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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Cosmological Redshift without Expanding Space

SN 2023ixf in the Galaxy Messier 101

Running Man

Great Images

by Marjorie Somerville

Figure 1 – This image of magnificent noctilucent clouds was taken on 2020 July 11 with her iPhone by Marjorie Somerville of Nottingham, England. Unknown to her until later, and upon examining the photo, she had captured Comet NEOWISE (C/2020 F3 NEOWISE) at far right. Very serendipitous!

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

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The Running Man (NGC 1977) is seen here in Andrea Girones' stunning image. "NGC 1977 located in the Orion's Belt, is often overlooked in favour of its famous neighbour, the gloriously bright and dynamic Great Orion Nebula. However, this enormous reflection nebula full of natural colours is well worth a close-up look," she says. Andrea captured the image using a Celestron 11″ SCT with a 0.7× reducer and the ASI2500MM camera with RGB filters for a total of 6 hours integration time.

Journal

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

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President's Corner

A Northern Hemisphere Astronomer in the South

by Michael Watson, President
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The southernmost point in Canada is Fish Point Provincial Nature Reserve on Pelee Island, which is halfway across Lake Erie to the United States and 75 km almost due east of Toledo, Ohio. From this position, at 41.7°N, Canadian starwatchers can see the celestial sphere down to declination 48.3°S, but no further. This means that almost 17 percent, or one-sixth, of the sky is permanently below the horizon and invisible as seen from that location. If we consider that decent views require objects in the sky to be at least 10° above the horizon, then almost 24 percent of the sky either is invisible or cannot properly be observed from Canada. (The area of a sphere that is "above" or "below"—or in astronomical terms, north or south of—a particular angle or latitude is often referred to as the "spherical cap." The formula for the area of a spherical cap is 2 × π × R2 × (1- SIN latitude), where R is the radius of the sphere.)

What does this mean for Canadian astronomers who are homebodies, and never leave the country? A large portion of the sky either is permanently hidden from view by the bulge of planet Earth to the south of us, or is observable only under unfavourable, close-to-the-horizon conditions. From Canada we can never see the first magnitude stars Rigel Kentaurus and Hadar (Alpha and Beta Centauri), Peacock (Alpha Pavonis), Achernar (Alpha Eridani) and Canopus (Alpha Carinae), as well as the lovely asterism in the constellation Crux known as the Southern Cross, and Proxima Centauri, the closest star to us after the Sun. Hidden from view too are some famous deep-sky objects that many northerners know only from photographs, including the Large and Small Magellanic Clouds, the wonderful Eta Carinae Nebula (NGC 3372), the Southern Pleiades (IC 2602), the dwarf galaxy remnant Omega Centauri, and the bright globular star cluster 47 Tucanae.

At least as frustrating for us northerners is that the centre of the Milky Way, in the constellation Ophiuchus at right ascension 47h 45m, declination –29° 00′, never gets more than 19° above the horizon for southern Ontarians, and never more than 10° up in the sky for skywatchers observing, for example, from the RASC Calgary Centre's Wilson Coulee Observatory. The central bulge of our home galaxy is therefore tantalizingly ill-situated for our visual contemplation.

I had my first opportunity to look skyward from the Southern Hemisphere in June 1983, when I joined an expedition out of London to observe the very long (5 minutes 9 seconds) total solar eclipse of June 11 that year from the north coast of the island of Java in Indonesia. I will never forget my first view of

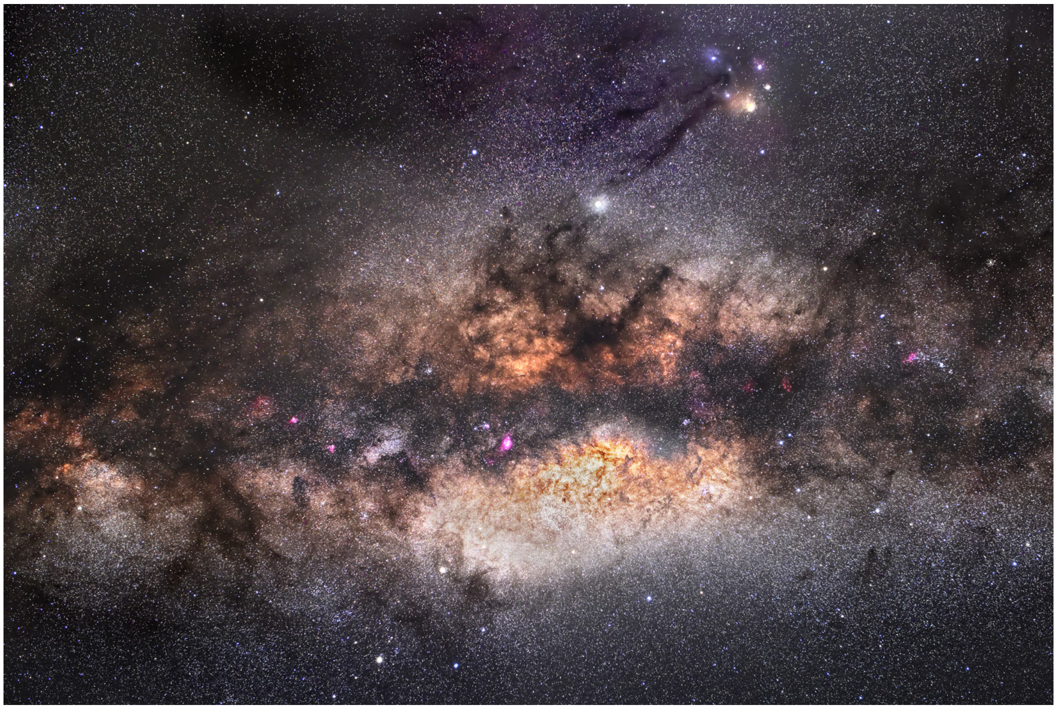

Figure 1 — Wide-angle view (35 mm) of the centre of the Milky Way, captured by Michael Watson from the Australian Outback, September 2019.

the southern sky the night before the eclipse, when I camped out under the stars at latitude 6.9°S, and saw the central bulge of the Milky Way rising almost straight up from the east-southeastern horizon as the sky darkened. By midnight, when it was centred on the meridian 67° high in the sky, the Milky Way stretched from horizon to horizon, with the centre almost frighteningly bright above me. Adrenaline was rushing and my heart was pounding. For months—even years—I had imagined this view, but the reality overwhelmed me and surpassed anything I had imagined.

But there was something else, and it was discombobulating. I was so used to seeing the familiar star patterns of Scorpius and Sagittarius close to the horizon that I couldn't recognize them when they were so high in the sky above me. And the northern constellations of Boötes, Corona Borealis, Hercules, Lyra, and Cygnus all seemed upside down to me, since I had to face north to get a good view of them, rather than south as I did in Canada.

After the eclipse I went to Australia, and for a few nights visited and observed with Tom Cragg, the Chief Night Assistant at the Anglo-Australian Observatory in Coonabarabran, New South Wales. The location is without doubt the darkest observing site I have ever experienced. The dark green of the surrounding eucalyptus trees prevented any reflection back into the sky from the meagre skyglow. I couldn't see even the faint outline of my hand in front of my face, let alone my telescope and Schmidt camera, without using a red light.

From the –31° latitude of the observatory, the centre of the Milky Way was now a little north of the zenith. When I turned around to the north to look up, the familiar teapot shape of the brightest stars in Sagittarius, and the head and tail of the scorpion in Scorpius, vanished; I couldn't make them out at all. Only when I turned south and craned my neck backward a little to the north did they pop back into view. This taught me a valuable lesson that has remained with me 40 years later: We recognize a visual pattern not only by the relative positions of the points of the pattern with respect to each other, but also by the orientation (i.e. angle) of the entire pattern in front of us. And it takes only a few tens of degrees of rotation before a previously familiar pattern becomes difficult for us to spot, bordering on unrecognizable.

Since that first visit to an antipodal latitude in 1983, good fortune has taken me south of the equator nine more times, and often to the Outback of Australia. Every time, the overwhelming impression I have is how majestic the Milky Way looks as seen from that vantage point. Only from the south can we see the thin disk of the galaxy on both sides of the central bulge splayed across the sky. When we see it from this perspective, it is so obvious that the Milky Way is the same type of object as are the distant galaxies that we know so well, such as M31 in Andromeda. A long time ago I heard, and I summoned up this memory when writing this column, the theory that if the centre of the Milky Way were located as far north on the celestial sphere as it actually is in the south, then Northern Hemisphere astronomers would have concluded decades or even centuries earlier that the Milky Way and these other objects were of the same type. The so-called Great Debate of 1920 between Harlow Shapley and Hebert Curtis about the nature of the Milky Way, "spiral nebulae" (as they were called then), and the dimensions of the Universe might have been well and truly settled long before.

My experiences south of the equator have brought me to agree so strongly with the view that every serious astronomer, and even the perhaps less obsessed and more casual stargazer, who lives in the Northern Hemisphere, should endeavour to travel south of the equator at new Moon at least once in that person's lifetime to behold the splendour of the celestial sphere from that vantage point. There is so much to see, and in which to revel, away from home. ✶

News Notes / En manchette

Compiled by Jay Anderson

M87's central black hole déjà vu

The Event Horizon Telescope (EHT) Collaboration, an organization shepherding an array of radio telescopes stretching across the globe, has released new images of M87*, the supermassive black hole at the centre of the galaxy Messier 87, using data from observations taken in April 2018. The black hole, 6.5 billion solar masses, resides at the centre of the galaxy Messier 87 (M87) in the Virgo cluster, 55 million light-years from Earth. With the participation of the newly commissioned Greenland Telescope and a dramatically improved recording rate across the array, the 2018 observations give us a view of the source independent of the first observations in 2017.

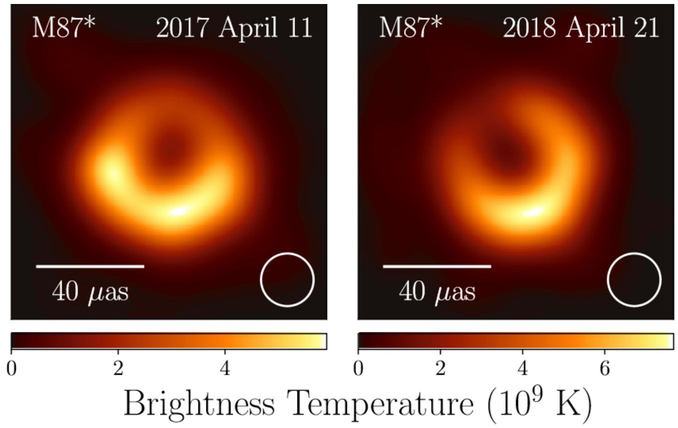

Figure 1 — Side-by-side comparisons of M87 in 2017 and 2018 show how the bright spot in the ring of matter around the black hole has shifted. Credit: EHT Collaboration.*

The new images from the 2018 data reveal a familiar ring, surrounding a dark central depression, the same size as the one observed in 2017. In the earlier image, several bright spots were embedded in an arc of higher emission in the southern part of the ring. In the new image, the brightness peak of the ring has shifted by about 30° compared to the images from 2017, which is consistent with our theoretical understanding of variability from turbulent material around black holes.

Because of the immense gravitational field around M87*, photons within a critical distance of the black hole have significantly curved trajectories and cannot escape to infinity. These lost photons create a dark hole in the otherwise bright image of M87*, forming a donut-shaped structure whose size is completely determined by the mass of the black hole. The donut itself arises from photons bent around the black hole without falling into it, creating a ring of light that can be seen no matter which angle the black hole is viewed from. While the new view of M87* confirms the interpretation of data received during the 2017 observations, researchers in Japan have produced completely different images from the earlier dataset.

"A fundamental requirement of science is to be able to reproduce results," says Dr. Keiichi Asada, an associate research fellow at Academia Sinica Institute for Astronomy and Astrophysics in Taiwan. "Confirmation of the ring in a completely new dataset is a huge milestone for our collaboration and a strong indication that we are looking at a black hole shadow and the material orbiting around it."

The new era of black hole direct imaging has opened a window that lets researchers investigate black hole astrophysics and allows them to test the theory of general relativity at a fundamental level. Theoretical models predict that the state of the material around M87* should be uncorrelated between 2017 and 2018. Thus, the new and future observations of M87* will help place independent constraints on the plasma and magnetic field structure around the black hole and help disentangle the complicated astrophysics from the effects of general relativity.

The Greenland Telescope, far above the Arctic Circle, joined the EHT for the first time in 2018, just five months after its construction was completed. This new telescope significantly enhanced the image fidelity of the EHT array, improving the coverage, particularly in the North-South direction. The Large Millimeter Telescope in Mexico also participated for the first time with its full 50-m surface, greatly refining its sensitivity. The EHT array was also upgraded to observe in 4 frequency bands around 230 GHz, compared to only 2 bands in 2017.

Repeated observations with an improved array are essential to demonstrate the robustness of the findings and strengthen confidence in the results. In addition to the ground-breaking science, the EHT also serves as a technology testbed for cutting-edge developments in high-frequency radio interferometry.

The analysis of the 2018 data features 8 independent imaging and modelling techniques, including methods used in the previous 2017 analysis of M87* and new ones developed from the collaboration's experience analyzing Sgr A*, the Milky Way's black hole. To avoid creating an image that conformed to theoretical expectations, the researchers tested their image-processing algorithms with synthetic data: a suite of simulated images with simple geometric shapes. Those data are run through the algorithms to produce an image. If the output image is true to the input image, they know the algorithm is working correctly and would be able to accurately derive structures around the black hole.

The image of M87* taken in 2018 is remarkably similar to what was seen in 2017: a bright ring of the same size, with a dark central region and one side of the ring brighter than the other. The mass and distance of M87* will not appreciably increase throughout a human lifetime, so general relativity predicts that the ring diameter should stay the same from year to year. The stability of the measured diameter in the images from 2017 to 2018 robustly supports the conclusion that M87* is well described by general relativity. Further analysis of the data from 2017 also revealed the structure of M87* in polarized light, giving us greater insight into the geometry of the magnetic field and the nature of the plasma around the black hole.

"One of the remarkable properties of a black hole is that its radius is strongly dependent on only one quantity: its mass," said Dr. Nitika Yadlapalli Yurk, a former graduate student at the California Institute of Technology (Caltech), now a postdoctoral fellow at the Jet Propulsion Laboratory in California. "Since M87* is not accreting material (which would increase its mass) at a rapid rate, general relativity tells us that its radius will remain fairly unchanged over human history. It's pretty exciting to see that our data confirm this prediction."

While the size of the black hole shadow did not change between 2017 and 2018, the location of the brightest region around the ring did change significantly. The bright region rotated about 30º counterclockwise to settle in the bottom right part of the ring at about the 5 o'clock position. Historical observations of M87* with a less sensitive array and fewer telescopes also indicated that the shadow structure changes yearly but with less precision. While the 2018 EHT array still cannot observe the jet emerging from M87*, the black hole spin axis predicted from the location of the brightest region within the ring is more consistent with the jet axis seen at other wavelengths.

The shift in position of the brightest spot in the ring could be due to turbulence in the swirling flow around the black hole, or to a misalignment of M87*'s jet with the black hole's spin, much like the precession of a top.

"The biggest change, that the brightness peak shifted around the ring, is actually something we predicted when we published the first results in 2019," said Dr. Britt Jeter, a postdoctoral fellow at Academia Sinica Institute for Astronomy and Astrophysics in Taiwan. "While general relativity says the ring size should stay pretty fixed, the emission from the turbulent, messy accretion disk around the black hole will cause the brightest part of the ring to wobble around a common centre. The amount of wobble we see over time is something we can use to test our theories for the magnetic field and plasma environment around the black hole."

While all the EHT papers published so far have featured an analysis of the first observations in 2017, this result represents the first efforts to explore the many additional years of data that have been collected. In addition to 2017 and 2018, the EHT conducted successful observations in 2021 and 2022 and is scheduled to observe in the first half of 2024. Each year, the EHT array has improved in some way, either through the addition of new telescopes, better hardware, or additional observing frequencies.

Composed with material provided by Event Horizon Telescope Consortium.

Giving the JWST a new pair of glasses

Resolution of astronomical scenes, by eye or camera, is a subject dear to the heart of serious observers. We talk of the resolving power of telescopes and the limits of detail in our images—how far apart on the sky do two stars need to be so you can distinguish them from each other? And while the visual observer can only cope with a larger telescope, the imager can apply any one of a number of deconvolution algorithms to sharpen up stars and galactic detail.

The well-known Raleigh criterion sets one of the limits of resolution: $1.22\lambda/D$, where λ is the wavelength and D is the telescope aperture (same units of course). The limitation is driven by diffraction and the way that light passes through a circular aperture, and is often described as the point spread function (PSF)—the way that a pinpoint star spreads out into a disk once it's passed through a telescope and through the atmosphere. (A second measure of telescope resolution, the Dawes limit, is based on personal experience and is smaller than the Raleigh criterion.)

Mason Leist, a graduate research assistant at the University of Texas at San Antonio (UTSA), led a study on the best method to improve images obtained by the *James Webb Space Telescope* (JWST) using deconvolution. He was tasked by the Galactic Activity, Torus, and Outflow Survey (GATOS), an international team of scientists, to enhance JWST observations of the galaxy NGC 5728.

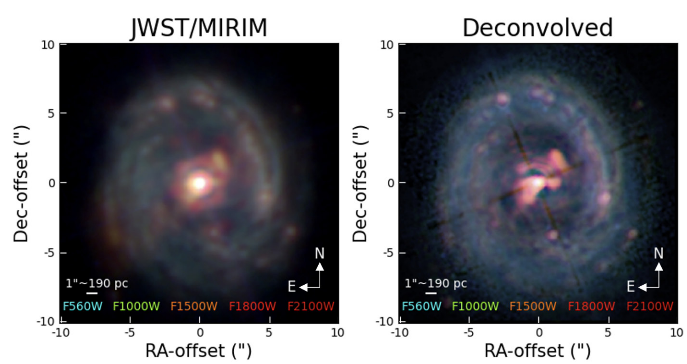

Figure 2 — Five-colour JWST/MIRIM (left) and Kraken deconvolved images (right). Each image is ~20"×20", oriented N–E, and log-scaled. Note the ~2.5" SE to NW extended nuclear emission visible in the deconvolved image. Evidence of the Airy ring remnant (~1" NW of the nucleus) and the F560W crosshair are also clearly visible in the deconvolved image. Credit: University of Texas San Antonio.

Though the JWST doesn't have to contend with atmospheric effects and its images are diffraction-limited (i.e. the Raleigh criterion), it has a complicated PSF because the telescope is composed of many hexagonal mirror elements that impose their shapes upon the image and many diffraction spikes caused by support structures.

Leist and his co-authors created a model image of an active galactic nucleus (AGN) and then mixed it with the JWST point spread function to create an artificial image in five wavelengths. The team then tested this artificial image with several different deconvolution algorithms, including the Richardson-Lucy algorithm that is probably familiar to most JRASC astrophotographers. From this experiment, they identified the Kraken method as the one most able to reproduce the test AGN image. Kraken is a high-performance multi-frame deconvolution algorithm developed by a team of researchers at Georgia State University.

At this point the research team returned to the real world and tested the Kraken method on images of the AGN in NGC 5728, a Seyfert galaxy, at five distinct wavelengths. In these observations, a faint extended feature was seen in only one wavelength. As Leist deconvolved the data, the faint extended emission feature was revealed in all wavelengths, demonstrating the effectiveness of Kraken deconvolution to improve JWST image quality and enhance faint, extended, emission features.

"We believe the extension could be part of an outflow from a supermassive black hole that could be interacting with the host galaxy. There's a lot more science that needs to be done," Leist said. "It is difficult to distinguish the extended structure in all of the JWST images, but by using deconvolution techniques, we reduced the image data to reveal the hidden faint emission feature."

Leist's work demonstrates deconvolution is an efficient and accurate tool for image processing. Similar methods, he said, can be applied to broader science cases using JWST observations. The approach has garnered significant interest from fellow scientists working on JWST image processing.

"We're doing important work using JWST data," Chris Packham, Leist's doctoral advisor, said. "But it's important because we can improve on the raw data and get better image quality to see those fainter details by using this approach. It shows the strength of collaboration within the GATOS, which is co-led from UTSA."

Leist's work to enhance the JWST observations of the galaxy NGC 5728 is a new piece in the puzzle that further demystifies the origins of the Universe. The full scope of the deconvolved images and other astrophysical results will be described in forthcoming studies currently underway by the GATOS.

"It goes back to the generation of galaxies shortly after the Big Bang," Packham explained. "If we really want to understand our place within our own galaxy, within our own Solar System and within the Universe in general, we have to understand what's going on within black holes in our galaxy and, indeed, other galaxies. We can understand the formation of our galaxy, our Solar System, the Earth and life on Earth. It's really part of that big picture question."

The research team did not test deconvolution algorithms at short wavelengths such as those from the JWST's infrared cameras as the PSF in those imagers is much more compact than those at mid-infrared and the benefits would not be as generous.

Compiled in part with material from the University of Texas at San Antonio.

Shrinking Moon (are eclipses threatened?)

Earth's moon shrank more than 46 metres in circumference as its core gradually cooled over the last few hundred million years. In much the same way a grape wrinkles when it shrinks down to a raisin, the Moon also develops creases as it shrinks. But unlike the flexible skin on a grape, the Moon's surface is brittle, causing faults to form where sections of crust push against one another.

