eclipse.gsfc.nasa.gov/SEsaros/SEsaros132.html).

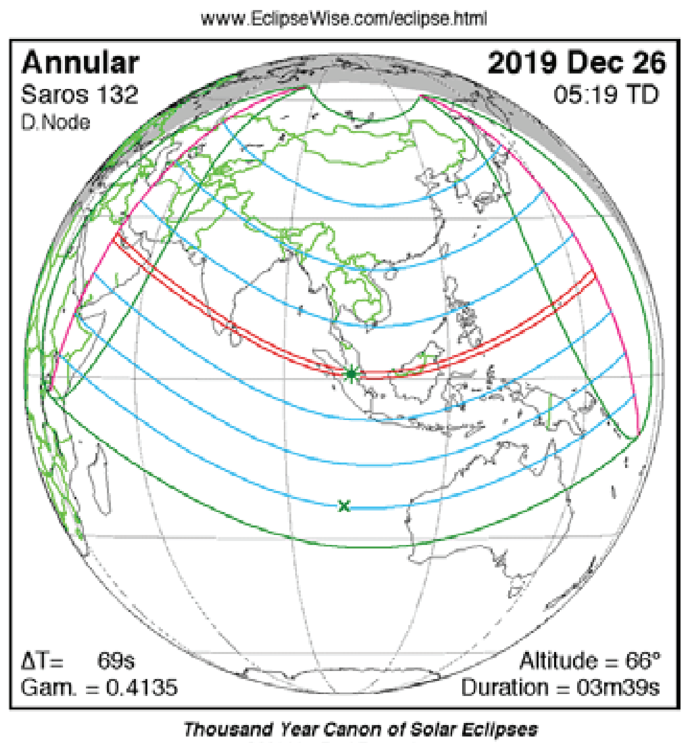


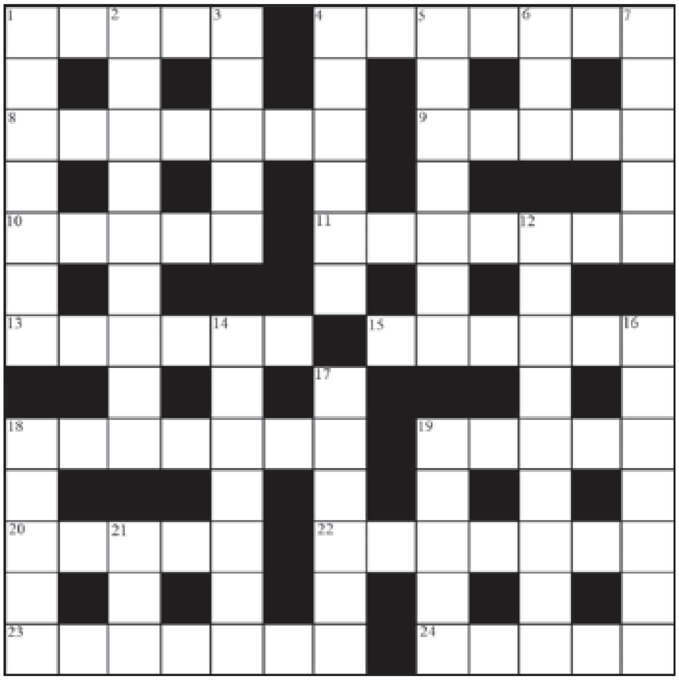
Figure 3 — The December 2019 annular eclipse.

For many of us, the rite of passage into the world of eclipse chasers occurred during the total eclipse of 2017 August 21. If you were so smitten by that event, then you may have to travel a bit for the upcoming eclipse. As shown from the *Thousand Year Canon of Solar Eclipses*, the annular eclipse will be visible from Saudi Arabia, southern India, and parts of Indonesia, whereas those in Europe, parts of Asia, and Northwest Australia should see a partial eclipse, weather permitting of course. ✶

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

Astrocryptic

by Curt Nason



ACROSS

1. Groan about inert gas emissions (5)
4. ED could do two at crazy tomes (7)
8. Old eyepiece found where sheep might sleep (7)
9. Politically incorrect constellation in Hindu star lore? (5)
10. Jason and Magellan had them on a cruise I hear (5)
11. Fifty-one coins produced in massive stars (7)
13. Sound ship speed is really nothing (6)
15. Might need seer to reorganize a comparator for asteroid detection (6)
18. He brewed barley around Denmark's capital seeing aberrant starlight (7)
19. Exobiology equation derived by a quack? (5)
20. Australia familiarly has one UV absorber (5)
22. No women out for good observing this time of month (3,4)
23. Namesake of proposed Solar System mover and shaker (7)
24. Sal is disturbed by what she saw in Vela (5)

DOWN

1. Kenyan saw the tail drop off a recent comet (7)
2. Bubble cloud? (3,6)
3. Orbital points where I left Edison in confusion (5)
4. Nagler joined a soccer league to star in Sagittarius (6)
5. Three bagger ends with Tasco's first apochromat (7)
6. Moon not new but in its arms soon after (3)
7. Astronomer Royal now associated with vacuum work (5)
12. Small firm electronics company will roil around the heart of Charles (3,6)
14. Lane in high school discovered a famous comet (7)
16. Stormy plain has no cause to be round (7)
17. Young pitcher leads wildebeests down the Milky Way (6)
18. As a dwarf, Peter failed star course at Western (5)
19. Sawed off amateur astronomer with limited resolution (5)
21. German physicist started hydroxide maser experiments (3)