A team of scientists discovered evidence that this continuing shrinkage of the Moon led to notable surface warping in its south polar region—including areas that NASA proposed for

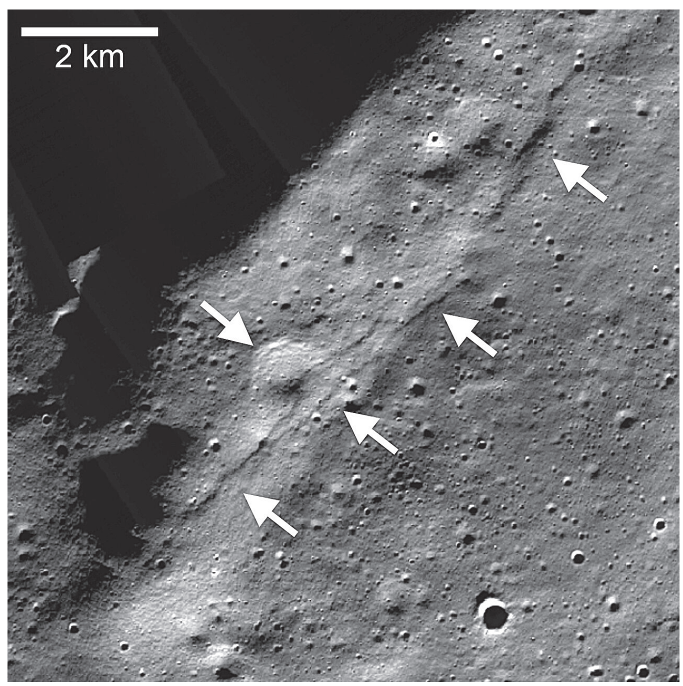

Figure 3 — Lunar Reconnaissance Orbiter Camera *(LROC), Narrow Angle Camera (NAC) mosaic of the Wiechert cluster of lobate scarps (left-pointing arrows) near the lunar south pole. A thrust-fault scarp cut across an approximately 1-kilometre (0.6-mile)-diameter degraded crater (right-pointing arrow). Credit: NASA/LRO/LROC/ASU/ Smithsonian Institution.*

crewed Artemis III landings. Because fault formation caused by the Moon's shrinking is often accompanied by seismic activity like moonquakes, locations near or within such fault zones could pose dangers to future human exploration efforts.

In a paper published in *The Planetary Science Journal*, the team linked a group of faults located in the Moon's South Polar Region to one of the most powerful moonquakes recorded by Apollo seismometers over 50 years ago. Using models to simulate the stability of surface slopes in the region, the team found that some areas were particularly vulnerable to landslides from seismic shaking.

"Our modelling suggests that shallow moonquakes capable of producing strong ground shaking in the South Polar Region are possible from slip events on existing faults or the formation of new thrust faults," said the study's lead author Thomas R. Watters, a senior scientist emeritus in the National Air and Space Museum's Centre for Earth and Planetary Studies.

"The global distribution of young thrust faults, their potential to be active, and the potential to form new thrust faults from ongoing global contraction should be considered when planning the location and stability of permanent outposts on the Moon."

Shallow moonquakes occur near the surface of the Moon, just 100 or so miles deep into the crust. Similar to earthquakes, these moonquakes are caused by faults in the Moon's interior and can be strong enough to damage buildings, equipment, and other human-made structures. But unlike earthquakes, which tend to last only a few seconds or minutes, shallow moonquakes can last for hours and even a whole afternoon—like the magnitude 5 moonquake recorded by the Apollo Passive Seismic Network in the 1970s, which the research team connected to a group of faults detected more recently by the *Lunar Reconnaissance Orbiter*.

According to Nicholas Schmerr, a co-author of the paper and an associate professor of geology at the University of Maryland, this means that shallow moonquakes can devastate hypothetical human settlements on the Moon.

"You can think of the Moon's surface as being dry, grounded gravel and dust. Over billions of years, the surface has been hit by asteroids and comets, with the resulting angular fragments constantly getting ejected from the impacts," Schmerr explained. "As a result, the reworked surface material can be micron-sized to boulder-sized, but all very loosely consolidated. Loose sediments make it very possible for shaking and landslides to occur."

The researchers continue to map out the Moon and its seismic activity, hoping to identify more locations that may be dangerous for human exploration. NASA's *Artemis* missions, which are set to launch their first crewed flight in 2025, ultimately hope to establish a long-term presence on the Moon and eventually learn to live and work on another world through Moon-based observatories, outposts, and settlements.

"As we get closer to the crewed *Artemis* mission's launch date, it's important to keep our astronauts, our equipment and infrastructure as safe as possible," Schmerr said.

"This work is helping us prepare for what awaits us on the Moon—whether that's engineering structures that can better withstand lunar seismic activity or protecting people from really dangerous zones."

Compiled with material from the University of Maryland.

Slower traffic in the Milky Way suburbs

By clocking the speed of stars throughout the Milky Way Galaxy, MIT physicists have found that stars further out in the galactic disk are travelling more slowly than expected compared to stars that are closer to the galaxy's centre. The findings raise a surprising possibility: The Milky Way's gravitational core may be lighter in mass, and contain less dark matter, than previously thought.

The new results are based on the team's analysis of data taken by the *Gaia* and APOGEE instruments. *Gaia* is an orbiting space telescope that tracks the precise location, distance, and motion of more than 1 billion stars throughout the Milky Way Galaxy, while APOGEE is a ground-based survey.

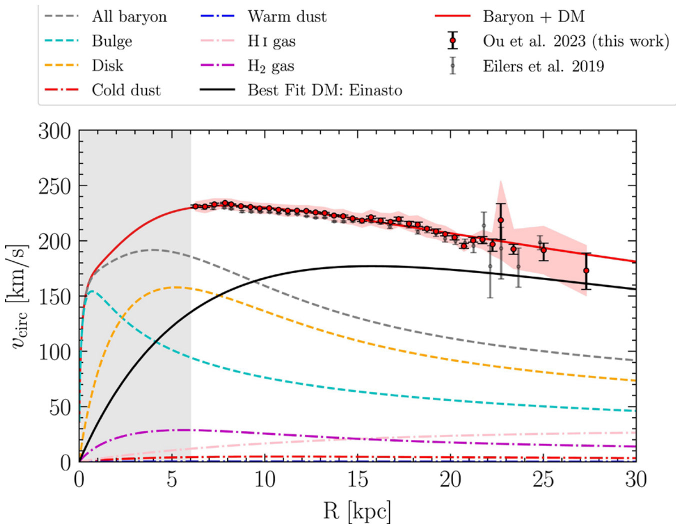

Figure 4 — Comparison between the circular-velocity curve measured from Eilers et al. (black) and from this work (red). The best-fitting Einasto DM profile, with the baryonic model from de Salas et al., is also shown here. The gray-shaded region represents the bulge region, which is not modelled due to the non-axisymmetric potential near the galactic bar. The red shaded region represents the total uncertainty estimate from the dominating systematic sources.

The physicists analyzed *Gaia*'s measurements of more than 33,000 stars, including some of the farthest stars in the galaxy, and determined each star's circular velocity, or how fast a star is circling in the galactic disk, given the star's distance from the galaxy's centre.

The scientists plotted each star's velocity against its distance to generate a rotation curve—a standard graph in astronomy that represents how fast matter rotates at a given distance from the centre of a galaxy. The shape of this curve can give scientists an idea of how much visible and dark matter is distributed throughout a galaxy.

"What we were really surprised to see was that this curve remained flat, flat, flat out to a certain distance, and then it started tanking," says Lina Necib, assistant professor of physics at MIT. "This means the outer stars are rotating a little slower than expected, which is a very surprising result." The study's MIT co-authors, including Necib, are first author Xiaowei Ou, Anna-Christina Eilers, and Anna Frebel.

The team translated the new rotation curve into a distribution of dark matter that could explain the outer stars' slowdown, and found the resulting map produced a lighter galactic core than expected. That is, the centre of the Milky Way may be less dense, with less dark matter, than scientists have thought.

"This puts this result in tension with other measurements," Necib says. "There is something fishy going on somewhere, and it's really exciting to figure out where that is, to really have a coherent picture of the Milky Way."

Like most galaxies in the Universe, the Milky Way spins like water in a whirlpool, and its rotation is driven, in part, by all the matter that swirls within its disk. In the 1970s, astronomer Vera Rubin was the first to observe that galaxies rotate in ways that cannot be driven purely by visible matter. She and her colleagues measured the circular velocity of stars and found that the resulting rotation curves were surprisingly flat. That is, the velocity of stars remained the same throughout a galaxy, rather than dropping off with distance. They concluded that some other type of invisible matter must be acting on distant stars to give them an added push. Rubin's work was one of the first strong pieces of evidence for the existence of dark matter.

Since then, astronomers have observed similar flat curves in far-off galaxies, further supporting dark matter's presence. Only recently have astronomers attempted to chart the rotation curve in our own galaxy with stars. "It turns out it's harder to measure a rotation curve when you're sitting inside a galaxy," Ou notes.

In 2019, Anna-Christina Eilers, assistant professor of physics at MIT, worked to chart the Milky Way's rotation curve using an earlier batch of data released by the *Gaia* satellite. That data release included stars as far out as 25 kiloparsecs, or about 81,000 light-years, from the galaxy's centre.

Based on these data, Eilers observed that the Milky Way's rotation curve appeared to be flat, albeit with mild decline, similar to other far-off galaxies, and by inference, the galaxy likely bore a high density of dark matter at its core. But this view now shifted, as the telescope released a new batch of data, this time including stars as far out as 30 kiloparsecs—almost 100,000 light-years from the galaxy's core.

"At these distances, we're right at the edge of the galaxy where stars start to peter out," Frebel says. "No one had explored how matter moves around in this outer galaxy, where we're really in the nothingness."

Frebel, Necib, Ou, and Eilers jumped on *Gaia*'s new data, looking to expand on Eilers' initial rotation curve. To refine their analysis, the team complemented *Gaia*'s data with measurements by APOGEE—the Apache Point Observatory Galactic Evolution Experiment, which measures extremely detailed properties of more than 700,000 stars in the Milky Way, such as their brightness, temperature, and elemental composition.

"We feed all this information into an algorithm to try to learn connections that can then give us better estimates of a star's distance," Ou explains. "That's how we can push out to farther distances."

The team established the precise distances for more than 33,000 stars and used these measurements to generate a three-dimensional map of the stars scattered across the Milky Way out to about 30 kiloparsecs. They then incorporated this map into a model of circular velocity, to simulate how fast any one star must be travelling, given the distribution of all the other stars in the galaxy. They then plotted each star's velocity and distance on a chart to produce an updated rotation curve of the Milky Way.

"That's where the weirdness came in," Necib says.

Instead of seeing a mild decline like previous rotation curves, the team observed that the new curve dipped more strongly than expected at the outer end. This unexpected downturn suggests that while stars may travel just as fast out to a certain distance, they suddenly slow down at the farthest distances. Stars at the outskirts appear to travel more slowly than expected.

When the team translated this rotation curve to the amount of dark matter that must exist throughout the galaxy, they found that the Milky Way's core may contain less dark matter than previously estimated.

"This result is in tension with other measurements," Necib says. "Really understanding this result will have deep repercussions. This might lead to more hidden masses just beyond the edge of the galactic disk, or a reconsideration of the state of equilibrium of our galaxy. We seek to find these answers in upcoming work, using high-resolution simulations of Milky Way-like galaxies." ✶

Compiled with material provided by the Massachusetts Institute of Technology

Feature Article / Article de fond

Cosmological Redshift without Expanding Space

by Simon Brissenden, Sunshine Coast Centre
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Abstract

A recent JRASC paper (Brissenden 2020) demonstrated that a kinematic doppler interpretation of cosmological redshift can match Type 1a supernova measurements without expanding space or dark energy. This result is reviewed, and the omission of gravitational redshift, implications for general relativity, and the relevance of Milne cosmology are discussed. A new cosmological model is described where radius *r* replaces coordinate time-based *ct*. With this model, expansion of the Universe is associated with a kinematic increase in radius, and not the Friedmann-Robertson-Walker expanding space scale factor, *a(t)*. A new metric tensor is proposed, to replace the FRW metric of standard cosmological theory.

1. Introduction

For more than a century, astronomers have been measuring the redshift of extra-galactic objects (Slipher 1912, Hubble 1929). Although there have been attempts to explain these observations with static models of the Universe, most scientists now agree that this redshift data is compelling evidence that the Universe is expanding.

Measurements of redshift are usually reported as values of *z*, where *z* is defined by the equation:

$$z = \frac{(\lambda_{obsv} - \lambda_{emit})}{\lambda_{emit}} \quad (1)$$

Standard cosmology theory posits that the mechanism causing observed redshifts is predominantly the stretching of photon wavelength by expanding space. Mathematically this is represented by the Friedmann-Robertson-Walker (FRW) metric (Friedmann 1922, Robertson 1935, Walker 1937):

$$ds^2 = -(cdt)^2 + a^2(t)\{\frac{dr^2}{1-kr^2} + r^2 d\theta^2 + r^2 sin^2\theta d\varphi^2\} \quad (2)$$

With this metric, the position of a galaxy is described with a set of spherical (r, θ, ϕ) coordinates that remain largely unchanged for the life of the Universe. These are usually referred to as *comoving* coordinates. Expansion of the Universe is modelled with the scale factor $a(t)$ that is applied to the space, but not time, coordinates.

The scale factor is defined as being 1 for the current epoch and 0 at the time of the Big Bang. Its evolution between 0 and 1 as a function of time is determined by the stress-energy tensor on the right hand side of the Einstein field equation.

The time coordinate t in the FRW metric is usually referred to as *coordinate time* or *cosmic time*. In relativity theory, coordinate time is an idealized measurement of time, unaffected by motion or gravity. It cannot be measured by clocks, which are real objects necessarily subject to the effects of mass and gravity.

The time measured by clocks in relativity theory is called *proper time*, represented by the symbol τ, although this convention is widely ignored outside of relativity and cosmology, as most equations with measurements of time still use the symbol t, reflecting the Newtonian history of physics.

With this theoretical basis, standard cosmology has three mechanisms that can cause photon redshift; (1) kinematic redshift which is a relativistic doppler effect of objects moving through space, (2) gravitational redshift as predicted by general relativity, and (3) redshift due to the stretching of photon wavelength caused by the expansion of space.

The third of these mechanisms is sometimes called *cosmological redshift* but this can lead to ambiguity between descriptions of observations and theoretical mechanisms. This paper will use the term "cosmological redshift" to refer to observations of extra-galactic redshifts, not the theoretical redshift mechanism of expanding space.

With cosmological models based on the FRW metric, galaxies are considered embedded in the cosmic fluid that experiences the Hubble flow, and this is the predominant cause of observed redshifts, with peculiar velocities, such as the movement between the Milky Way and Andromeda galaxies, causing small kinematic doppler shifts that can be ignored at a cosmic scale.

The mechanisms of kinematic redshift and gravitational redshift have been confirmed by experiments on Earth. The redshift mechanism of expanding space has not.

Redshift measurements of Type 1a supernovae, first reported in 1998 (Perlmutter et al. 1999, Riess et al. 1999) were at higher z values than had been possible previously using cepheid variable stars. These supernova measurements did not match predictions made by contemporaneous FRW models. This mismatch between observations and theory was interpreted as evidence for the accelerated expansion of the Universe due to dark energy. The 2011 Nobel prize was awarded to Perlmutter, Schmidt and Riess for this discovery.

However, there is another possible explanation for the supernova redshift measurement discrepancy, which is that the FRW expanding space redshift mechanism is incorrect and cosmological redshift is predominantly a kinematic effect. This would require a revision of standard cosmology theory and was not discussed by Perlmutter, Schmidt, Riess et al.

Such a possibility was evaluated and rejected by Davis & Lineweaver in their seminal paper "Expanding Confusion: common misconceptions of cosmological horizons and the superluminal expansion of the Universe" (Davis & Lineweaver 2003) which was subsequently made into a Scientific American article (Davis & Lineweaver 2005). In this paper they state that "the interpretation of the cosmological redshift as an SR Doppler effect is ruled out at more than 23σ compared with the ΛCDM concordance model."

Unfortunately, this statement is factually incorrect. A kinematic explanation for cosmological redshift fits the supernova measurements much better than Davis & Lineweaver claim.

A possible error in the Davis & Lineweaver paper was noted by (MacLeod 2004). (Brissenden 2020) subsequently showed that a calculation error may have been the source of the incorrect Davis & Lineweaver conclusion, and demonstrated

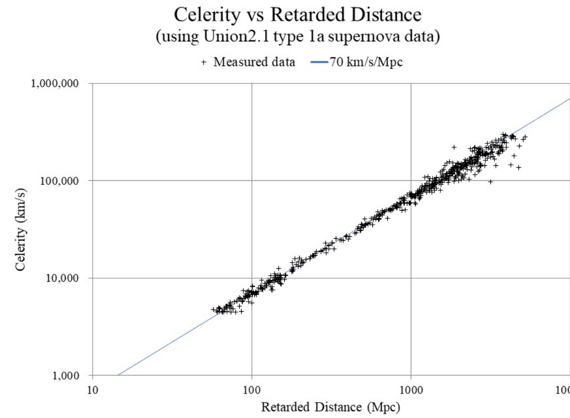

Figure 1 – Celerity vs retarded distance (using Union 2.1 Type 1a supernova data), taken from Figure 3 "Matching supernova redshifts with special relativity and no dark energy", Brissenden S.J., April 2020, JRASC.

that by using celerity (aka proper velocity) instead of peculiar velocity, it is possible to plot a straight line relationship between celerity and distance from supernova measurements (Figure 1). This straight line relationship suggests that expansion of the Universe is not accelerating and the unproven concept of dark energy is not required.

Papers by (Chodorowski 2005) and (Farley 2009) have since been found that also identified the Davis & Lineweaver error. Several expert cosmologists have now reviewed (Brissenden 2020) and, apart from Chodorowski, none were previously aware of the Davis & Lineweaver error, and all were subsequently persuaded that the Davis & Lineweaver 23σ conclusion is incorrect. From this admittedly small sample, it appears most cosmologists are unaware that a kinematic explanation of cosmological redshift can match supernova redshift measurements.

This paper will attempt to address issues that have been raised in these reviews, drawing on material from two papers that describe a novel "Big Bubble" cosmological model (Brissenden 2019 "It's time to stop talking about time" (Brissenden 2019 Big Bubble Theory).

A new metric tensor that substitutes radius r, for coordinate time-based ct, will be developed, and it will be shown that this approach resolves many long-standing problems in physics and cosmology.

2. Omission of Gravitational Redshift?

The equations that were used to prepare Figure 1 assume that cosmological redshift is exclusively a kinematic phenomenon. Gravitational redshift was not discussed in (Brissenden 2020).

There can be no doubt that some degree of gravitational redshift affects supernova redshift measurements. Type 1a supernovae are binary star systems consisting of a white dwarf and another star. White dwarves have a Chandrasekhar limit of about 1.44 solar masses.

Photons leaving the supernova binary system will experience a gravitational redshift as they climb out of the gravity well into the host galaxy, experience small gravitational effects from the host galaxy (depending on supernova position), coast through intergalactic space, and then become blueshifted as they arrive in the Milky Way before being detected on Earth.

If the supernova had the same mass as the Sun, was in a similar position in a similar spiral galaxy as the Milky Way, and photons were detected at the surface of the Sun, in the absence of any other gravitational perturbation, the redshift and blueshift would cancel out and there would be no net gravitational redshift detected.

(Weinberg 1972 p. 191) states that the gravitational redshift due to photons arriving at Earth from the surface of the Sun is equivalent to a kinematic velocity of 0.6 km/s, so the net error that results from ignoring gravitational redshift from a Type 1a supernova is likely to be less than 5 km/s. If cosmological redshift is indeed a kinematic effect, separation velocities for the most distant currently observable supernovae are greater than 100,000 km/s.

As the supernova host galaxy position and combined supernova mass are often unknown, gravitational redshift is likely to appear as a small factor uncorrelated with supernova distance that may be eliminated by data preprocessing.

The omission of gravitational redshift from the preparation of Figure 1 is technically incorrect, but it simplifies the calculation and has negligible effect on the final result.

3. Presumption of Milne Cosmology?

Figure 1 assumes that the supernova redshift measurements are a relativistic doppler effect caused by the relative movement of source and observer through space. It has been suggested that this analysis implies that the Universe is represented by Milne cosmology, which must be incorrect as, unlike the real Universe, Milne cosmology contains no mass.

This argument would seem to be logically flawed. It is usual in physics to use the simplest analysis method that achieves the desired result. You can predict the orbit of Mars quite accurately with Newtonian gravity, but must use general relativity to accurately predict the precession of Mercury.

Successfully landing a spacecraft on Mars using a Newtonian gravity calculation does not invalidate general relativity.

Figure 1 uses special relativity formulae to obtain a linear relationship for celerity versus distance from Type 1a supernova measurements, but this analysis does not require that the Universe has no mass. This methodology is discussed by (Weinberg 1972 p. 474): "Suppose we want to study some physical system S, such as the solar system or the rotating bucket of Newton, whose size is much less than the cosmic scale factor R. We can imagine S to be placed in a spherical cavity, cut out of the expanding Universe, and so long as the size of this cavity is much less than R, we can safely consider this cavity to be empty apart from the system S. If S were absent, the gravitational field inside the cavity would be a spherically symmetric field with $R_{\mu\nu} = 0$, and hence according to the Birkhoff theorem … it would have a flat-space metric equivalent to the Minkowski metric $\eta_{\mu\nu}$."

4. Implications for General Relativity?

Any new idea in physics and cosmology should aim to solve more problems than it creates. A kinematic explanation for cosmological redshift is a departure from standard cosmology, and concern has been expressed about the implications for general relativity.

To quote (Carroll 2022 p. 213): "Classical mechanics, … is not a theory of physics. Rather it is a framework within which honest theories can be constructed…. Relativity is also a framework, not a theory."

Einstein's field equations were first presented in 1915. The FRW metric for expanding space was developed from work by Friedmann in the 1920s, and Robertson & Walker in the 1930s. Discarding or revising the FRW metric would be a major revision to concordance cosmology, but this is not a threat per se to the framework of general relativity. However, adopting a kinematic interpretation of cosmological redshift will make it necessary to revisit the concepts of four-dimensional spacetime and a unique cosmic reference frame for motion and position.

5. A Cosmological Model without Expanding Space

Pedagogically, the reasoning adopted by this paper has been to start with a kinematic interpretation of cosmological redshift, show a good agreement with supernova data that can eliminate the concepts of dark energy and expanding space, then proceed to describe the mathematics of an alternative cosmology. However, this is not the sequence in which these ideas arose.

The path leading here began in 2008 with a talk by Julian Barbour on the nature of time (Falk & Barbour 2008). He questioned the need for the concept of time, and said that he considered Julius Caesar to be just as much alive as he is, albeit in a different location.

This thought-provoking idea led the author of this paper to appreciate that proper time and coordinate time have quite different physical characteristics, with coordinate time being like space (a dimension that can exist everywhere without objects), while proper time appears to have characteristics in common with energy (a scalar property associated with objects that is affected by speed and gravity). Linking coordinate time and proper time under the collective term *time* is a throwback to a Newtonian era and may be inappropriate physics for a relativistic world. These ideas were documented in (Brissenden 2019 It's time to stop talking about time).

This led to a novel concept for the structure of the Universe, where the familiar 3-D classical world is the hyper-surface of an expanding bubble in four-dimensional space.

With this cosmological model, unlike the FRW metric, bubble radius, *r* is increasing as the Universe expands. This results in cosmological redshift being predominantly a kinematic effect, rather than being due to expanding space. As the Universe is a hyper-surface in 4-D space, kinematic expansion with a uniform distribution of redshifts around the sky does not imply the Earth is located in a preferred location at the centre of the Universe as it might for kinematic expansion in 3-D space, thus satisfying the Copernican principle.

When a kinematic interpretation of cosmological redshift was compared with supernova redshift measurements, the Davis & Lineweaver error was revealed, Figure 1 was created, and the requirement for dark energy was eliminated.

Overall, this new cosmological concept appears to be effective at resolving major long-standing problems in physics and cosmology:

- The mechanism driving expansion of the Universe is internal photon radiation (and perhaps neutrino) pressure.
- The bubble structure and minimal surface physics explains the cosmological flatness and cosmological horizon problems without inflation.
- The apparent "river of time" is due to all baryonic matter being carried at high speed in the R+ direction by expansion of the Universe.
- Missing antimatter is the far side of the bubble travelling in the R- direction (analogous to Feynman's concept that antimatter is normal matter travelling backwards in time).
- The cosmic microwave background is doppler shifted black body radiation originally emitted as starlight from the far side of the Universe.
- The anomalously fast rotation curves of spiral galaxies (and the anomalously slow rotation curves of elliptical galaxies) are due to Newtonian torque-induced precession on the bubble surface without needing dark matter or MOND.
- A mechanism of action for Mach's principle, linking local inertia to the distant stars can be established through bubble physics.
- The equivalence of inertial and gravitational mass comes from gravity acting like surface tension in a soap bubble.
- Conservation of momentum can be viewed as bubble physics resisting the creation of surface holes from unbalanced movement of baryonic matter.
- The classical world is the 3-D hyper-surface of the bubble while the quantum world is the full 4-D space.
- Quantum measurement is the interaction of objects in 4-D space with the 3-D hyper-surface of the classical world, and does not require the intervention of a conscious observer.

This would seem to be a substantive list of accomplishments for a limited number of new assumptions. More details are given in (Brissenden 2019 Big Bubble Theory).

Given the significance of these changes to standard cosmology, it is reasonable to be concerned about the effect on general relativity. The bubble Universe concept does imply the existence of a preferred reference frame for position and motion, which unlike a preferred reference frame for acceleration and rotation, is not currently a standard feature of general relativity.

To avoid unnecessary change to existing theory, consideration was given to whether this new cosmological concept could be represented with the standard FRW metric.

(Weinberg 1972 p412) says about the FRW metric that: "For k = +1 the spatial Universe can be regarded as the surface of a sphere of radius R(t) in four-dimensional Euclidian space… and R(t) can justly be called the radius of the Universe."

This has some similarities with the proposed new cosmological concept, but it does not solve the problem that the FRW metric uses static comoving coordinates that are fundamentally incompatible with a kinematic description of cosmological redshift and its associated time dilation effects. It would seem that the new cosmological model requires a new metric tensor.

6. A New Metric Tensor

Deriving a new metric tensor is a daunting prospect for someone as under-qualified for the task as this paper's author, but boundary conditions are provided by the new cosmological model:

- There should be four space dimensions, not three.
- A spherically symmetric solution is required to represent the shape of a bubble, suggesting the use of spherical coordinates (r, ϕ, θ, ψ)
- Galaxies should move through space, with changing space coordinates.
- A monotonically increasing r coordinate can model cosmic expansion, eliminating the need for the FRW scale factor *a(t).*
- Time dilation should be represented by the metric.

- In the present epoch, the bubble surface should be moving through space with a celerity of 23c relative to the centre of mass (COM) of the Universe, in order to match the observed cosmic microwave background with Compton-Getting redshifted starlight from the far side of the bubble.
- The current radius of the Universe can be estimated geometrically from measurements of the Hubble factor and CMB doppler shift celerity.

A bubble surface expanding through space at a celerity of 23c is a big departure from standard cosmology, which assumes a peculiar velocity for Earth of about 600 km/s relative to the CMB. While a celerity of 23c is perfectly allowable with special relativity, this figure may be surprising to some readers. A celerity of 23c equates to travelling 1 metre of distance in 0.145 nanoseconds of proper time. Light travels 1 metre of distance in zero nanoseconds of proper time, i.e. infinite celerity. A bubble surface celerity of 23c does not mean faster-than-light travel.

The average acceleration required to reach a celerity of 23c in 13.8 billion years is only 0.5 m/s/year, i.e. 618 million times weaker than the acceleration due to gravity on Earth. (The age of the Universe is probably significantly older than 13.8 billion years if Big Bubble geometry and time dilation is included.) It seems plausible that such a low acceleration rate could be caused by net radiation pressure inside a self-inflating cosmic bubble.

In contrast to 23c seeming unreasonably fast, it is arguably quite bizarre that cosmology currently assumes that the Earth is scarcely moving through space, after experiencing an initial Big Bang and an expanding Universe for so long, and when the night sky is dominated by highly redshifted light from extra-galactic sources.

The mathematics of general relativity is based on the concept of four-dimensional spacetime. This mathematical structure can accommodate four space dimensions, as noted previously by Weinberg, but doesn't leave room for another dimension. A way to address this issue is to substitute radius *r*, for coordinate time *t*, in a new metric.

With an expanding Universe, during the expansion phase there will be a direct mapping from bubble radius to coordinate time. This one-to-one mapping would break down for a cyclic Universe if the bubble pops and the Universe collapses, and in this event a revised mathematical model will be needed (although the scientific community may prove incapable of performing the necessary studies in the prevailing circumstances).

Substituting radius for coordinate time requires a mental adjustment in dealing with velocities. We are used to considering time as an invariant Newtonian benchmark against which we can measure a variable distance travelled. With relativistic cosmology, spatial distance is a more consistent measuring stick, while proper time is a scalar that varies from person to person, and place to place.

Instead of measuring speed as "metres per second" (with "second" often left unclear whether it is a coordinate time or proper time unit) it is better to think in terms of *inverse-speed*, where distance is the denominator, not time. This is a measurement of the number of seconds of proper time it takes to travel one metre.

With a kinematic interpretation of cosmological redshift and a bubble surface sweeping all baryonic matter through space at a celerity of 23c relative to the COM of the Universe, baryonic objects cannot take more than 0.145 nanoseconds of proper time to travel one metre. They can take less proper time by adding movement relative to their local surroundings. The entire range of inverse-speeds available to baryonic matter relative to the Universe's COM is thus > 0 to ≤ 0.145 × 10−9 seconds of proper time per metre. Values outside this range are not possible. (This raises the interesting question of what is "rest mass" for baryonic particles that are never at rest.)

The proposal to map coordinate time onto radius can be seen in two ways;

1. a minimalist perspective, where it is merely a coordinate transformation, or
2. a maximalist perspective, where coordinate time can be eliminated as an unnecessary human construct with no real equivalent in the natural world.

The author of this paper prefers the second interpretation, but the reader is free to adopt the first without undermining the mathematical result.

Incorporating the boundary conditions listed above with four-dimensional spherical coordinates leads to the following metric for a Big Bubble cosmological model:

$$ds^2 = -dr^2 + r^2[d\varphi^2 + sin^2\varphi(d\theta^2 + sin^2\theta d\psi^2)] \quad (3)$$

This is based on the standard four-dimensional geometry of a *3-sphere*. A minus sign is applied to the *dr* term by analogy with the minus sign used with *ct* in conventional FRW cosmology (subject to the sign convention being used). This gives a Minkowskian characteristic to the metric, which preserves the use of standard general relativity terminology and techniques (e.g. spacelike and timelike distinctions).

The resulting metric tensor is:

$$g_{\mu\nu} = \begin{bmatrix} -dr^2 & 0 & 0 & 0 \\ 0 & r^2 d\phi^2 & 0 & 0 \\ 0 & 0 & r^2 sin^2\phi d\theta^2 & 0 \\ 0 & 0 & 0 & r^2 sin^2\phi sin^2\theta d\psi^2 \end{bmatrix} \quad (4)$$

Standard FRW cosmology	Big Bubble cosmology
Four coordinates are required to fix a position	Four coordinates are required to fix a position
r, θ and ϕ coordinate values for the Milky Way are arbitrary and unchanging	r, θ, ϕ and ψ coordinate values for the Milky Way have their origin at universe's COM
t coordinate is orthogonal to the others and common to all galaxies	r coordinate is orthogonal to the others and common to all galaxies
Cosmic expansion comes from increasing a(t)	Cosmic expansion comes from increasing r
Space has 3 dimensions that we can move in	Space has 4 dimensions but we can only move freely in 3 of them
Space is expanding	Space is not expanding
"Stationary" objects are actually moving through spacetime at $\pm ct$	"Stationary" objects are actually moving through space at $d\tau/dr$ = 0.145 × $10^{-9} sm^{-1}$
Time dilation is not significant	Time dilation is significant
Issues with cosmological flatness, cosmological horizon, dark energy, dark matter, vacuum catastrophe, missing antimatter, quantum measurement, origins of inertia, Mach's principle, JWST early spiral galaxies, etc.	These problematic issues are resolved by bubble geometry and minimal surface physics

Table 1 – FRW Cosmology vs Big Bubble Cosmology

If you take a minimalist position on using radius instead of coordinate time, and wish to be able to convert between them, the cosmic reference frame for coordinate time should be based at the Universe's COM which doesn't move, rather than on the moving bubble surface which does.

An observer placed at the COM would currently see the bubble surface moving away at close to the speed of light, but would not experience the effects of kinematic time dilation that result from this movement. The conversion between bubble radius and coordinate time for the current epoch is therefore $\Delta r = \beta c \Delta t$, where β is a factor close to 1.

The relationship between radius and coordinate/proper time in the early Universe is uncertain. There may have been an initial Big Bang explosion, resulting in the bubble surface attaining a high speed very quickly, with little change in speed thereafter. Alternatively, the bubble could have formed in a leisurely fashion and accelerated slowly over eons to its current observable speed.

This doesn't have to be a binary choice, and there may have been a combination of these processes (Big Bang and/or leisurely acceleration) at work. Detecting a difference between no recent acceleration and acceleration at least 618 million times weaker than the acceleration due to gravity on Earth, is likely to be difficult with the redshift observations and other data currently available.

However, under any of these scenarios, the age of the Universe quantified in coordinate time at the Universe's COM, will be significantly more than the 13.8 billion years that is currently concordance cosmology's best estimate of the age of the Universe, measured in comoving Earth years.

7. Conclusions

The quantity and quality of astronomical data have increased enormously over the past century. This new data has challenged our view of how the Universe is structured and behaves, and has required a series of ad-hoc patches to be applied to the theoretical foundations of cosmology that were laid down in the 1920s and 1930s. This process of observations being problematic to reconcile with theory continues today, e.g. the *impossibly early galaxy problem* implied by recent JWST observations (Melia 2023).

It is a privilege for a professional cosmologist to be able to work on these fascinating problems, but this privilege comes with responsibilities. Academic cosmologists cannot stray too far from standard theory without compromising their academic reputation.

Professional cosmologists are required to have faith in the standard model of cosmology. They are expected to believe the Universe is about 13.8 billion years old, and that expansion of the Universe is accelerating, driven by dark energy. They should believe in a period of faster-than-light inflation, that dark matter makes spiral galaxies rotate quickly and that the underlying physics of elliptical galaxies (a Boltzmann-type collision-less fluid) is different to spiral galaxies (Kepler-type orbits). They should believe that Earth is moving through space with a peculiar velocity of about 600 km/s relative to the CMB, despite the measured high redshifts of extra-galactic objects.

Underpinning all this, is a belief in the FRW metric, with its idea that space itself is expanding, represented mathematically by the scale factor *a(t)* and comoving coordinates, and a corresponding belief that a kinematic explanation of cosmological redshift can't match astronomical observations.

Each of these assumptions is dubious, but taken together they suggest that something is seriously wrong with the foundations of cosmology. This paper shows that the last of these beliefs is demonstrably false, and that replacing *ct* by *r* in a new metric tensor, can eliminate speculative cosmological dogma and chronic problems in physics.

A summary of the proposed new cosmological model is given in Table 1.

This may seem like a radical change for cosmology, but science has been here before, and that debate has left its mark in the English language. A *flat-earther* is a person who underestimates the number of spatial dimensions in our world, despite overwhelming evidence to the contrary. As a discerning reader of this publication, you surely don't want to be one of them.

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SN 2023ixf in the Galaxy Messier 101 (NGC 5457)

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Abstract

On 2023 May 19, Koichi Itagaki detected Supernova 2023ixf in the galaxy Messier 101 (NGC 5457), which lies at ~21 million ly away in the constellation of Ursa Major. It was then at a magnitude of around 14.9. Observations were subsequently made from the Dorval Observatory and the Mont St-Joseph Observatory, Mégantic, Québec, Canada.

Our questions and guidelines

- At the Dorval Observatory, we used a ZWO 1600 colour camera (CMOS) coupled with an Optolong-L pro filter, at the f/10 prime focal point of a C8 (EDGE-HD) telescope, for a ~0.8″/pixel sampling. With this equipment in urban areas and in filtered visible light, can we estimate the magnitude variations of the SN 2023ixf over time with sufficient precision to draw its light curve over time? Would the quality of this curve make it possible to identify which type of supernova it is with sufficient certainty, either "Type I" or "Type II"? Some have suggested that it may be a supernova that would be a subtype of Type II-L.
- In addition, at the Observatoire du Mont St-Joseph (OMSJ), Mégantic, a series of observations were carried out on the evening of 2023 May 22, with the "BVRcIc" filters of the Johnson-Cousins series (Optolong).

Résumé

La galaxie Messier 101 (NGC 5457), qui se situe à ~21 millions al., dans la constellation de la Grande Ourse. Le 19 mai 2023, Koichi Itagaki y a détecté la Supernova 2023ixf, elle est à cette époque autour de la magnitude 14.9. Des observations de celle-ci ont donc été effectuées de l'observatoire de Dorval, Québec, et de l'Observatoire du mont St-Joseph, Mégantic, Québec.

Nos questions et orientations;

- À l'observatoire de Dorval, nous avons utilisé une caméra (CMOS) couleurs ZWO 1600 couplées à un filtre Optolong L-pro, au foyer F/10 d'un télescope C8 (EDGE-HD), pour un échantillonnage par pixel de ~0.8″/pixel. Avec cet équipement en milieu urbain et en lumière visible filtrée, peut-on arriver à mesurer les variations de la magnitude de la SN 2023ixf dans le temps avec suffisamment de précision, pour en tracer la courbe d'intensité sur le temps. La qualité de cette courbe permettrait-elle d'identifier de quel type de SN il s'agit avec suffisamment de certitude, soit de "Type I" ou de "Type II". Certain ont suggérer qu'il peut s'agir d'une Supernova qui serait un sous-type du type II-L.
- En plus à l'Observatoire du Mont St-Joseph (OMSJ), Mégantic, une série de mesures ont été effectués la soirée du 2023-05-22, en filtre "BVRcIc" de la série Johnson Cousin (Optolong).

Introduction: Classification of Supernovae (SN)

SN Type-1a, so-called thermonuclear.

The SN of Type-1a, by their luminous homogeneities are referential candles sometimes used to calculate distances. They are possibly binary star systems, one of which exchanges material with a companion that is a white-dwarf star. The SN seems to be the product of a thermonuclear explosion of a white-dwarf star that reached the critical mass of 1.44 solar mass (the limiting mass of Chandrasekhar). (Sylvain Baumont 2010 CNRS).

A new similar type of similar SN has recently been found (2013) SN 1ax.

Although less powerful than SN Type-1a, the white dwarf survives the explosion and the origin of these SN are also by the thermonuclear explosion of the white dwarf (phys.org/news/2013-03-astronomers-kind-supernova.html) .

SN Type II

These are >8 $M_\odot$, usually turned red giants or red supergiants because of their advanced ages, which creates an imbalance of internal properties in the star. At this point, the star then leaves the main sequence of the HR diagram and takes the path that will lead to its explosion. A Type II supernova is then observed. What remains of this explosion of more massive stars may be a neutron star, but if the rest of the explosion has sufficient mass, it can produce conditions conducive to the formation of a black hole (NASA January 2011). It is the mass of the white dwarf that determines whether the star will end as a neutron star (>1.44 and <3 solar masses) or black hole (>3 solar masses) (Philippe Grandclement, CNRS/ Observatoire de Paris)

The classification of SN Type II is determined by the presence of certain elements in its spectrum, like a strong level of hydrogen, but also by the intensity of the descent curve in the days following the explosion, either as a "plateau" or a "linear" shape. The "plateau" curve may show near-horizontal stability for more than 100 days after the rapid climb (Supernova Explosion, David Branch and J. Craig Wheeler, Springer), while the "linear" curve, as the name suggests, is a gradual descent. It should also be noted that in spectroscopy, they have lines marked with hydrogen (NASA, January 2011).

SN 1b are classified by significant presence of helium.

SN 1c is the absence of hydrogen and helium.

Type SLSN-I—since 2015 June 14, the supernova ASASSN-15lh has introduced a new type of "super-luminous" supernova that has been named SLSN-I (Carnegie's Wendy Freedman et al. 2013).

Observations: Summary of this follow-up to SN 2023ixf

As most readers may know, the spring of 2023 was marked by smoke from intense wildfires across Canada. In addition, there were prolonged cloudy and rainy periods in the Montréal area of Québec. So the weather did not help us for this project. Nevertheless, we were able to carry out more than 30 evenings of imaging dedicated to the SN 2023ixf, which extends over 140 days, the "Table ixf-1," presents all the observations used for this summary.

Table ixf-1 discussion;

In May and June, the wildfires were very active, so all these observations were affected by the smoke from the fires. Subsequently, toward mid-July, the smoke began to be a little less intense, hence, the sky conditions were more carefully noted each evening of observation.

All images of this project except for one date, were taken using of the Optolong L-pro filter. This filter covers areas of the visible spectrum, it seems effective in reducing light pollution. By using this filter, we hoped to better target what are the

Epochs	**Epochs**	**Epochs**
(OMSJ) May 22		
(Dorval) May 25	August 05 (Good sky, last quarter Moon rising at 23:00)	September 03 (Cloudy periods, dense fog, waning gibbous Moon rising in the East)
May 27	August 11 (foggy with cloudy periods around 23h)	September 04 (Good sky 3/5, Moon rise ~23:00)
May 29	August 14 (Cloudy periods/poor transparency/ CCD cooler not functioning)	September 05 (Good sky, transparency and turbulence degrading, Moon rising at the end of the evening)
May 30	August 16 (Good sky/camera cooler not functioning properly)	September 06 (Very good sky, 3/5, Moon high at ~00h)
	August 18 (Frequent cloudy periods + occasional fog at lower altitudes)	September 13 (frequent cloudy periods, 80% cover, below average sky, 2/5 between clouds, good transparency, 30-60 sec exposures maximum)
May 03	August 23 (Cloud cover ~70%/Average transparency/Short exposures of 60 sec.)	September 20 (sky 3/5 and better, clouds in the east at 01:00)
May 19	August 27 (Cloudy periods, turbulence/Gibbous Moon to the south/poor seeing)	September 21 (sky 2/5, poor transparency)
May 20	August 28 (Fog/cloudy periods/Gibbous Moon to the south/seeing 2/5)	September 22 (Poor transparency, 80% cloud cover, short intervals of clear sky)
June 21	August 31 (Sky 3/5, above average turbulence/ rising Moon)	September 24 (Sky 3/5, increasing cloudiness, poor after 23:00)
		September 25 (Sky 3/5, many small clouds over whole sky)
July 05		September 27 (Sky 2/5, poor transparency and waxing gibbous Moon rising)
July 19 (frequent clouds)		September 30 (Sky 3/5, waning gibbous Moon in the east)
July 20 (acceptable)		
July 22		October 02 (Sky 2/5, poor transparency, M101 low in the NW, frequent small clouds)
July 23 (foggy with cloudy periods)		October 03 (Sky 3/5, thin clouds ~23 :00)
July 23 (foggy with cloudy periods)		October 04 (Guiding problems (>0.8″), object low on the horizon)
July 25 (3 images, cloudy periods and fog)		October 12 (--------------------------------------)
July 27 (poor transparency + moonlit sky)		
July 31 (average sky with full Moon low to the south)		

Table ixf-1 – Observation Periods

main chemical elements present in our images. See Table ixf-2. A graph of the transmission of this filter is available at the following site:

all-startelescope.com/fr/products/optolong-l-pro-light-pollution-suppression-filter-1-25-opt-l-pro-125

It must be considered that one of our objectives with this colour CMOS camera was to check if it is possible to estimate the changes in the magnitudes of the SN in time with an acceptable accuracy and to validate certain aspects this SN. A map of the galaxy's environment was used, on which a series of reference stars shown using the Variable Star Plotter of the AAVSO site. We have inserted on one of our images, a number of the stars that correspond to the AAVSO reference stars, to better determine which stars are most likely to be used as reference stars (see Figure ixf-1).