Answers to October's puzzle

ACROSS

1 TABIT (tab+it); **4** SERONIK (anag); **8** P LOWELL (Pluto-UT+well); **9** SEDGE (anag); **10** DICKE (hid); **11** RR Lyrae (anag+r); **12** FRIDAY EVENING (anag); **15** RADIANT (anag); **17** SHARP (2 def); **18** NEWER (anag); **19** IMBRIUM (2 def); **21** STROMLO (an(ROM) ag); **22** LIGHT (2 def)

DOWN

1 TLP (2 def); **2** BROCCHI (2 def); **3** THEBE (anag); **4** SOLAR NEUTRINO (anag); **5** RESOLVE (2 def); **6** NADIR (anag); **7** KEELER GAP (keel+anag); **10** DEFERENTS (defer+anag); **13** ANAGRAM (example); **14** IMAGING (an(magi)ag) **16** DEWAR (dew+Ar); **17** SOBEL (anag); **20** MMT (moment-one)

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Compiled by James Edgar

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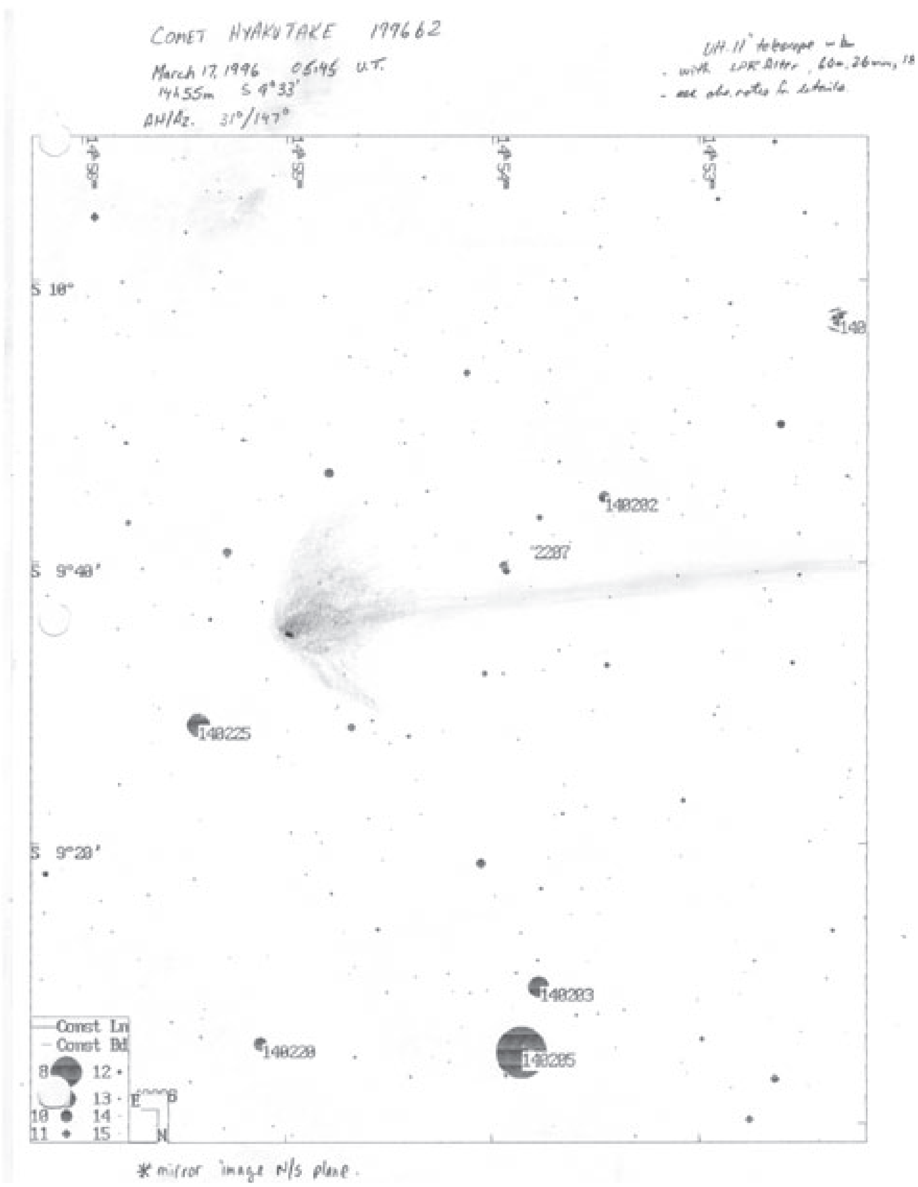
Great Images

by Ian Wheelband

Ian Wheelband shared his sketch of Comet Hyakutake's pass over Canada in 1996. Ian used his new-at-the-time Celestron Ultima 11 telescope, at ƒ/10, to sketch from his backyard in Ashburn, Ontario. He writes "Back than, I had about a Bortle 4 sky even though Ashburn is only about 60 km as the crow flies from downtown Toronto...not so much today." He used a Celestron Light Pollution Rejection filter in the visual back, and Celestron Ultima 60-mm and 18-mm eyepieces, as well as a Tele Vue Plossl 26-mm. He printed the field of view using Project Pluto star maps and drew the comet right on that printer paper using a selection of pencils from his case.

He says, "My usual sketching 'workflow' is an outline using something like an F or HB pencil, then going to as soft as 4B or as hard as 2H and also using a stump blender (probably the most important tool in my sketch kit)."



Journal

Ron Brecher imaged Sharpless 2-86 (Sh2-86), found in Vulpecula, the Little Fox. He used a Takahashi FSQ-106 ED IV @ ƒ/3.6, QHY367C (a one-shot colour camera) on a Paramount MX, unguided. All processing was done using PixInsight. The image was acquired from Ron's SkyShed in Guelph. Ron used an Optolong L-eNhance filter for a total of 19 hours and 40 minutes.