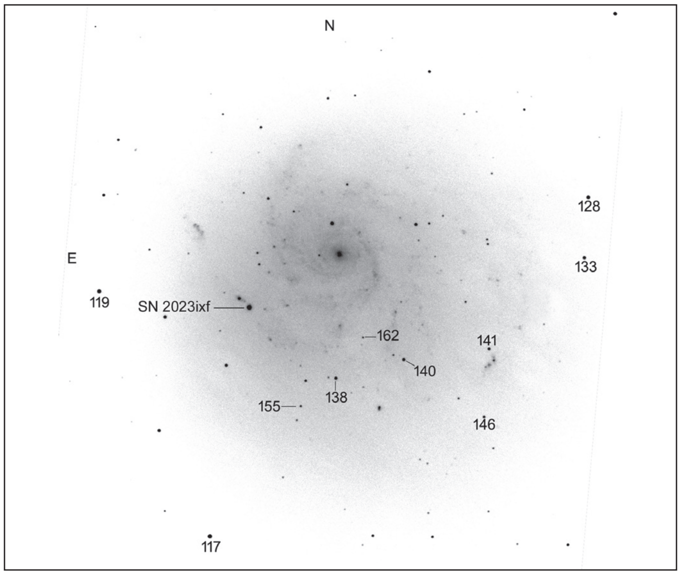


Figure 1 – M101 SN 2023ixf (G. St-Onge) / references stars AAVSO

Figure ixf-1 -Summary

- The image is from the Dorval Observatory, Québec.
- The magnitudes indicated on the image correspond to the reference stars of the map produced by the AAVSO site.

We used two pairs of stars to validate measurements such as;

- **Stars: 138 (mV 13.801), (mR 13.230) and the star 155 (mV 15.475), (mR 15.133)**

A few times when the star 155 was impossible to measure because of bad sky conditions, we then used;

- **Stars: 138 (mV 13.801), (mR 13.230) and the star 140 (mV 13.991), (mR 13.581). These measurements are in red on the Table ixf-3.**

Regions of the visible electromagnetic spectrum	This filter shows an overall transmission between ~89% to ~97%. Transmission in nm.	Detectable chemical elements per zone/ in "nanometre"
Blue	A ~12 nm (half maximum) a thin band centred on ~425 nm (89% efficiency)	~ Continuum
Green	A much wider bandwidth ranging from ~450 nm to ~530 nm (half maximum) and ~95% transmission. And a thin bandwidth of ~12 nm (half maximum), centred on ~ 564 nm, transmission of ~92%	*Hb* Hydrogen at 486.1 nm [OIII] Oxygen at 495.9 nm [OIII] Oxygen at 500.7 nm ~ Continuum
Red	Another thin bandwidth of ~12 nm (half maximum), centred on ~605 nm, transmission of ~92%	~ Continuum
Near Infrared	Another wide band that ranges from ~645 nm to ~700 nm, ~95% efficiency	[NII] Azote+ at 654.8 nm HI Hydrogen at 656.3 nm [NII] Azote+ at 658.4 nm [HeI] Helium at 667.8 nm [SII] Sulphur + at 671.7 nm [SII] Sulphur + at 673.1 nm

Table 2 – Filter transmission Optolong L-pro.

SN 2023ixf, UT 2023 May 22 03:11, (Johnson's filter) B ≈11.44 ±0.01 / V ≈ 11.32 ±0.01 / R ≈ 11.73±0.01
These measurements come from the Mont St-Joseph observatory in Mégantic.

Date	B–Avg	V–Avg	Rc–Avg	Ic–Avg	B–V	T (K)
May 21-A	11.185	11.354	11.354	11.34225	–0.198	10888.97
May 21-B	11.343	11.392	11.343	11.343375	–0.049	10715.55
1	2	3	4	5	6	7

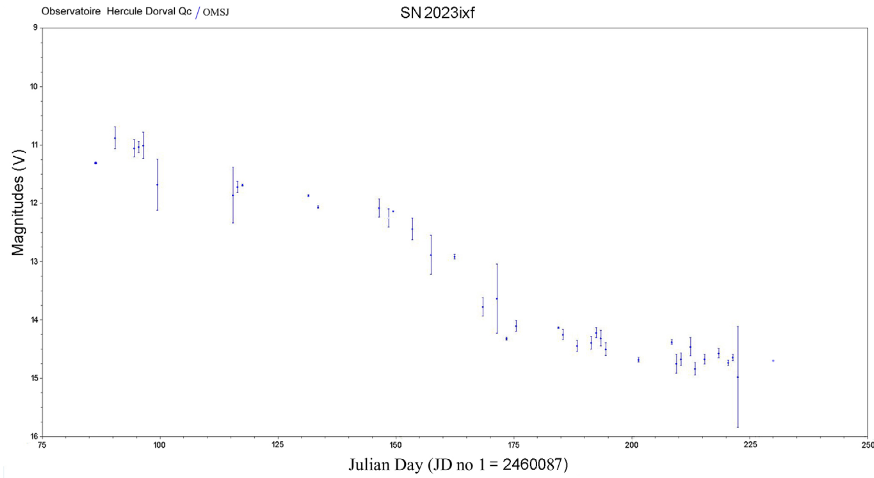
A–B (Before and after meridian reversal). In Box 7, estimate of the the surface temperature in Kelvins, calculated according to (Sekiguchi et al. 2000)
Table 3

Our Results

Magnitudes estimates using the AAVSO reference stars in (V and R) were made as mentioned in Figure 1. Only the estimates from the "Johnson V" were kept, they seemed to us the most appropriate to the type of colour detector used. The Table ixf-3-1 presents all the "V reconstituted" magnitudes that we obtained with this method.

Graph1-ixf

The first measurements are from the Mont St-Joseph observatory, Mégantic, Johnson filter measurements on the 2023 May 21:



Graph1-ixf

Description of the Table 3

All the results of this table are from the Dorval Observatory except one from OMSJ de Mégantic.

All these measurements use as references the "Johnson V" magnitudes of stars in the region of the SN 2023ixf which are produced by the AAVSO.

References stars, 138 (mV 13.801), 155 (mV 15.475).
*In red; stars, *138 (mV 13.801), *140 (mV 13.991).

Column (1) on the left, indicates the dates of observations in MMM-DD

The following column (2) indicates the Julian Days (JD) corresponding to the observation dates.

Column (3) that follows, indicates the values of magnitude "V- Reconstituted" as measured on our colour images, these values represent an approximation of the result with the "V Johnson" filter as produced on the graph of the AAVSO. To perform these "V- Reconstituted" measurements, the Johnson "V" filter reference stars noted on the scorecard proposed by the AAVSO were used. Refer to "Figure ixf-1."

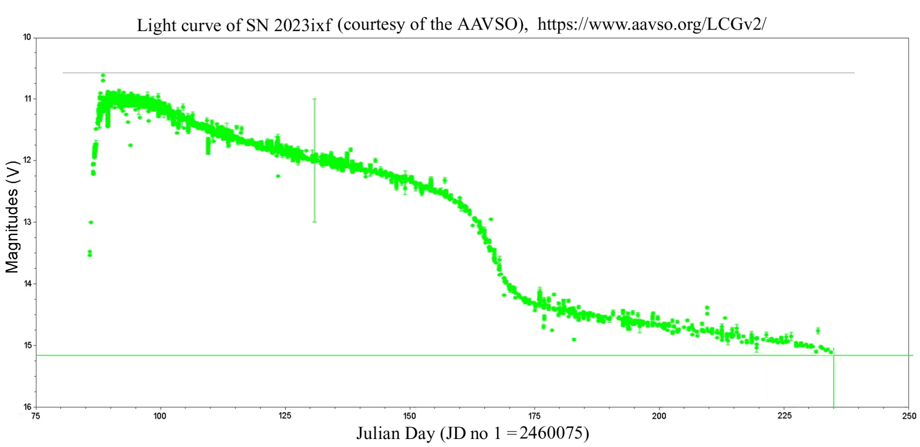
Column (4) on the right, (discussion/notes); On our colour images, our Mag estimates.

(V Reconstituted) are for the most part a little more intense than those produced by the AAVSO, so the difference between the two is a negative value; Example, for the estimate of May 25, AAVSO (Johnson V) 11.052, and we obtained (reconstituted V) 10.88, the difference is given as –0.1720 magnitude.

We also note the difference between the AAVSO and us of 0.2 magnitude or more for 24 of 39 measurements.

Some values in red* indicate that the second pair of reference stars (stars 138 and 140) had to be used a few times.

The Graph1-ixf, presents our results of the estimation of Magnitudes "V Reconstituted" (Rec), as evaluated in Table ixf-3. These estimates of the magnitude "V (Rec.)" thus obtained, allowed us to produce a graph of the luminosity curve of the SN for a large time period "Graph1-ixf." That is from May 22 to October 12, after this period the region of Messier 101 was too low in the NW, therefore practically unobservable from the observatory.



Graph 2-ixf

Graph1-ixf

Summary of Graph 1-ixf.

Our observation results are from the observatory in Dorval and the OMSJ in Mégantic, Québec. On the vertical axis, we find our estimates of the variations of magnitudes "V (Rec)" of the SN, indicated over the total observation period in (JJ) which is presented on the horizontal axis. This graph makes it possible to identify the trend of the flux variations that the SN presented for this observation period.

Photometry of the SN 2023ixf	(JD)	SN2023 ixf	Error rate
Dates of observations	Julian Day	Our estimates of the magnitude "V reconstituted"	In relation to data from the AAVSO
	Julian Day (JD)	mag. "V reconstituted"	Differences
(OMSJ)			
May 22	2460086.67	11.32 ±0.01	0.0880
(Dorval)			
May 25	2460090.5	10.88 ±0.19	–0.1720
29	0094.5	11.06 ±0.15	–0.0680
30	0095.5	11.03 ±0.10	–0.0710
31	0096.5	11.01 ±0.23	–0.1040
June 03	0099.5	11.68 ±0.44	0.4590
19	0115.5	11.86 ±0.48	0.1410
20	0116.5	11.72 ±0.10	–0.0120
21	0117.5	11.69 ±0.02	–0.0650
July 05	0131.5	11.87 ±0.02	–0.1740
07	0133.5	12.06 ±0.03	0.0830
20	0146.5	12.08 ±0.16	–0.2200
22	0148.5	12.25 ±0.16	–0.0910
23	0149.5	12.13 ±0.01	–0.2420
27	0153.5	12.44 ±0.19	–0.0820
31	157.5	12.88 ±0.34	0.3090
August 05	0162.5	12.91 ±0.04	–0.0710
11	0168.5	13.77 ±0.16	–0.1200
***14**	0171.5	13.63 ±0.60	–0.5670
16	0173.5	14.32 ±0.03	–0.0190
18	0175.5	14.10 ±0.10	–0.2910
27	0184.5	14.13 ±0.02	–0.3910
28	0185.5	14.25 ±0.09	–0.3280
31	0188.5	14.44 ±0.10	–0.1630
September 03	0191.5	14.39 ±011	–0.2140
04	0192.5	14.22 ±0.09	–0.4280
05	0193.5	14.31 ±0.14	–0.3460
06	0194.5	14.50 ±0.11	–0.1560
13	0201.5	14.68 ±0.04	–0.0700
20	0208.5	14.37 ±0.04	–0.4360
21	0209.5	14.75 ±0.17	–0.0360
***22**	0210.5	14.67 ±0.11	–0.1470
24	0212.5	14.46 ±0.16	–0.4040
***25**	0213.5	14.83 ±0.11	–0.0300
***27**	0215.5	14.67 ±0.09	–0.2110
30	0218.5	14.57 ±0.08	–0.3670
October 02	0220.5	14.73 ±0.05	————
03	0221.5	14.64 ±0.06	–0.2340
04	0222.5	14.97 ±0.87	0.0210
12	0230.5	14.72 ±0.09	–0.3510
1	2	3	4

Table 3

From the outset, not knowing if our measurements were accurate enough to determine what type the SN was, since a colour CMOS detector was used, we had to take as a basis what the literature indicated, that it would be a Type II SN, (a massive star at the end of life that explodes).

A brief description of the curve obtained

Note that the maximum intensity detected does not show a point clearly above the plateau that follows. Then the slope that follows the maximum is soft and it shows about the same level of inclination just as at "JD" ~160. Later we observe a pronounced decrease in magnitude, between "JD" 160 and ~175. Then follows a slope that softens again, even which seems a little less inclined than the previous slope with more intense magnitudes.

An attempt was therefore made to determine to which type exactly SN 2023ixf belongs, comparing the measured curve as on the Graph1-ixf, with the curves predicted by the models, either Type II-L or Type II-P. It was difficult for us to reach a satisfactory corresponding curve pattern.

Testing our observation method with the AAVSO light curve of the SN 2023ixf

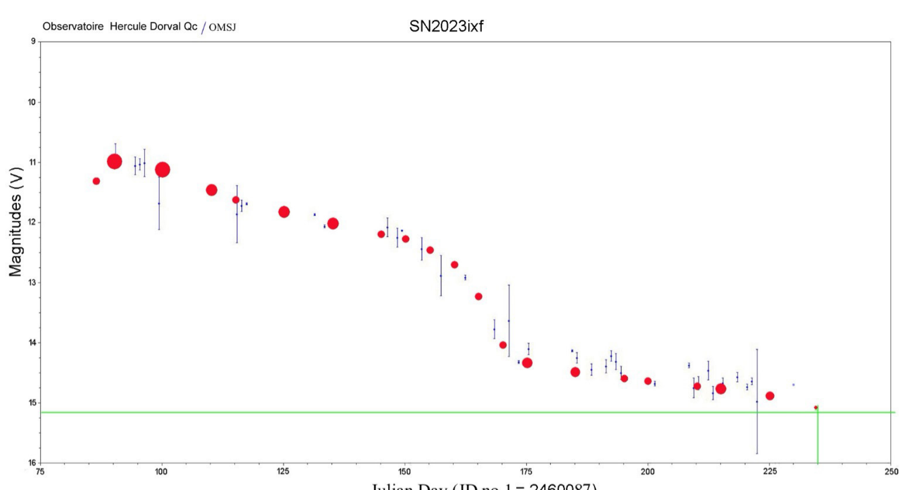
To validate our Graph 1-ixf, we had access to a graph prepared from observations of the SN 2023ixf, groups of the AAVSO using Johnson "V" filter, it is Graph 2-ixf. By superimposing the AAVSO graph on our Graph 1-ixf, we were able to evaluate our SN measurements on the Graph 3-ixf.

Graph 3-ixf Summary

Our measurements are in blue and the red reference points come from the graph (Graph 2-ixf) of the AAVSO "Johnson V" filter, (courtesy of the AAVSO). www.aavso.org/LCGv2/

Curve of the AAVSO group (Red dots on Graph 3-ixf)

We integrated the two curves on top of each other, in blue our measurements and in red control points on the curve produced by the AAVSO group. We can see that there is a good correlation between the two curves. Although we used a colour CMOS camera and the Optolong L-pro filter, our curve corresponds quite well with that of the AAVSO. The size of the control points in red represents for each measurement position the error bar area of the AAVSO curve measurements. The variable line thickness of this graph (AAVSO) was used as an indication of the accuracy of each measurement.



Graph 3-ixf

Discussion; The light curve of the SN 2023ixf

SN 2023ixf in M101 is the closest SN explosion observed in the last decade and it appears to be of Type II-P. (Its distance being estimated at 6.9 megaparsecs, or surrounding M101 (iopscience.iop.org/article/10.3847/2041-8213/acf2ec/pdf).

But during our analysis, the profile of its slow curve and its shallow plateau challenged us and inspired us to study more closely the progenitor star. It turns out that this research taught us that we were not the only ones to be undecided on the classification of this supernova. Some reported it as Type II-L (Bianciardi G. et al. 2023), others as Type II-P (Danfeng Xiang et al. 2023). In addition, we also found several scientific papers, which noted that the red giant had already reached a more advanced stage before the explosion and that it was already in advanced matter loss (Panjkov, S et al. 2023). It even says that stellar winds began 80 years before the explosion (L. Martinez et al. 2023).

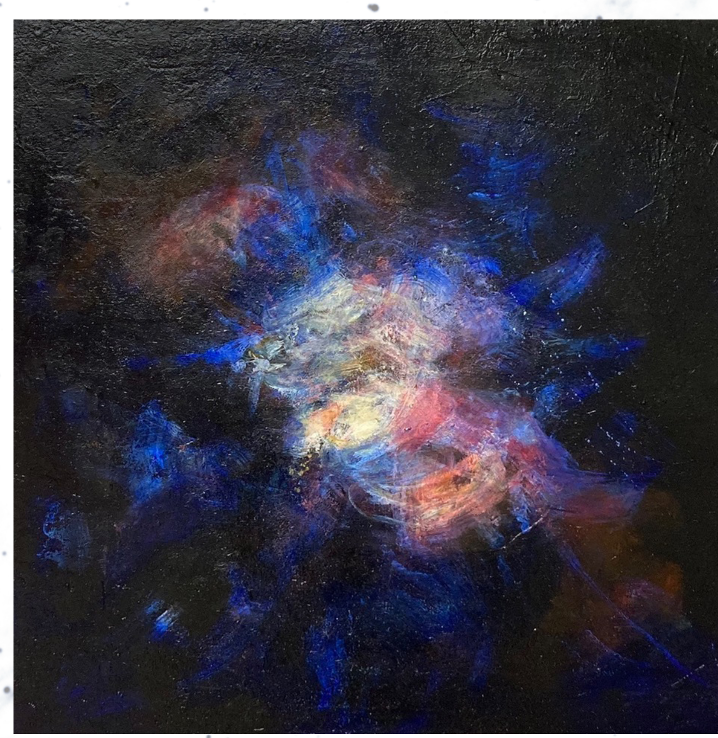
This model suggests the possibility that the star was surrounded by a halo of circumstellar material (CSM) before the SN explosion. A bit like symbiotic stars, which could perhaps explain the less pronounced curve of the plateau that mystified more than one observer. Some evidence suggests that stellar winds have even increased significantly in recent years and these also suggest a wind of more than 50-km/second (Schuyler D. Van Dyk et al. 2023). This wind would have caused an increased mass loss in the last 2 to 3 years before the event. In his paper (arXiv:2310.08733v1), (L. Martinez et al. 2023), therefore, concluded that the wind acceleration taken into account suggests that the increased mass loss was initiated 80 years before the SN. These time scales are related to the last stages of the evolution of massive stars (L. Martinez et al. 2023), although the details are unknown.

Given the high mass-loss rate and relatively high wind speed presented here, as well as the pre-explosion observations made about two decades ago, the ancestor of SN 2023ixf could be a yellow hypergiant that evolved from a red

Continues on page 76

Figure 1 – What's it all about? That is seemingly what the Universe is asking with the Question Mark Nebula (NGC 7822), seen here in this beautiful image from Rob Lyons. "Different camera and telescope combinations produce different results, and sometimes going wide instead of telescopic produces exciting results," he writes. For this image, Rob used a widefield William Optics RedCat 51 telescope paired with his Sony A7R. He also used the Altair dual narrowband 4nm Hα/OIII and SII/OIII filters to create this Hubble palette image. The image was taken over 2 nights in October 2023, with a total of 15 hours of integration shot over 2 nights. Rob says, "I have shot this target several times with different cameras, telescopes, and filters, and each time reveals completely different aspects of the nebula. So, I guess the question is, how should I shoot it next?"

Figure 2 – Messier 17, 62 × 62 cm, o/panel, Julian Samuel, 2024



Continues on page 75

What's Up in the Sky?

April/May 2024

Compiled by James Edgar and Scott Young

Observing Highlights for April 2024

Solar System Highlights

Mercury is visible for the first few days of April, very low in the west-northwest, but rapidly fades as it sinks lower into the evening twilight. It reappears in the morning toward month-end but stays very low for Canadian observers.

Venus is lost in the solar glare during April. Watch for it to reappear in the evening sky in early summer.

Mars spends April too close to the Sun and too low in the sky to be easily visible this month.

Jupiter sinks low into the evening twilight by the end of the month, but early April sees it still hanging around low in the west. The crescent Moon is north of Jupiter on the evening of the 10th.

Saturn reappears in the morning sky this month, slowly rising out of the predawn twilight. It lies close to Mars on the mornings of April 10th and 11th, but the low altitude of both planets will make this a very challenging observation. By the end of April, Saturn is visible low in the ESE just before dawn.

Uranus is found near Jupiter in the evening sky, with the Moon just to the south. It passes less than a degree from the giant planet on the nights of April 19 and 20.

Neptune is too close to the sun to be easily spotted this month.

Dwarf planets **Ceres** and **Pluto** rise about 4 a.m. and 5.a.m., respectively, only about 20 degrees apart in eastern Sagittarius and western Capricorn. Ceres is near magnitude 9 and is visible in small telescopes or large binoculars, while Pluto remains near magnitude 14.5 and is invisible without at least a 20-cm telescope. Finder charts for both dwarf planets are available in the 2024 Observer's Handbook.

Near Jupiter in the evening is **Comet 12P/Pons-Brooks**, which begins the month in Aries. The comet brightens as it moves to pass under Jupiter on the 13th, and may become visible in binoculars in the evening twilight. See Figure 1. The best view of the comet may come during the Total Solar Eclipse, where it will be visible high in the sky for the few minutes of totality.

Sky Calendar for April 2024

April 1: Last Quarter Moon

April 7: A daytime occultation of Venus by the Moon is visible in eastern Canada, but this occurs very close to the Sun and will be a difficult observation. See p. 165 of the 2024) Observer's Handbook for details.

April 8 - Total Solar Eclipse: This eclipse will no doubt be one of the astronomical highlights of the year. Western Canada (and most of North America) will see a partial eclipse, while Ontario and points east have ready access to the path of totality. (See www.eclipsewise.com/solar/SEprime/2001-2100/SE2024Apr08Tprime.html)

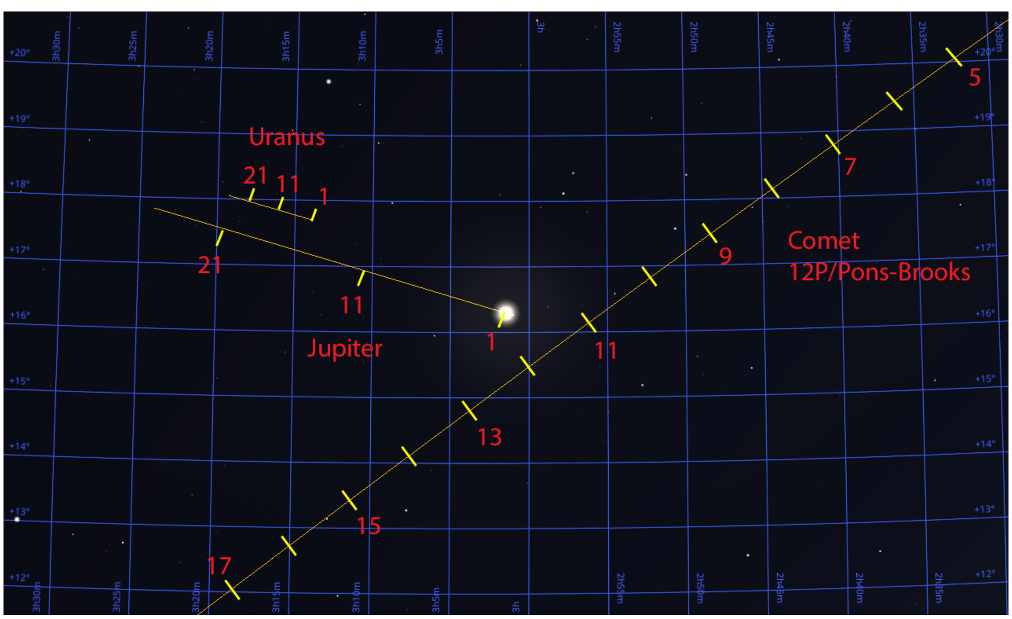


Figure 1 — Periodic comet 12P/Pons-Brooks passes near Jupiter and Uranus in April's evening sky. The comet's position is shown daily at 7:30 p.m. PDT = 8:30 p.m. MDT = 9:30 p.m. CDT = 10:30 p.m. EDT = 11:30 p.m. ADT. [Image: S. Young/Stellarium]

April 10: Mars and Saturn are within a degree of each other low in the predawn sky, while the crescent Moon is north of Jupiter in the evening sky.

April 11: Mars and Saturn are within a degree of each other low in the predawn sky.

April 15: First-quarter Moon

April 21/22 - the Lyrid meteor shower peaks in the early hours of April 22, but the nearly full Moon will wash out most of the meteors.

April 23 - Full Moon

Continues on page 74

The Sky April/May

Compiled by James Edgar with cartography by Glenn LeDrew

Celestial Calendar
(bold=impressive or rare)

Apr. 1 Moon at last quarter

Apr. 6 Mars 2.0° north of Moon

Apr. 6 Saturn 1.2° north of Moon

Apr. 7 Neptune 0.4° north of Moon

Apr. 7 Venus 0.4° south of Moon

Apr. 7 Moon at perigee (358,850 km)

Apr. 8 new Moon at 2:21 p.m. EDT (lunation 1253)

Apr. 8 Total Solar Eclipse, visible across much of North America

Apr. 10 Uranus 3.6° south of Moon

Apr. 10 Jupiter 4.0° south of Moon

Apr. 10 Mars 0.5° north of Saturn

Apr. 11 Moon 0.4° north of Pleiades (M45)

Apr. 15 Pollux 1.5° north of first-quarter Moon

Apr.15 Moon at first quarter

Apr. 19 Moon at apogee (405623 km)

Apr. 20 Jupiter 0.5° south of Uranus

Apr. 22 Lyrid meteors peak at 3:00 a.m. EDT

Apr. 23 Spica 1.4° south of full Moon

Apr. 23 full Moon at 7:49 p.m. EDT

Apr. 26 Antares 0.3° south of 17-day-old Moon

Apr. 29 Mars 0.04° south of Neptune

May 1 Moon at last quarter

May 5 Eta Aquariid meteors peak at 5 p.m. EDT

May 5 Moon at perigee (363,163 km)

May 6 Mercury 4° south of Moon

May 7 new Moon at 11:22 p.m. EDT (lunation 1254)

May 11 Mercury greatest elongation west (GEW)(26°)

May 12 Pollux 1.6° north of Moon

May 15 Moon at first quarter

May 17 Moon at apogee (404,640 km)

May 20 Spica 1.4° south of Moon

May 23 full Moon at 9:53 a.m. EDT

May 21 Antares 0.4° south of Moon

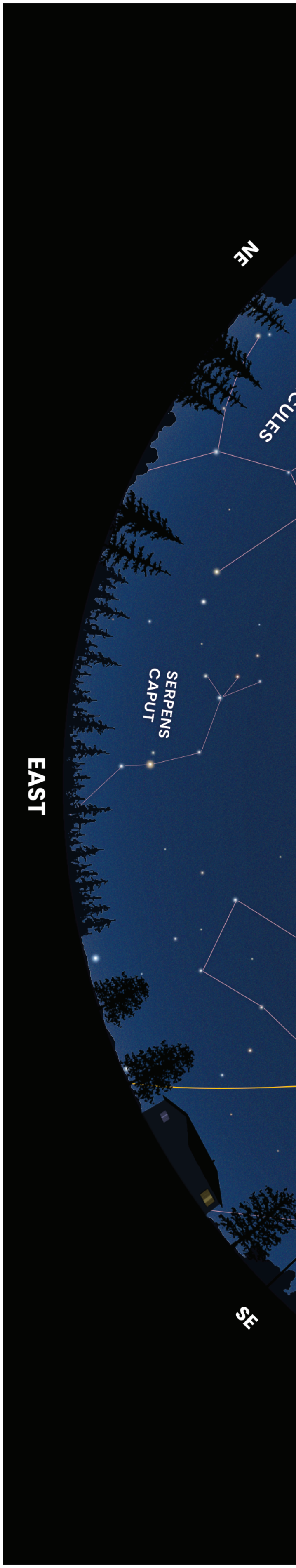
May 27 Ceres 0.9° north of Moon

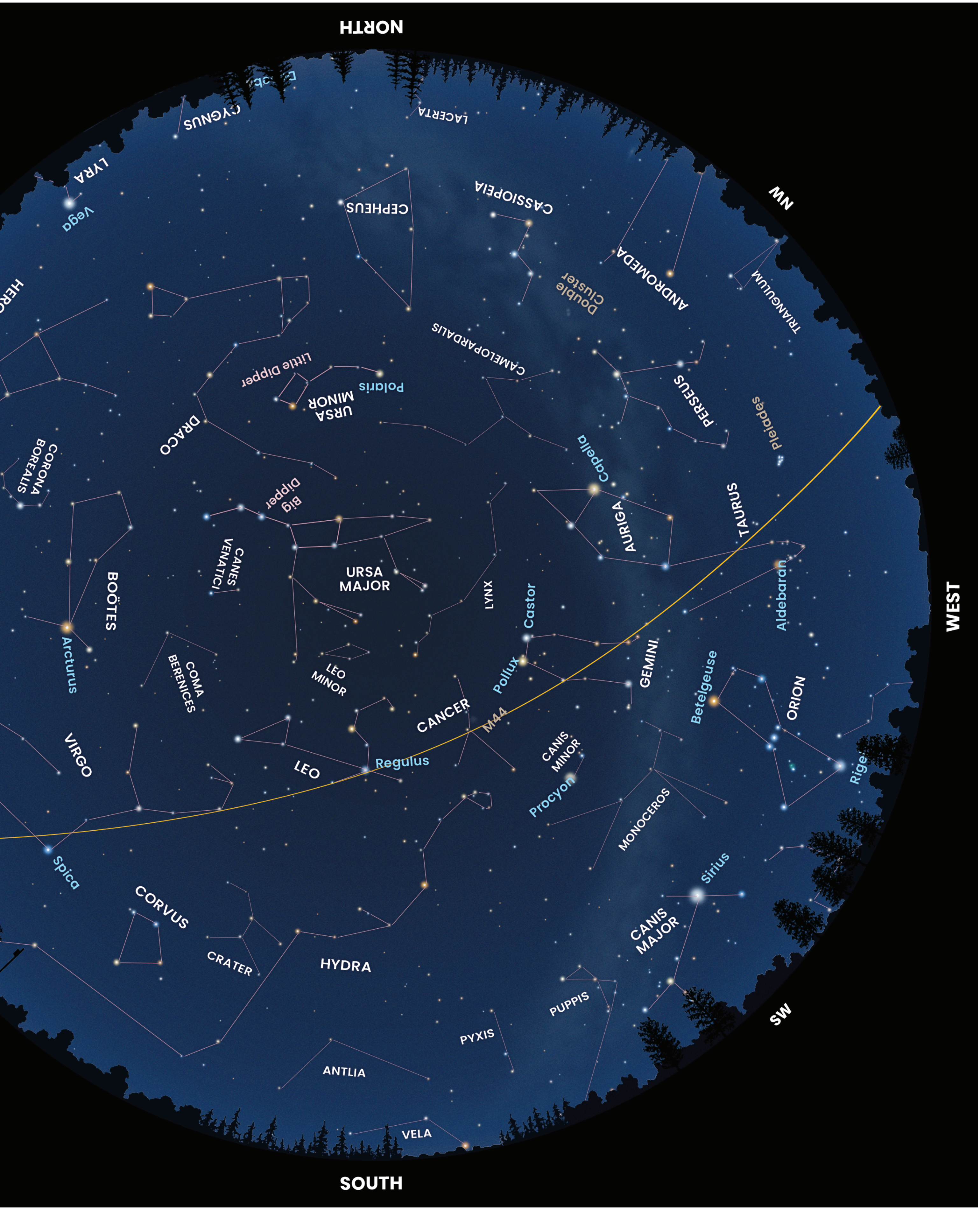
May 30 Moon at last quarter

May 31 Saturn 0.4° north of Moon

Planets at a Glance

	DATE	MAGNITUDE	DIAMETER (″)	CONSTELLATION	VISIBILITY
Mercury	Apr. 1	1.4	9.3	Pisces	Evening
	May 1	1.0	9.6	Pisces	Evening
Venus	Apr. 1	—	10.3	Pisces	—
	May 1	—	9.8	Aries	—
Mars	Apr. 1	1.2	4.5	Aquarius	Morning
	May 1	1.1	4.7	Gemini	Evening
Jupiter	Apr. 1	–2.1	34.1	Aries	Evening
	May 1	–2.0	32.9	Taurus	Evening
Saturn	Apr. 1	1.1	15.7	Aquarius	Morning
	May 1	1.2	16.2	Aquarius	Morning
Uranus	Apr. 1	5.8	3.4	Aries	Dusk
	May 1	—	3.4	Aries	—
Neptune	Apr. 1	—	2.2	Pisces	—
	May 1	7.9	2.2	Pisces	Morning




NORTH
SOUTH
WEST
NW
SW
CYGNUS
LACERTA
LYRA
Vega
CEPHEUS
CASSIOPEIA
ANDROMEDA
TRIANGULUM
Double Cluster
CAMELOPARDALIS
Little Dipper
Polaris
URSA MINOR
DRACO
PERSEUS
Pleiades
Capella
CORONA BOREALIS
Big Dipper
AURIGA
TAURUS
CANES VENATICI
URSA MAJOR
BOÖTES
LYNX
Castor
Aldebaran
Arcturus
COMA BERENICES
LEO MINOR
Pollux
GEMINI
Betelgeuse
ORION
CANCER
M44
VIRGO
LEO
Regulus
CANIS MINOR
Procyon
Rigel
MONOCEROS
Spica
Sirius
CORVUS
CANIS MAJOR
CRATER
HYDRA
PUPPIS
PYXIS
ANTLIA
VELA

Continued from page 71

Observing Highlights for May 2024

Solar System Highlights

Mercury swings into the morning sky but remains too low to be easily seen from Canadian latitudes.

Venus is too close to the Sun to be seen, heading toward its superior conjunction behind the Sun in early June.

Mars is slowly creeping above the eastern horizon in the predawn sky, but it remains low enough all month to be difficult to spot. On the morning of the 5th, the crescent Moon is nearby.

Jupiter disappears into the evening twilight early in the month as it swings behind the Sun. It is in conjunction with the Sun on May 18, and basically invisible all month.

Saturn becomes visible later in the month, rising about 3 a.m. local time but hugging the southeast horizon at dawn.

Uranus is in conjunction with the Sun on May 13 and thus invisible, while **Neptune** has reappeared in the predawn sky.

Dwarf planets **Ceres** and **Pluto** remain in the morning sky. Ceres brightens to 8th magnitude by month-end, but Pluto remains at magnitude 14.5.

Comet 13P/Olbers is visible in the evening sky, hovering above the western horizon throughout the month as it moves through the stars of Auriga. If it lives up to predictions, 13P/Olbers may reach 8th magnitude in May and become a binocular object for much of the summer if it follows its predicted behaviour (which is never a safe bet for comets!)

Sky Calendar for May 2024

May 1: Last-quarter Moon

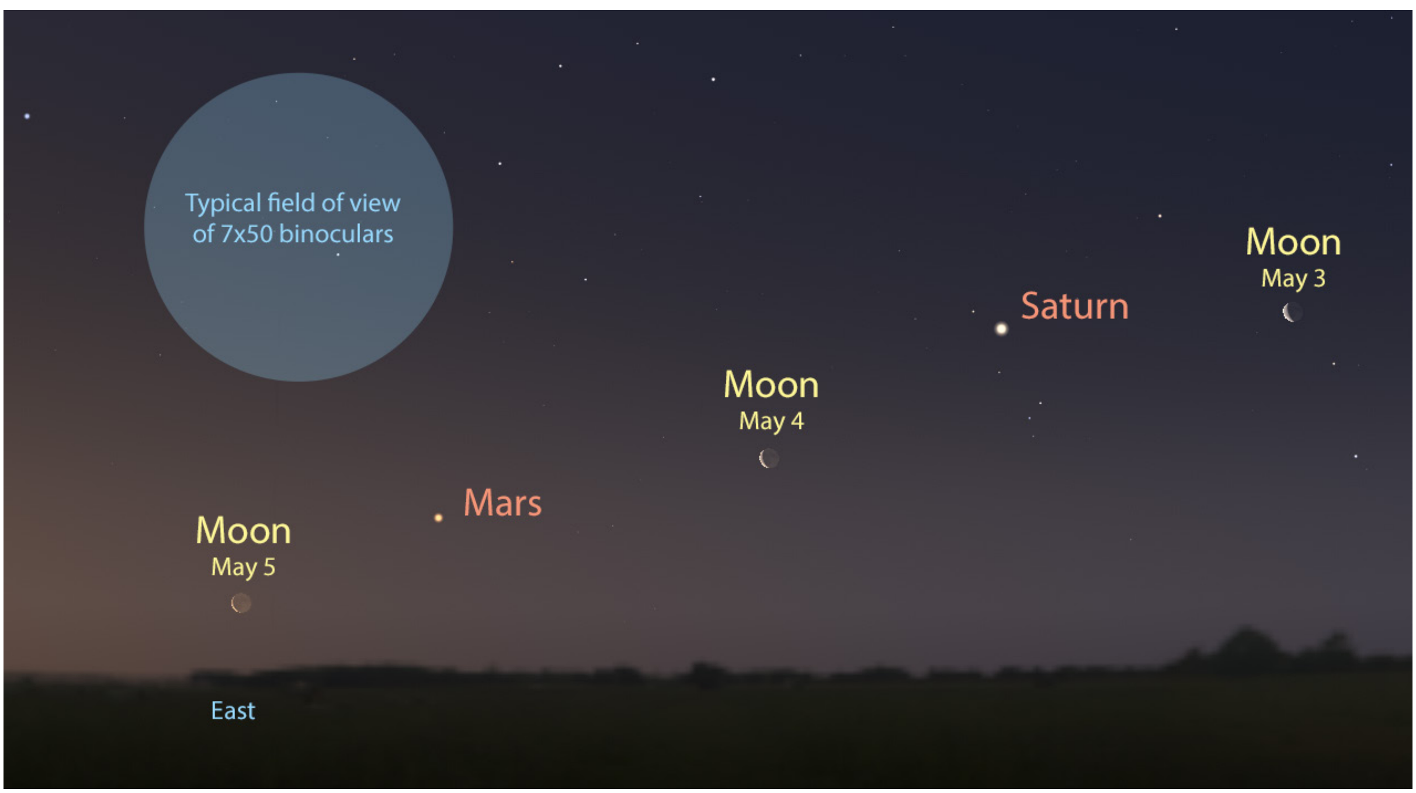
May 5: The annual **Eta Aquariid meteor shower** peaks about 21h UT. Even though it occurs near new Moon and has an expected zenithal hourly rate of up to 50 meteors per hour, the southerly location of the meteor shower's radiant translates into an expected rate of about 10 meteors per hour for observers in Canada.

May 7 / 8: New Moon

May 15: First-quarter Moon

May 27: the dwarf planet Ceres is about a degree away from the waning gibbous Moon.

May 31: The waning crescent Moon is south of Saturn in the predawn sky. ✶



The thin-crescent Moon passes Saturn and Mars in early May. The view is shown at 5:15 a.m. local time, facing east. [Image: S. Young/Stellarium]

Continued from page 70

Figure 3 – The Cocoon Nebula (IC 5146) is a reflection/emission nebula in the constellation Cygnus that is a favourite of many astrophotographers. "The cluster is about 4,000 light-years away, and the central star that lights it formed about 100,000 years ago," Jason says. "When viewing IC 5146, dark nebula Barnard 168 (B168) is an inseparable part of the experience, forming a dark lane that surrounds the cluster and projects westward forming the appearance of a trail behind the Cocoon. This image also shows some hydrogen emission in the surrounding area of the nebulosity." Jason used a Sky-Watcher Esprit 100 ED APO telescope on a Sky-Watcher EQ6R-Pro mount, with a ZWO ASI 2600MM Pro camera and Optolong Hα/LRGB filters, guided by a Sky-Watcher EVOGuide Scope with ZWO ASI120MM camera. Total integration time was roughly 55 hrs. using Hα/LRGB from his Bortle 4/5 backyard near Halifax, Nova Scotia. The image was pre-processed and processed using PixInsight.

Figure 4 – As astronomers, we may get annoyed when our Moon washes out the night sky, but our nearest neighbour can also be a wonderful photographic target. Shelley Jackson imaged Luna, pulling out its different mineral compositions. It was a process, she says. "Stacking and processing was quite different from what I am used to as well. For DSO I use PixInsight to do the entire pre- and post-processing. For lunar, it was MUCH different and involved using ImPGG to align my capture, Autostakkert! to stack the images, and PixInsight to edit," she says. She used an Askar V at 80-mm aperture with an FL 485 flattener, a ZWO ASI183mm camera pro-cooled to –10 °C, a 50-mm guide scope with ZWO 120 mono guide cam, and a ZWO electronic filter wheel with an Hα filter together with a Pegasus Focus cube and a Pegasus Falcon rotator on a Sky-Watcher EQ6R pro mount. The final image was stacked using PixInsight and Gimp for editing.

Continued from page 69.

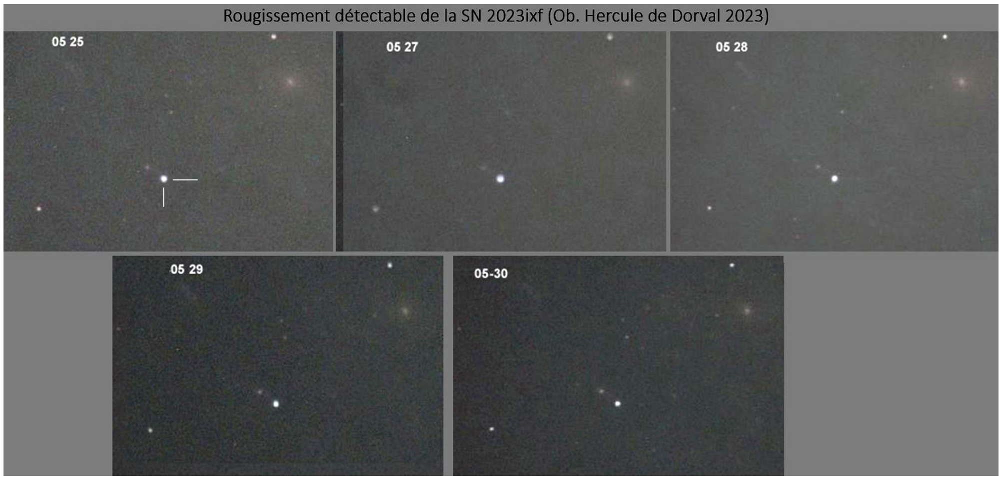


Figure ixf-2 – are the SN at the end of May, it was very intense and rather white/blue.

Figure ixf-3 – the SN in June and July, shows that in early July, it is still rather white, but at the end of July around the 22nd, it begins to have a redder shade.

Figure ixf-4 – SN is now very red in September and October.

supergiant shortly before the explosion (Yu-Jing Qin et al. 2023). Some studies also suggest that the progenitor star of SN 2023ixf would have a mass not exceeding 11 solar masses (Danfeng Xiang et al. 2023).

Colouring of the SN 2023ixf

The use of the colour camera revealed that the SN has changed its apparent colour over time. The SN changed from very intense blue-white at the beginning of the appearance of SN, to very red further along the timeline. This change of hue seems to be as follows: At the beginning it is a blue-white colour, it is still almost white on July 05. Then a few days later, on July 19, it shows a pink tint, and around August 11, the SN is much less intense and it becomes very red.

Some have produced papers that seem to show that the star was active for years before becoming SN in 2023 (Daichi Hiramatsu et al. 2023). Material could therefore be expelled from the star in significant quantities, which created shells of circum-stellar material (CSM) that are all around the star, which may contribute to the reddening of the star's light. Question: Can we think that at the beginning, the brightness and the significant size of the emissive source could be intense enough that the contribution of this material (CSM) is not significant. But over time, the intensity of the SN and its environment could decrease by cooling so that this material (CSM) may also have played a more significant role and thus contribute to the colour changes, or the more pronounced visible reddening of the SN.

In any case, our images seem to show changes in the apparent colouration of the SN over time as suggested by (Daichi Hiramatsu et al 2023), the Figures ixf-2, 3, and 4 show these changes.

Some may argue that it is the sky conditions this year 2023 (smouldering fires, multiple clouds and mists) that would be mainly responsible for this reddening? If this were the case, the other stars of the field around the position of the SN would also suffer a reddening! But they do not experience this reddening with as much intensity, the SN seems to be the only one to be so affected by this reddening? It therefore seems possible to consider that this reddening could be caused by the cooling of the star materials after the explosion in SN. And perhaps there is also a contribution by some material from the surface of the star that was ejected into its environment during intense activities of the star preceding the observable stage of the SN.

Conclusion

Our results seem to indicate that the use of a colour camera (CMOS) such as the ZWO 1600 coupled with an Optolong L-pro filter in an urban environment, can allow a follow-up in visible light, with an acceptable precision of objects of variable brightness, objects such as SN and variable stars. The correspondence is surprising between the two luminosity curves used, that with the colour CMOS of the Dorval group and that produced by the AAVSO team based on the reference measurements of the Johnson V filter. Moreover our intensity curve seems to agree with some who suggest that the SN 2023ixf does not follow very well the light-curve model predicted by a SN Type II-L.

The apparent colouration of SN that changes from blue-white to red over time.

(Bianciardi G. et al 2023) produced measurements of the SN 2023ixf colouration index in the paper "Multiband Photometry Evolution in the First Weeks of SN 2023ixf, a possible II-L Subtype Supernova." They indicate that the B–V of the SN, evolve from –0.20 ±0.02 to +0.85 ±0.02 in the first 50 days of the SN. So there has clearly been a reddish shift in the colour of SN over time. Again, the colour CMOS detector used seems to agree with the more rigorous and scientific observations (B–V and R–I) as made by Bianciardi G. et al (2023). ui.adsabs.harvard.edu/abs/2023TNSAN.213....1B/abstract

We express thanks to Gerald MacKenzie and Dominique (RASC Montréal Centre) and Manon Bouchard (OMSJ) for the review of the translation.

Instruments used at the Dorval observatory for the SN 2023ixf project.

Telescope Celestron 8″ EDGE-HD at *f*/10 (Focal length ≈ 2000 mm)

Camera ZWO 1600 colour camera (CMOS) coupled to an Optolong L-pro

Detector sampling; (CMOS), 12-bit ADC, BIN 2×2 pixels, for 7.6 µm pixels and 0.7828″ /pixel sampling.

Epochs	FWHM – Avg (″)
May = ~ 30	~ 2.85″
June = ~ 03 to 21	~ 3.23″
July = ~ 07 to 27	~ 2.22″
August = ~ 11 to 27	~ 2.70″
September = ~ 03 to 27	~ 3.35″
October = ~ 12	~ 2.76″

Table ixf-4

Table ixf-4 Summary;

Table ixf-4, is a series of FWHM – Avg in arcseconds (″), estimation of seeing for the SN observation period, from the end of May to the beginning of October 2023. The FWHM - Avg (″), is estimated for some periods (spot check) as indicated in the Epochs section of Table ixf-4.

Exposures

Images from 30 seconds to 300 seconds were made for our program.

Data processing

The images have been reduced with the PRiSM software version 6.00.133 (© C. Cavadore & B. Gaillard). Centroid flow readings were produced and compiled for some stars with this same software.

The graphics are mainly produced with CurveExpert 1.3 software (by Daniel Hyams), it is a free version. Then they were put together in figures with the Irfan-View software, version 4.60, Irfan Skilijan, Graduate of Vienna University of Technology.

Microsoft Excel, was also used as a calculator. ✶

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Jupiter, my Favourite, and Mystical Thoughts of the Night Sky

by David Levy, Kingston & Montréal Centre

This month I have a story to tell. A few nights ago, two close friends from Plattsburgh, Ed Guenther and Wendy Gordon, enjoyed a very pleasant wintertime visit with me. During that time another close friend, David Rossetter, drove us to the Chiricahua Astronomy Complex in southeastern Arizona. Although the weather was clear and cold when we left, dense clouds formed quickly and within a few minutes it began to rain heavily. There was thunder, lightning, and a giant tornado that lifted our car into the stratosphere and then gently set it down back on the highway. It was frightening and we thought the car was going to crash, but when it gently came back to the highway, we drove on.

By the time we arrived at our dark site, The sky was beautifully dark. The stars hung like baseballs from the sky. But it was so cold that our observing pad was covered with tons of ice. Metre-long icicles hung from our telescopes and from us. We needed and used cigarette lighters to free our frozen hands whenever they touched the eyepieces. I discovered 47 comets that night but forgot to report any of them. Ed disproved the theory of relativity by recalling how time always slows down when you are with your relatives. We finally needed to call 911 so that they could free our frozen forms and place them into makeshift crematoria. Three hours later they opened the doors of the crematoria and found all of us happy as clams to have warmed up as much as we did. We thanked them, treated them to a giant banquet meal, and then headed home. There was a 95-piece symphony orchestra on hand, but since we were approximately 95 pieces short, we just sang an aria or two. (I think that line comes from Victor Borge.)

Dear readers, if you believe a word of what I just wrote, I have a bridge that I could sell you. It is true that I have two very dear friends named Ed and Wendy. It is also true that I have two other dear friends, David and Pam Rossetter. And David did drive us, plus telescopes, to the dark site and back. And now for a few corrections: Although it was cold that evening, we did enjoy a beautiful night of observing. Our first object was Jupiter, long my favourite planet. Although Comet Shoemaker-Levy 9 would make Jupiter an obvious choice for that, that's not why Jupiter is my favourite planet. On 1960 September 1, my parents and I looked through my first telescope, Echo. I wanted to look at the brightest thing in the sky that evening. It was hanging in the south. When I finally found it, I was looking at Jupiter. I saw the disk of the planet, his four bright moons, and darker bands across the disk. I have never forgotten that night, and that is why Jupiter is my favourite planet.

Figure 1 — The Chiricahua Astronomy Complex welcome sign.

We then caught a good glimpse of Saturn's exquisite rings. As I began a two-hour visual comet search in the cold and lovely sky, the others enjoyed views of some lovely deep-sky splendours. At last, I stumbled across Messier 15, that absolutely gorgeous globular cluster I now call Wendee's cluster.

As we warmed up on our way home, we placed into our memories a sparkling night none of us will soon forget. We had a clear sky, star-filled views, beautiful deep-sky objects, and enough sky treasures to gladden our hearts and minds. Despite my continuing deep sense of loss, the exquisite night sky always warms my soul.

Mystical Thoughts about the Night Sky

In the autumn of 1976, my first "practice wife" and I visited Safed in northern Israel. In addition to being shown a 400-year-old Torah, we were introduced to the idea that Jewish mysticism, known as "Kabbalah," got its start and flourished there. A lot of that mysticism had to do with connecting Jewish (and later Christian) ideologies with the night sky.

Figure 2 — Miranda and my family of telescopes relaxing in their observatory.

Kabbalah comes from a Hebrew root word, which means to receive; the ideas were originally passed on from parent to child, from master to disciple. In this article, I explain what Kabbalah means to me. Several writers have attempted, with varying degrees of success, to compare Kabbalah with the origins of modern cosmology and with the formation of the Universe. I agree that there may be a valid argument here, but for me, Kabbalah has taken on a deeply personal connotation.

I am not a scientist. At McGill University in Montreal, I flunked twice in two successive years in my attempts to master physics. During a third try at Acadia University in maritime Canada, I very nearly failed again, this time in geology. It wasn't until I transferred out of science altogether into the world of English literature that I finally started to do well. I still have never taken a course in astronomy. Everything I know about the cosmos, about planetary science, about double stars, and about clusters of galaxies, comes from my own reading and my own observations of the night sky. I am in it because my heart and soul are forever linked to the magic and wonders of the night sky. I am much more at home with Kabbalah than I am with any scientific thoughts about the cosmos. I believe that the heart and soul of Kabbalah derives from personal experience, failure, and a sense of wonder.

In Psalm 36.10, We are told "By your light will I be enlightened." As each of us tries, in her or his own way, to comprehend our world and the Universe in which our world resides, we are struck by how complex, yet how simple, it can be.

The June2024 *Journal* deadline for submissions is 2024 April1.

See the published schedule at
rasc.ca/sites/default/files/jrascschedule2024.pdf

Figure 3 — Miranda at the Dorner Telescope Museum. The telescope was donated to the RASC and now resides in the Donner Telescope Museum.

Einstein himself said that "The most incomprehensible thing about the world is that it is at all comprehensible." It can work. We can understand. All it takes is a little patience, some intelligence, and the passion involved in looking up at a darkening sky. ✶

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* 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.*

CFHT Chronicles

Hello 2024!

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

Winter on Maunakea is always an adventure. I would never complain to our friends in Canada about the temperatures we experience—we can all agree that wind makes everything worse. Winter of 2023 was notable for its vast amounts of snow. We received so much snow in February 2023 that no observations were taken for the entire month. Much less snow (knock on wood, it's only February when I write this), but the end of 2023/beginning of 2024 has been WINDY.

CFHT evaluates wind from two aspects—observing and people. We stop observing at 50 knots (92.6 km/hr) and evacuate the summit at 56 knots (103.7 km/hr). As I type, the max wind speed over the last 10 minutes is 65 knots (120 km/hr). It is a Monday, which means our operations crew is not scheduled to work, they work Tuesday–Friday. No observing last night, and based on our current winds, I am not certain about at least the first half of tonight.

DATE	TIME	Windspeed (Km)
2024-01-12	15:03:00	100.22
2024-01-12	15:14:41	101.02
2024-01-12	11:38:39	101.1
2024-01-12	15:04:01	101.16
2024-01-12	15:13:42	103.29
2024-01-12	10:57:27	103.62
2024-01-12	15:03:10	105.17
2024-01-12	15:09:56	112.8
2024-01-12	15:09:02	118.25

Figure 1 — Our highest wind readings in January 2024. These samples were taken every 10 seconds from the CFHT weather tower. Every 10 seconds the highest value that occurred in the previous 60 seconds is recorded.

Despite the weather challenges, 2023 was a productive year of science. I do not have a count of our total publications for the year yet, but we anticipate another year with over 200 publications. Not bad for a 45-year-old telescope.

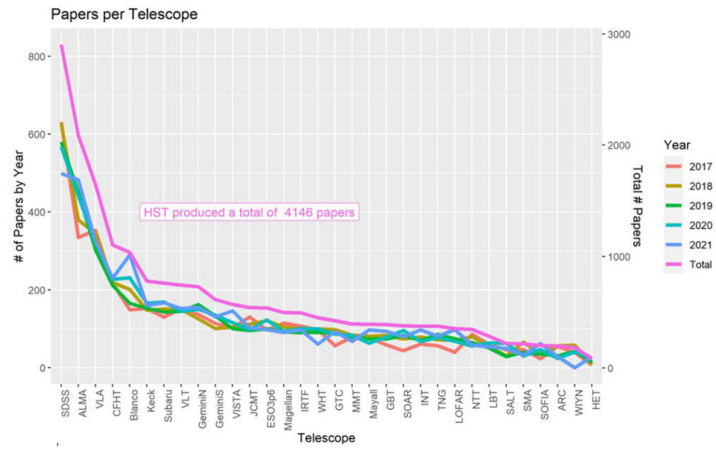

Figure 2 — Analysis and plots generated by Dennis Crabtree HAA, showing CFHT's publication rate 2017–2021 compared to other ground-based facilities. Note that the numbers for facilities with multiple telescopes (for example, the W.M. Keck Observatory) are based per telescope, not the entire facility.

Analysis and plots generated by Dennis Crabtree HAA, showing CFHT's publication rate 2017–2021 compared to other ground-based facilities. Note that the numbers for facilities with multiple telescopes (for example, the W.M. Keck Observatory) are based per telescope, not the entire facility.

And what do we do with that science….Let's take a look at our highest-profile observations of last year.

The biggest in terms of both impact and telescope time is our continuing support of the Euclid space mission via the UNIONS large program. The Euclid space mission aims to answer the big astronomy questions of our time: What is the Universe made of? What is the mysterious dark matter? How has the structure of the Universe evolved over billions of years?

The Euclid satellite's launch on July 1 was the culmination of countless hours and more than a decade of work to take the mission from concept to fully functioning, orbiting telescope. The first release of Euclid images occurred shortly after launch, in mid-July 2023. As we mentioned in our Euclid focused column last summer, members of the UNIONS team have been using telescopes in Hawai'i for years to create a complimentary data set. Anything I write on Euclid focuses on Hawai'i contributions, CFHT included, and are by no means a complete overview of the Euclid project or Canadian contributions to the project. I had the pleasure of working with a very robust Canadian communications team in June who were tasked with telling the story of Canada's Euclid contributions. The team did a phenomenal job and I'd like to take the space to acknowledge them here: Rebecca Elming from the University of Waterloo, Cara Chartrand from NRC/CNRC, Alex Walls from the University of British Columbia, Isabel Charron from the ASC/CSA, and everyone from the press and communications offices of those institutions.

For the Hawai‘i story of Euclid, I worked with teams from the University of Hawai‘i, Sarah Hendrix, Roy Gal, and Ken Chambes, along with Kumiko Usada-Sato from the Subaru Telescope. It was a team effort, and the remainder of the column pulls from a joint news release.

The Euclid mission plans to observe billions of galaxies across more than a third of the sky, building a 3-D map of the Universe. Unlike the *James Webb Space Telescope*, which observes a tiny portion of the Universe in great detail, Euclid will survey a large portion of the sky, seeing the entire image. Prior to Euclid's launch, the work of creating the map began in Hawai‘i through the UNIONS project, an ambitious imaging survey of the northern sky in the optical and near-infrared, conducted by three Hawai‘i based telescopes since 2017: the Canada-France-Hawaii Telescope (CFHT), Japan's Subaru Telescope on Maunakea, and the University of Hawai‘i Institute for Astronomy (IfA) Pan-STARRS telescope on Haleakalā, Maui.

By observing more than one-third of the observable sky outside the Milky Way, Euclid will image billions of targets out to a distance of ten billion light-years. Astronomers estimate the distances to these galaxies—and thus convert 2-dimensional images to a 3-D map of the Universe—using their observed brightness in different colour filters. The more filters are used, the better the distance estimate. Euclid has only four filters—one that spans most of what we see as visible light at 550–900 nm, and 3 that cover infrared wavelengths, 900–2000 nm, beyond what our eyes can see. The Hawai‘i telescopes will add observations in five visible-light filters, spanning the rainbow from the violet to far-red. In other words, the three Hawai‘i telescopes turn the black and white 2-D images from Euclid into a full-colour, 3-D map of the Universe. Because Euclid is mapping such a huge swath of sky, and ground-based telescopes have different capabilities, multiple observatories must contribute to provide all the data.

But how does one calibrate data from space to data taken on the ground? We can use the observations taken at CFHT as an example. The UNIONS team uses our wide-field optical imager, MegaCam, to observe in the u band (311–397 nm) and r band (566–714 nm). Our r-band observations overlap with Euclid's lone visible filter at 550–900 nm. The team uses the CFHT r-band data from each field as a reference point for the u-band data. Similarly, Subaru's "green" g-band observations bridge the gap between CFHT's u band and the start of the Euclid visible filter.

Regardless of where it's been taken, the goal of all this data is to try to unravel the mysteries of dark matter. Dark matter does not emit light like the more familiar planets, stars, and galaxies, rather its gravity is detected by observing large clusters of galaxies. In some cases, the immense gravity of a galaxy or cluster of galaxies can bend light from an object behind it, known as gravitational lensing. Ground-based observations will assist astronomers working on the Euclid gravitational lensing project.

Figure 3 — CFHT's Holiday Card (Happy New Year!) which includes images from the UNIONS program.

The Euclid mission will spend more than 6 years in space to accomplish the mission and will involve more than 2,000 scientists, including astronomers in Hawai‘i. The University of Hawai‘i team is especially interested in using this data to measure the parameters that characterize the properties of the Universe.

Euclid will build up a large archive of unique data, unprecedented by volume for a space-based mission, enabling research over all disciplines in astronomy. The data will be archived at the Canadian Astronomy Data Center (CADC) and accessible to astronomers around the world. The CADC will also provide colour information based on the observations from the Hawai‘i based telescopes.

"The Euclid images will be beautiful to look at, above and beyond the considerable scientific value of the data. I'm looking forward to seeing them," said Stephen Gwyn, Science Data Specialist at the Canadian Astronomy Data Centre. "Ultimately, data from the Hawai‘i telescopes—CFHT, Subaru, and Pan-STARRS—will turn the images into a 3-dimensional map of our Universe."

Welcome Viraja Khatu!

We welcomed our new resident Canadian astronomer in mid-January—Dr. Viraja Khatu. Viraja moved to CFHT from Western University where she completed a post doc with Dr. Sarah Gallagher. She studies active galactic nuclei (AGN), specifically the geometry, kinematics, and structure of the gas surrounding a supermassive black hole. When choosing her field of study, she knew she was interested in extragalactic topics. As one of the most powerful class of objects in the Universe, the decision to study AGNs felt obvious.

Viraja decided to apply to the CFHT resident astronomer position because it was a great opportunity to apply her existing skills, while learning about instrumentation. Viraja looks forward to contributing her skills in computer program-

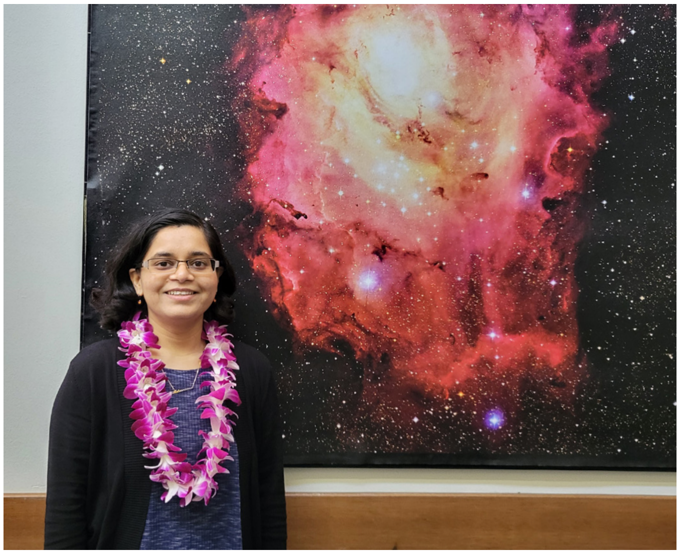

Figure 4 — Dr. Viraja Khatu, new CFHT Canadian resident astronomer.

ming, software development, and research to the CFHT community. She will first work with our wide-field optical imager, Megacam. Viraja has a passion for outreach. She's already joined our director of science operations, Nadine Manset, for some classroom visits.

In her spare time, Viraja loves art. It resonates with her love of exploration and is an incredible way to express herself. In the month she has lived in Hawai'i, the weather and Waimea's more relaxed vibe are her favourite things. ✶

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

John Percy's Universe

Mira, the Wonderful

by John R. Percy, FRASC
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Mira, the Wonderful (Star). Or more prosaically: the variable star omicron Ceti, or o Cet. But Mira also reminds me of my wife Maire (pronounced My'-rah, just like the star). She is a wonderful "star" scientist, teacher, mentor, author, and many other things.

History. There is some suggestion that the remarkable variability of Mira was known in antiquity, in China, Babylon, Greece, and/or perhaps elsewhere. That may be so. Our knowledge, understanding, and appreciation of non-Western science, past and present, often leaves much to be desired.

Credit for the discovery of Mira usually goes to David Fabricius who, in 1596, was using it as a comparison star to determine the position of Mercury (or Jupiter). This discovery, together with that of Tycho's supernova (1572) and Kepler's supernova (1604) was strong evidence against the Aristotelian belief that stars were perfect and unchanging. It was part of the Copernican Revolution. In 1603, Johann Bayer gave the star the name omicron Ceti. Johann Holwarda discovered its periodicity and its period—11 months. Johannes Hevelius (1611–1687) gave it the special name Mira, the Wonderful.

The Light Curve. Observations of Mira's brightness variability continued. The scientific value of the observations improved as the standardization of the comparison stars' magnitudes improved. Spurred on by appeals such as a famous one by Friedrich Argelander (1799–1875), skilled amateur astronomers began making observations of variable stars. In 1911, the American Association of Variable Star Observers (AAVSO: aavso.org) was established to encourage and facilitate such work. You can find the full 400+ years of observations of Mira's brightness variations in the AAVSO International Database (aavso.org/LCGv2). You can check out the light curve—magnitude versus time—and notice that the magnitude at maximum varies randomly from about 2.0 to 4.9 (Figure 1). The magnitude at minimum is relatively constant at about 9.5. You can also analyze these observations with VSTAR (aavso.org/vstar), the AAVSO's time-series analysis package. You will find that, although the average period of Mira is about 333 days, the period actually "wanders" between about 337 and 329 days. Right now, it is 326 days and wandering downward. Is something unusual happening?

Photometry—Alphabet Soup. A century ago, visual and photographic photometry were augmented with more accurate photoelectric photometry. Photometry really came of age with Harold Johnson and William Morgan's introduction of the now-standard UBV system, with standard filters for near-ultraviolet (U), blue (B), and visual (V) light. Most of Mira's radiation is at longer wavelengths than V, so the later introduction of R (red) and I (near-infrared) filters was helpful. With the development of infrared astronomy in the 1960s, the system was extended to J (1.1–1.4 μm), H (1.5–1.8 μm), and K (2.0–2.4 μm), which is where most of Mira's radiation is.

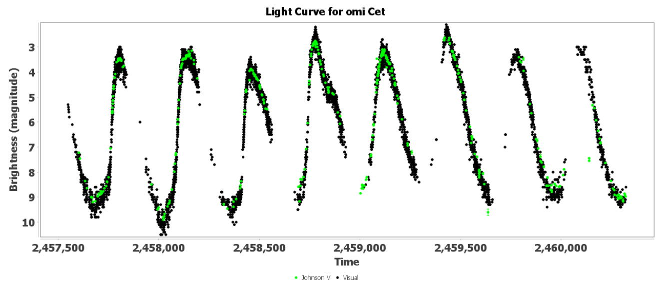

Figure 1 — The recent AAVSO light curve of Mira—apparent magnitude versus time (JD)—covering about 3000 days. The black points are visual, the green points are photoelectric V. Source: AAVSO.

In my most recent papers on pulsating red giants (Percy and Shenoy 2023, Percy and Zhitkova 2023), we use the absolute K magnitude M_K as a measure of Mira stars' luminosity. At these infrared wavelengths, Mira's amplitude of variation is only about a magnitude. The much larger amplitude in V is due to the high sensitivity of the V flux to temperature variations.

Spectrum—Bizarre. Spectroscopy of bright stars began in the mid-19th century, and blossomed a few decades later with the work of the famous Harvard College Observatory women astronomers (Sobel 2016)—including Antonia Maury and Annie Cannon, who developed the now-standard Harvard spectral classification system (OBAFGKM) and classified hundreds of thousands of stars, and the brilliant Cecilia Payne, who applied physics to the atmospheres of stars to explain and understand their spectra

The spectra of Mira stars are complex, and defy easy understanding, as a result of their extended, pulsating, convecting atmosphere. My late colleague Bob Garrison—RASC President 2000–2002 and Honorary President 2005–2009—was a world authority on the spectra of Mira stars. At a symposium marking the 400th anniversary of the discovery of Mira, he gave a lecture entitled "The Personalities of Mira Stars as Revealed by their Spectra: Verdict—Bizarre!" (Garrison 1997).

Evolution. At the same time, astronomers were developing an understanding of stellar evolution. Stars like the Sun spend most of their lives unchanged. Then as they run out of thermonuclear fuel, their cores shrink and heat up as they try to squeeze out a bit more energy. In response, their outer layers expand. They become red giants. As red giants, they also undergo "thermal pulses" every few hundred thousand years. In the end, their cores are transformed into dense, hot white dwarfs.

Mira B. A century ago, Alfred Joy suspected, from peculiarities in Mira's spectrum at minimum, that it might have a close companion. Robert Aitken soon found the companion by direct observation, barely 1″ from Mira itself. It was hot, faint, slightly variable, and now known to be a white dwarf, surrounded by a disk of gas accreted from Mira's wind. It helps to explain why Mira's magnitude at minimum tends to be about 9.5—which is the average magnitude of the companion. It also reminds us of the tremendous range of star sizes and luminosities, from red giants to white dwarfs.

A Mighty Wind. It's apparent from the spectra of Mira stars, and observations of their surroundings, that they are losing mass through a stellar wind. Also, some stars more massive than the Sun are known to become white dwarfs with masses of only half a solar mass. They must have lost mass somehow. But is the mass loss connected with pulsation? And what causes the pulsation in the first place?

It was known, over a century ago, that some stars pulsate, notably the Cepheids, named after delta Cephei. Understanding of the cause of the pulsation started to develop in the 1950s, through the work of Sergei Zhevakin in the USSR and John Cox in the US, among others. Real progress came in the 1960s, with hydrodynamic modelling of pulsation by Robert Christy and others.

Computer Simulations. It is possible, for a computer-constructed "model" star of a given mass, luminosity, and composition, to determine whether and how it will pulsate by using the laws of physics. It is necessary, however, to also know such atomic data as nuclear reaction rates, and the opacity of very hot gases—and to have a very powerful (for the time) computer. Fortunately, these had already been developed as a by-product of Cold War thermonuclear weapons research, notably at Los Alamos National Laboratory in New Mexico. Christy, incidentally, was one of the key figures in the Manhattan Project. In a landmark paper (Christy 1966), he studied the pulsational stability and behaviour of dozens of models of short-period RR Lyrae pulsating stars of various mass, luminosity, and composition, which could then be used to determine these quantities in observed stars.

Unfortunately pulsating red giants are much more complicated than RR Lyrae stars. Energy is transported through their outer layers, not so much by radiation but by giant cells of convection—a very poorly understood process. But in the 1980s, George Bowen (1988), a biophysicist attracted into astronomy by his colleague (and my friend) Lee Anne Willson, constructed hydrodynamical models of red giants. They indeed pulsated, and the pulsation drove mass loss through winds. The more luminous the star, the stronger the pulsation, and the stronger the wind. The model stars lost up to half their mass through pulsation and winds, in only a million years—a tiny fraction of their lifetime.

Ploughing through the Interstellar Gas. Progress and wonder continue. Figure 2 shows a remarkable image obtained in 2006 by NASA's GALEX (Galaxy Evolution Explorer) space telescope. It shows Mira, with its massive wind,

Figure 2 — GALEX image of Mira, ploughing through the interstellar gas at 130 km/sec, producing a bow shock in front (right) and a tail behind (left). Source: GALEX/NASA

ploughing through the interstellar gas at 130 km/sec—faster than a speeding bullet. In front of it is a bow shock, as its wind impacts the gas. Behind it is a tail, 13 light-years long. It dramatically shows the interactions between stars and the gas and dust around them.

In Summary: Mira is the prototype large-amplitude pulsating red giant, a star like the Sun in an advanced stage of evolution. Through its pulsation-driven wind, it is losing up to half its mass as it transitions to a white dwarf. Its surface is dominated by huge convection cells, which can be seen in some recent high-definition images. It is complex, ever-changing, and still not completely understood, even after four centuries of study. It is indeed wonderful! And you can help, by observing it, and contributing your observations to the AAVSO database! There's a simple finder chart on page 296 of the 2024 Observer's Handbook, and more detailed ones on the AAVSO website (aavso.org). See also the article about the Mira star R Leo by Richard Roberts on page 300 of the 2024 Handbook.

For More Information. AAVSO staffer Kerri Malatesta's (2006) AAVSO-centric review, and journalist Joe Rao's (2022) update are recommended. There's an excellent open-access semi-technical review by Lee Anne Willson and Massimo Marengo (2012). Or you could get my book (Percy 2007)! ✶

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Dish on the Cosmos

The Radio Telescopes at the Heart of Deep-Space Astronomy

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

While this space usually focuses on radio telescopes observing the distant Universe, this column focuses on a humble network of radio telescopes at the heart of so much astronomy and planetary exploration: NASA's Deep Space Network. In addition to providing a unique view of the skies, radio telescopes and transmissions are the essential communication link to all our satellites and planetary missions. While the Earth is dotted with the small antennae needed to detect the signals from low-Earth orbit, the satellites beyond these nearby orbits require a concerted communication effort provided by NASA. As we put progressively more satellites into deep space, the network is becoming packed with traffic and starting to show its age. It is quickly emerging as a weak link in the chain of modern astronomy.

The telescopes used for detecting natural radio light and the telescopes used for communication are fundamentally the same technology. The ubiquitous satellite dishes that communicate with satellites in low-Earth orbit are just the mirrors of radio telescopes. All light, be it the visible light that we see or the long wavelength radio emission, will reflect off conductive materials like metal. The rule of thumb in optics is that the mirror you are using is high quality if it is a smooth electric conductor with holes and irregularities that are smaller than 5% of the wavelength. For visible light, this means smooth surfaces at the scale of hundreds of atoms, but radio waves are much more forgiving: with waves ranging from centimetre to metre scales, a simple wire mesh is usually sufficient to be a mirror. The dishes that we see are just a smooth parabolic wire mesh or plate, often painted to protect from corrosion. These dishes focus the radio waves up into a receiver system, usually at the focus of the primary mirror, though some systems have a secondary mirror at that position and focus radio waves back into the support structure in a Cassegrain or Nasmyth optical system.

At the focus of the telescope, there is a radio receiver that measures the radio wave received. In the case of natural radio emission, the signal we receive is either static noise or the narrow wavelength ranges corresponding to the spectral signature of atoms and molecules. For human-made signals, they are also narrow-band—a wave at a single wavelength that the radio telescope can detect. For example, the radio transmissions in cellular telephones have strong signals with fixed wavelengths near 37.5 cm. By broadcasting with a single wavelength, the radio receivers can detect multiple signals. For example, they are able to distinguish a wave at 37.500 cm from a separate signal with 37.501 cm. These radio waves are called the "carrier wave" of the radio signal and the actual information is encoded in the wave through a form of modulation. The wave is slightly changed by the broadcaster, and the receiver can detect those changes and then decodes how the wave changes into the real signals.

Radio telescopes are reversible: the optics of the telescope focus the waves when they are received but the telescope also focuses radio waves on transmission. The dish focuses radio transmissions into a certain direction in a "tight beam," where the power spreads out slowly. Bigger radio-telescope dishes can focus the transmission into a tighter broadcast beam, and they are also able to collect fainter signals. Hence, communicating with distant satellites requires larger radio telescopes and sensitive radio receivers.

To support satellite and planetary missions away from the cradle of low-Earth orbit, NASA operates the Deep Space Network (DSN). The system is a set of radio telescopes at three main sites around the globe: the Goldstone site near Barstow, California, a site near Madrid in Spain, and one near Canberra, Australia (Figure 1). There are also several smaller facilities that connect to the network to improve access and network capacity. There are many antennae at every primary site, most of which are 34-metre-diameter radio dishes, with one large 70-metre telescope for the faintest signals. Between these three sites, the network can view any location near the ecliptic of the Solar System at any time. Some parts of the sky cannot be accessed all the time, but most of our deep-space missions are being sent out to destinations near the plane of orbits in the Solar System, so the restriction to the ecliptic is usually not a complication. However, it is essential to maintain complete coverage in all directions as the Earth rotates. The most obvious need for continuous coverage is in the case of deep-space crewed missions like the past and upcoming missions to the Moon. However, communicating with robotic missions during vital phases like landings is also a priority.

One of the most amazing things about the DSN and radio astronomy in general is the capacity for the systems to detect incredibly faint signals. The DSN still routinely receives signals from the *Voyager* missions, launched in the 1970s and currently transitioning into true interstellar space. These missions are still powered by low-energy nuclear sources and they transmit signals with a power of a few watts, less power than an LED lightbulb. The radio signals are still detected and the Voyager missions are tracked using the DSN.

Lately, one of the most reliable users of the DSN has been the *James Webb Space Telescope* (JWST), and much of how that

Figure 1 — Aerial view of the DSN complex near Canberra, Australia, with a 70-m antenna at the centre of frame and 34-m antennae in the background.

See what the DSN is doing now: eyes.nasa.gov/dsn/dsn.html

telescope mission operates is dictated by the peculiarities of the DSN. The DSN is a shared resource, and the telescope only connects with the network a few times per day. In between contacts, the JWST follows a set of instructions and a strict set of internal rules. The most important rule is "never ever point toward the Sun." This rule is so important that if the systems on JWST do not know exactly where the telescope is pointing, JWST will enter its safe mode, stop collecting data, and focus all efforts on enforcing the "no Sun" rule. If all is well, JWST works through a queue of observing instructions, capturing data on a large set of internal data recorders. These recorders have a finite capacity and fill up with observations. In the few daily "contacts" with the DSN, JWST receives a new set of instructions from the control centre and then spends most of its time transmitting down the data that were collected since the previous contact, allowing the data to be deleted from the onboard recorders, making room for a new set of observations. In between contacts, JWST operates autonomously with no connection to ground control. After a contact is complete, the control room empties out and the operators go home: there is nothing they can do if the telescope encounters a problem. They will have to hope that the engineering team programmed in enough contingencies for the telescope to make its way safely to the next contact.

The contacts with DSN are not guaranteed. Sometimes JWST will miss a contact due to internal issues or it will be pre-empted by other users of the network. Early in the JWST mission, NASA also launched the first Artemis mission to the Moon, which severely limited the number of contacts JWST could have with the ground. These peculiarities place an unusual constraint on how the telescope operates so that the most vital resource on JWST becomes data rate. In times where limited access to DSN is available, the telescope must observe programs that do not collect a lot of data, using the instruments on the telescope that only need to fill the data recorders slowly. JWST is a deeply capable telescope with several different cameras in its focal plane. If the telescope were not so constrained by data, several of its cameras could be turned on at once, literally doubling or tripling the information we get from a JWST observation.

The pressure on the DSN is growing. With progressively more missions to deep space, including the NASA initiatives to return to the Moon, the need for expanded access in the DSN is becoming acute. The DSN is also subject to simpler pressures like weather: radio telescopes are so big that they cannot be built in enclosures. Storms can damage a telescope and the DSN suffered a recent setback when one of the secondary sites in Guam lost several antennae in a typhoon. There are some planned upgrades and repairs, but the needs for contacts and connection will continue to grow. The next Great Observatory being planned is the Habitable Worlds Observatory, a massive optical telescope that follows JWST's basic pattern: a remote deployment in deep space. With next-generation instruments collecting larger amounts of data, the HWO will just be one mission among many pressing on the DSN. Compared to the missions themselves, the budget for the DSN is tiny and remains under pressure. But the radio telescopes and transmitters in the DSN serve as the vital connection to our observatories and missions across the Solar System. ✶

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

Astronomical Art & Artifact

More on Eclipse Viewers

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Abstract

More evidence for the history of simple eclipse viewers is presented here to supplement the account in Rosenfeld (2024). This includes an example specifically for the Canadian market from the short period when the modern commercial eclipse viewer was introduced and rose to dominance (1925–1932). Also discussed is Canadian evidence for the production of pre-modern eclipse viewers by an optician in the 19th century, which may have a connection to earlier practice.

A "Canadian" Viewer for the Solar Eclipse of 1932

The previous number of the *Journal* presented a first attempt at sketching the history of the solar-eclipse viewer, and earlier technologies for viewing solar eclipses with the simplest means, from antiquity to the present (Rosenfeld 2024).

One surprising and not fully accounted for finding of that research is that the modern form of the eclipse viewer arose over a scant seven years during three solar eclipses, those of 1925 January 24 (North America), 1927 June 29 (England), and 1932 August 31 (North America). The modern form of the eclipse viewer has three characteristics: 1) commercial production from industrially produced materials deemed safe at the time; 2) commercial distribution, either through sales, or as a promotional item; and 3), successful adoption by a growing segment of the population that has abandoned DIY production of eclipse viewers from household materials. Historical texts documenting the technologies of eclipse viewers, and accessible collections of historical eclipse viewers, such as the Collection of Eclipse Viewers assembled by Luke Cole at Williams College, and the historical eclipse viewers in the collections of the Specvla astronomica minima (Toronto) provide the material basis for this conclusion.

One eclipse viewer manufactured for the 1932 August 31 eclipse mentioned above, examples of which can be found in both collections, is notable for having been prepared specifically for the Canadian market. The "Sun Eclipse Viz-o-Scope" was a promotional item for Winchester Cigarettes (manufactured in Canada by Imperial Tobacco) (Figures 1–2). Distributing these devices via promotional marketing was part of the story of the modern eclipse viewer from its inception; Thorp & Martin Company (Boston) used this strategy in 1925, as did both *The Boy's Magazine*, and the *Journal & North Star* (Newcastle) in 1927 (Rosenfeld 2024).

Figure 1 — Front of the Viz-O-Scope marketed for the 1932 August 31 eclipse in Canada, as a promotional item by Imperial Tobacco's Winchester Cigarettes. Reproduced courtesy of the Specula astronomica minima.

Figure 2 — Back of the Viz-O-Scope. Reproduced courtesy of the Specula astronomica minima.

The "Sun Eclipse Viz-o-Scope" belonged to that class of solar-eclipse viewer that offered general instruction on eclipses, and information on the particular eclipse for which it was manufactured, often including a map, printed on the viewer itself, or on its protective envelope, or both (other examples are the Lockwood sol-a-clipse of 1925 and 1927, and the Harvey & Lewis Opticians' eclipse-o-scope of 1932). The Viz-o-Scope presented more, and more varied information to help and instruct its users than any other in its class for the 1932 eclipse (its designer, or designers, made the most of its unequal triptych format).

Panel 1 (Figure 3) gives information on the sublimity and rarity of the event, its path, and its duration. The expectations of the eclipse goer are raised by the promise of witnessing "the rare and majestic spectacle…a phenomenon of striking and unforgettable character," yet none of the potentially striking phenomena of the eclipse are specified: environmental effects, Baily's Beads, the Diamond-Ring, and the sudden visibility of the chromosphere and corona (perhaps space was an issue). Panel 2 gives a brief account of how eclipses happen, data on the physical characteristics of the Sun and Moon, and a health warning and encomium of the virtues of the Viz-o-Scope:

Don't take the chance of injuring your eyes while viewing the eclipse, or miss the wonders of the great event by being unable to see it clearly. This Viz-O-Scope is just right for complete and comfortable enjoyment of the eclipse. Until it is total look at it only through a Viz-O-Scope, as even the last visible crescent of the sun's surface may permanently injure an unprotected eye.

The promotional nature of the eclipse viewer is graphically prominent on three of the four panels, and both on sides of the integral eclipse viewer itself:

This folder with attached Viz-O-Scope was specifically prepared for the occasion of this great phenomenon and is issued for your convenience by the manufacturers of Winchester Cigarettes *Blended Right!*

Stretching across panels 3 and 4 is a map of the path of the eclipse in Canada, from Victoria to Halifax, with estimates of times of duration for those outside the path of totality running through Québec.

As is the case for nearly all these early commercial viewers, the filtering material is exposed silver nitrate film, and the mounting for the filters is cardboard, which offered the advantage of bearing text and graphics. The exposed film was thought to provide sufficient protection at the time (but not now).

How accurate for the time is the astronomical information offered by the Viz-O-Scope? Compared to the figures in an authoritative contemporary text meant for undergraduate instruction, Henry Norris Russell and colleagues' Astronomy: A Revision of Young's Manual of Astronomy (1926), the figures are acceptable approximations. According to the device, the Sun-Earth distance is 9.3×10^{7} miles (cf. 9.287×10^{7} miles in Russell et al. 1926, 188), the diameter of the Sun is equal to 110 Earth diameters (cf. 109.1 in Russell et al. 1926, 188), the mass of the Sun is 3.26×10^{5} Earth masses (cf. 3.33195×10^{5} in Russell et al. 1926, 190), and the Sun's volume is 1.3×10^{6} that of the Earth (the identical figure is given in Russell et al. 1926, p. 189). The Earth-Moon distance is 2.39×10^{5} miles (cf. 2.38857×10^{5} in Russell et al. 1926, 165), the diameter of the Moon is 2.5×10^{-1} Earth diameters (cf. 2.73×10^{-1} in Russell et al., 166), and its mass is 1.25×10^{-2} Earth masses (cf. 1.2267×10^{-2} in Russell et al. 1926, 167). The greatest divergence is in the figure for the Moon's diameter, but it may have been thought justifiable because "1/4" of the Earth's diameter would be easier for the average person to comprehend than a less round number.

Unlike the Thorp & Martin Company eclipse viewer of 1925 that invoked the authority of the Harvard College Observatory for the reliability of its data and account of the phenomenon, no scientific body is cited in the texts carried by the Viz-O-Scope. None of the eclipse viewers in this class (i.e.

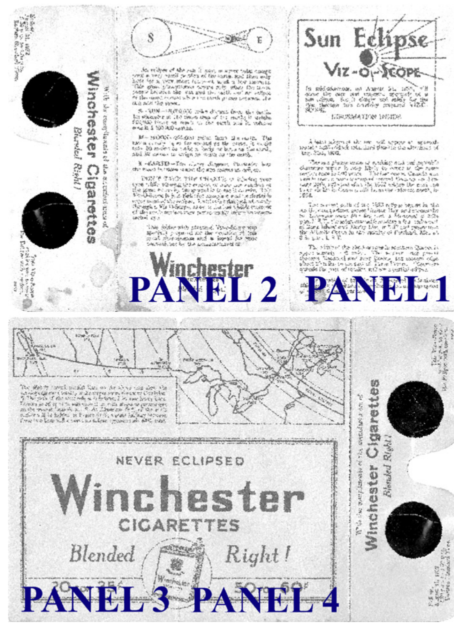

Figure 3 — Diagram showing the designation of the panels of the Viz-O-Scope. Reproduced courtesy of the Specula astronomica minima.

text-rich) provide the names of the authors of their texts. Perhaps Imperial Tobacco turned to a Canadian astronomer such as C.A. Chant for theirs (if so, he is silent about it in his autobiography).

One could say that the Imperial Tobacco brand Winchester Cigarettes provided an eclipse viewer for those who didn't want to smoke their own class to make a viewer!

Prepared Glasses

It not infrequently happens that when trying to gather data on the history of astronomy, particularly as it relates to little-studied technologies, or astronomical practices, modern terms can take one back only part of the way, or can reveal only part of the story, as the names for things alter with time (e.g. Rosenfeld & Muir 2017). So it is with eclipse viewers.

After reading the author's earlier contribution, Peter Broughton forwarded notice of an important document for the Canadian history of eclipse viewers, thereby earning his gratitude. The document is an advertisement placed in the Montreal Star for 1869 August 5, by the optician Charles Hearn, advertising "prepared glasses for observing the great eclipse" of 1869 August 7 (Figure 4; for Hearn, see Brooks & Daniels 1993, 1041–1042). The important element here is the term "prepared glasses."

Unfortunately, Hearn doesn't illustrate his "prepared glasses," and thus far no image of the device, or actual surviving example has come to light. Could the "prepared glasses" have been a pair of spectacles fit with dark-tinted glass lenses?

There is the further possibility that Hearn's "prepared glasses" of 1869, provided that they refer to the same class of object, could be something similar to Benjamin Martin's "…dark Glasses…for viewing the Eclipse to the best Advantage" advertised for the solar eclipse of 1764 April 1 (Rosenfeld 2024), suggesting a continuity of practice in the optical community of providing professionally made simple eclipse viewers, over at least a century. It is a tempting suggestion. Before this can become more than a suggestion, however, better evidence will have to be uncovered. (It is important to note, however, that even if a tradition of professional production can be established, the evidence points to homemade eclipse viewers still predominating in the period 1760–1860).

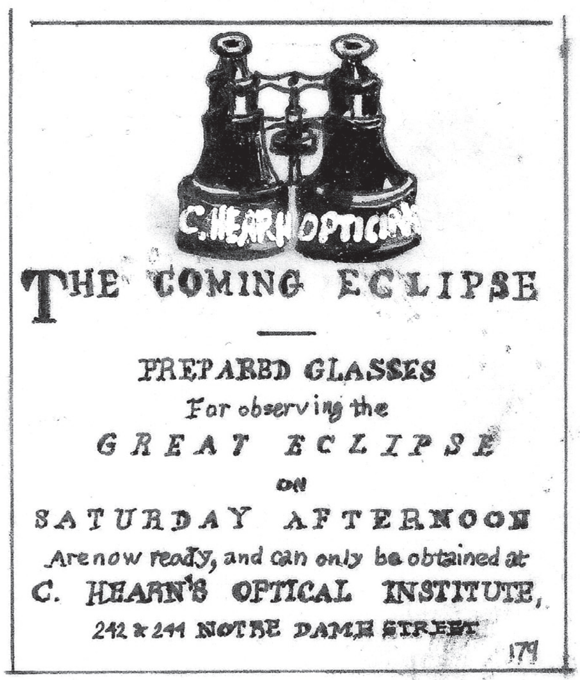

Figure 4 — Facsimile of Charles Hearn's advertisement for "prepared glasses" for the solar eclipse of 1869 August 7, as it appeared in The Montreal Star *on August 5. Reproduced courtesy of the Specula astronomica minima.*

One problem is the multivocality of some terms for instruments—a term may refer to several quite different things. For instance, "prepared spectacles" also referred to glasses with one blue, and one red lens for viewing anaglyphs (Anon. 1901). Only context can serve to clarify which meaning is the right one. And even then, all may not be clear. In the following passage "prepared glasses" could refer to glass filters tied to opera glasses; but they may also be spectacles with dark lenses tied to opera glasses:

> Leaving aside all scientific instruments and arrangements out of consideration, it was interesting to see the amateur preparations for viewing the eclipse...On one of these [hills] a large telescope was mounted; some had provided themselves with thermometers, to gauge the fall of the mercury, others with small telescopes. Two table cloths were spread out near us for the clearer viewing of the shadow-bands; a pail or water for the reflection of the eclipse; a camera set at fifty degrees; prepared glasses tied on opera glasses; and smoked glass without number (Abbott 1898, 217–218)

A mild satiric piece provides evidence for both the lowest grade of commercial eclipse viewers, and for the dominance of DIY devices:

> The shops, everywhere, exhibited "eclipse glasses, price sixpence," formed of a fragment of coloured crystal framed in a wooden eyepiece; but the shops found their trade undermined by the street hawkers, who supplied pedestrians with the same article for twopence...On the sunny side of every street, windows and doors were thrown open, and the observers, armed with telescopes, opera-glasses, spectacles, lenses, and smoked fragments of window-panes, took up their stations in eager yet solemn expectation of the event…there was plenty of broken glass of convenient sizes for smoking; this we had smoked according to the most approved process, and had in readiness in the back garden… (Anon. 1858, 277–278).

It is not at all inconceivable that the nature of Georgian "dark glasses" and Victorian "prepared glasses" marketed for viewing solar eclipses will finally receive proper illumination from the holdings of some museum or archive. ✶

Acknowledgements

The author is extremely grateful to R. Peter Broughton for bringing the important evidence of C. Hearn's advertisement to his attention. This research has made use of NASA's Astrophysics Data System. Any errors remaining in this supplement and the fuller history of simple viewers for solar eclipses in the previous number of the Journal are attributable to the author alone.

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Imager's Corner

Dragon's Ring

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

We will be taking a break from image-processing techniques in this edition to announce a possible discovery image. I'd like to take a moment to introduce you to the Dragon's Ring. The ring is the very faint, blue elliptical shape in the upper-left quadrant of the image in Figure 1 — The Dragon's Ring is faintly visible in the upper-left quadrant of the image..

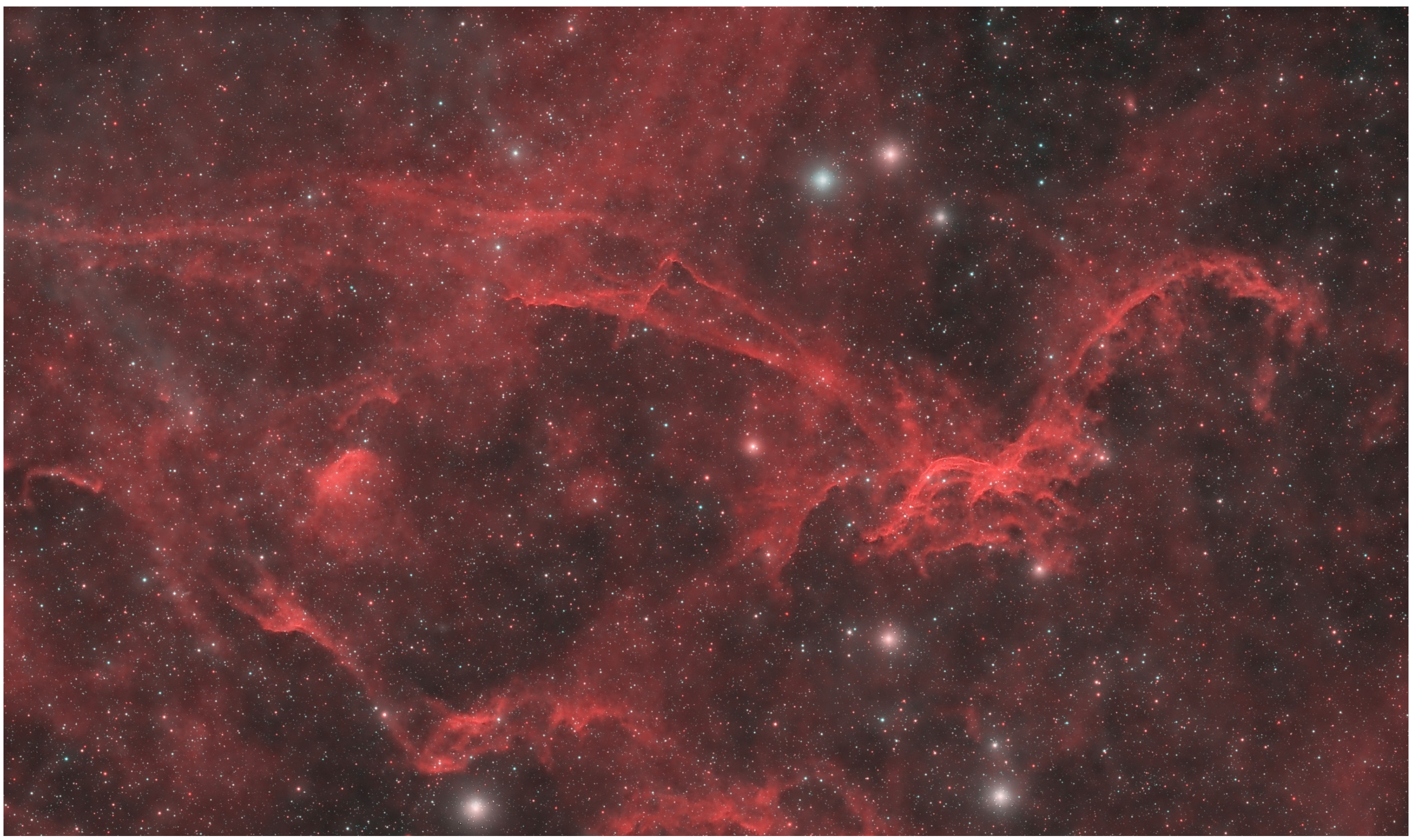

Figure 1 — The Dragon's Ring is faintly visible in the upper-left quadrant of the image.

This is why you should **never, never** throw away data! On 2023 August 22, I was photographing SH2114, the Flying Dragon Nebula from the Bortle 4 skies of our cottage. My initial attempts at processing the data produced the usual view of the deep-red Hα field along with enough background mottling that it limited the ability to really stretch the image. In early November I took another look at the data and redid the processing using some newer tools available in PixInsight. After separating the stars from the rest of the image, I decided I would apply multiple small stretches with some noise reduction in between, rather than a single big stretch to push the image brightness to its final value in one step. Upon examination of the image after the first stretch I noticed a very faint bluish ring to the left of SH2-114 and above (in the image) SH2-113. During the rest of the processing, I concentrated on preserving the ring, no easy task as it became overwhelmed very quickly by the red Hα emission so prominent in the area.

The data were collected under Bortle 3 to 4 skies at my cottage using a Sky-Watcher Esprit 120 APO refractor fitted with an Optolong LeNhance dual-band filter. The camera used was a one-shot colour (OSC) ZWO ASI2600MC Pro. The filter pass bands are shown in Figure 2.

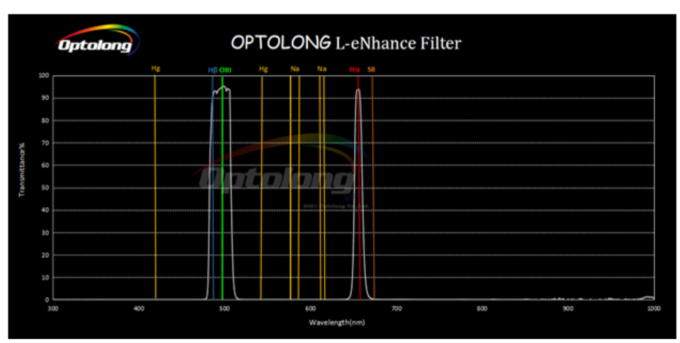

Figure 2 — The spectral response of the Optolong L-eNhance dual-band filter. The passband at Hα wavelengths is approximately 14-ηm wide, while it is 30-ηm wide at Hβ and OIII wavelengths.

Since I had not seen this ring in other images, I started looking for it in every catalogue I could find with no luck. It seemed I had a potential discovery image of an object I have begun calling the Dragon's Ring for its proximity to the Flying Dragon Nebula. After all, what self respecting dragon can't blow smoke rings?

There are several catalogued deep-sky objects in the field, including a small planetary nebula PK083-08.1 embedded within the ring. The presence of this planetary raised the possibility that the ring was the remnant of an earlier, unknown outburst or an outer shell of material possibly expanding around the planetary. The annotated image, Figure 3, shows the position of the planetary as well as several other deep sky objects in the field.

If the bubble was an earlier outburst, it would likely have a filamentary structure and very narrow band emissions similar to the outer shell around M57 shown in Figure 4.

At this point I contacted Dr. David Turner, a retired professor of astronomy from St. Mary's University and fellow RASC member, who has been immensely helpful in establishing the likely type of object the ring represents. Dr. Turner put me in touch with Brian Skiff at the Lowell Observatory. Brian quickly took the time to search for references to the ring but was unable to find any sign of it in either catalogue or image databases. Brian then put me in contact with Dana Patchick who has several planetary-nebula finds to his credit. Dana suggested acquiring narrower band OIII data in an attempt to determine if the ring is a planetary-nebula shell emitting at OIII wavelengths. Assuming the ring was emitting light at OIII frequencies, then the ring should become more distinct as the bandwidth of the OIII filter is reduced. Data were acquired by several RASC members from across the country, Jason Dain of the Halifax Centre captured several hours of 7-ηm OIII and Hα data, and Roman Kulesza in Ontario captured just over an hour of 3-ηm data graciously using some of his time on a remote telescope to acquire the data.

Figure 4 — M57 showing the outer shells of material surrounding the main nebula.

Jason's data, shown in Figure 5, once processed, clearly shows the ring structure. His monochrome camera and 7-ηm filter do not suffer from the channel crosstalk inherent in my OSC camera and dual-band filter system. With little Hα emission leaking through the OIII filter, the ring stands out nicely against the starry background.

The situation becomes somewhat different when looking at the Hα data, also taken by Jason through a 7-ηm filter. At these wavelengths, the ring is not visible as you can see from the images in Figure 6. This compares the signal at Hα and OIII wavelengths after the stars have been removed (for the most part). The ring is easily visible in the OIII filter, while it is almost non-existent in the Hα frame. Both of these images have had the same stretch applied.

The 3-ηm data collected by Roman Kulesza, Figure 7, however, shows that when viewed at narrower OIII bandwidths, the ring becomes much less visible. While still there, the ring is much less prominent than in either the 7-ηm or the original L-eNhance data. In fact it is almost as faint as in the 7-ηm Hα image.

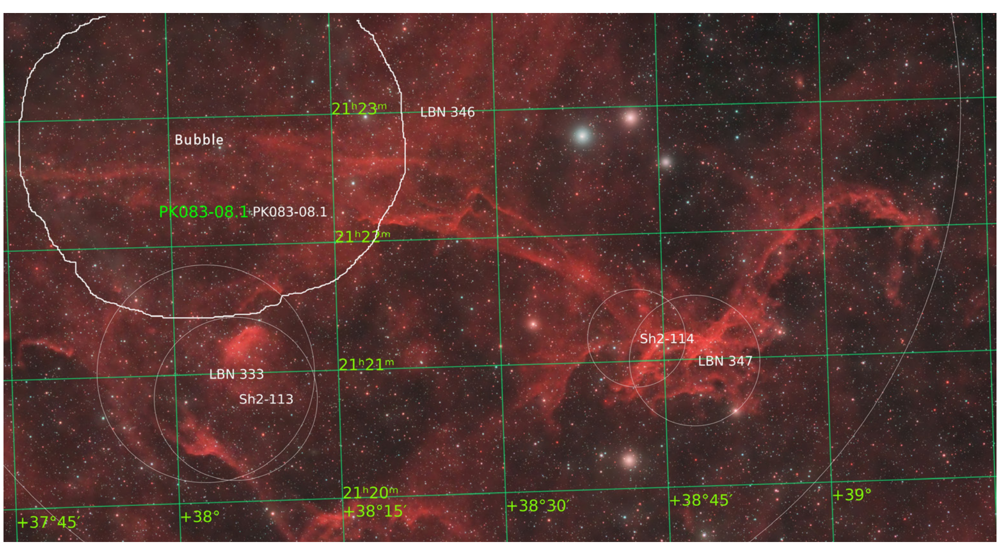

Figure 3 — Annotated version of the image showing the positions of several deep-sky objects. The location of the Dragon's Ring is shown within the hand-drawn white oval labelled Bubble.

Since the ring is more visible in the wider band data, and since it

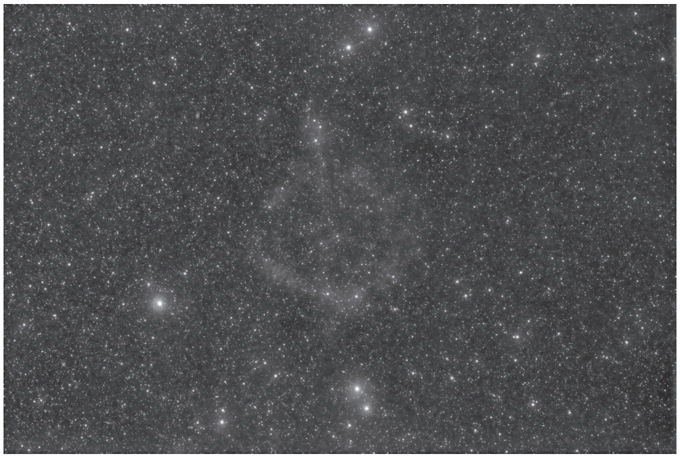

Figure 5 — Jason Dain's 7-ηm data clearly showing the ring structure.

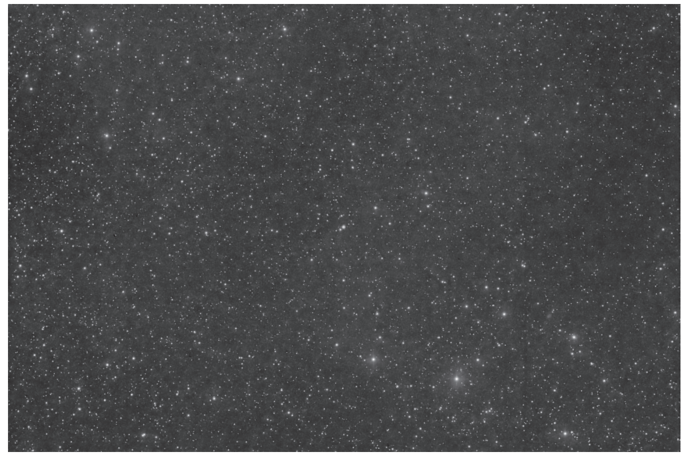

Figure 7 — The ring is just visible in this 3-ηm data. It is mostly below centre in the lower-right quadrant.

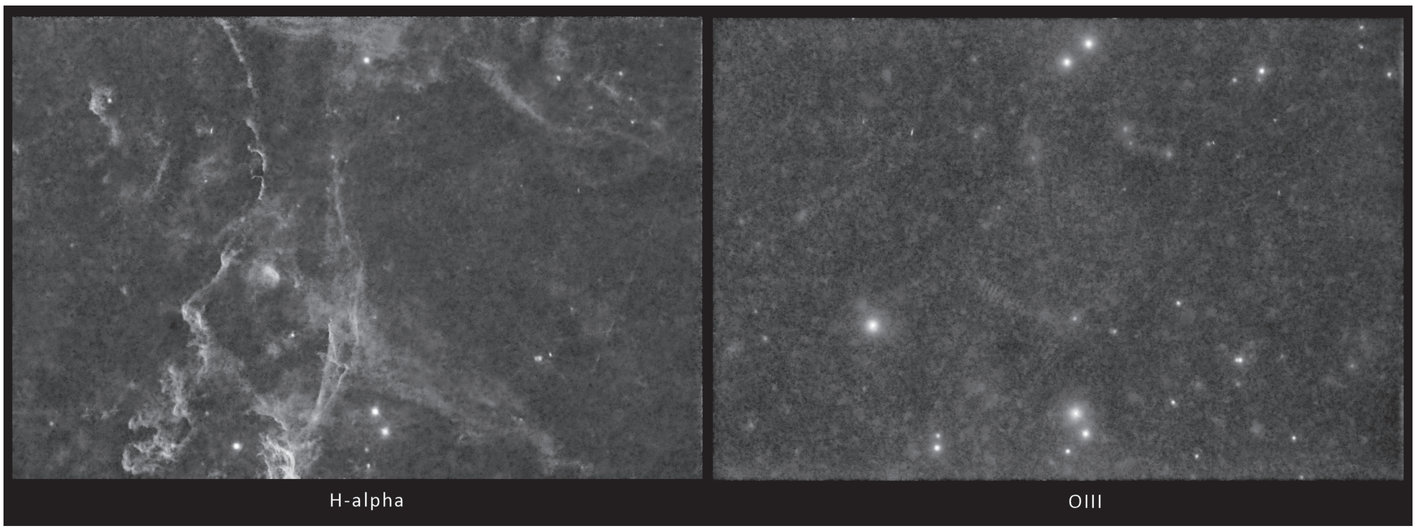

Figure 6 — Hα and OIII 7-ηm data after star removal

lacks any filamentary structure, it is unlikely that the ring is the shell of a planetary nebula emitting at OIII wavelengths.

With no narrow band emission, the source of the rings' glow is likely due to reflected light from a nearby star or cluster of stars. The bluish colour can be accounted for by noting the way in which light scatters from very small dust grains. Reflected light scatters off interstellar dust, and when the size of the dust grains is on the order of a wavelength or less, then the light undergoes Rayleigh scattering. The scattering efficiency reduces as the fourth power of increases in wavelength, thus emphasizing the blue end of the spectrum. As the grain size increases, this reduces to being inversely proportional to wavelength. In both cases the amount of scattered light will drop off as wavelength increases, so we would expect there will be more scatter at OIII than at Hα wavelengths. This is the same phenomenon that makes the dust surrounding M45 blue. The lack of filamentary structure, reducing visibility at narrow OIII filter bandwidths, low visibility at Hα wavelengths as well as a bluish colour all point to the ring structure likely being a very-low-surface-brightness reflection nebula in a field that is obviously rich in gas and dust.

There were several people who helped with the data collection and the possible identification of the object type; I'd like to mention and thank three that all stand out: Jason Dain and Roman Kulesza for collecting additional OIII data, and Dr. David Turner for his guidance and expertise in identifying the likely type
of object.

Next edition I'll return to discussions of image processing techniques, maybe some that were used in processing the Dragon's Ring image presented in this edition. Remember, this column will be based on your questions so keep them coming. You can send them to me at b.macdonald@ns.sympatico.ca. Please put "IC" as the first two letters in the topic so my email filters will sort the questions. ✶

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

Blast from the Past!

Compiled James Edgar
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CHARLES A. YOUNG

By Edwin B. Frost, in *Science* for January 24, 1908.

[This article first appeared in the *Journal* in 1908, Vol. 2, p. 27]

The past five months have brought severe losses to astronomy in the deaths of five of its distinguished men; in Germany, Vogel, of Potsdam; in France, Loewy, of Paris, and Janssen, of Meudon; in this country, Asaph Hall; and now Charles A. Young, who died at Hanover, N.H., on January 3.

There is some consolation, however, in the fact that all of these men had reached advanced years,* and had in a measure rounded out their scientific careers, although the three first named were still in active service as directors of large observatories. [*Average age, 75 years.]

Charles Augustus Young was born on December 15, 1834, at Hanover, where his grandfather and father successively occupied the chair of natural philosophy in Dartmouth College during the period from 1810 to 1858. He entered college early and graduated with distinction in 1853 as bachelor of arts. During his student days he assisted his father in astronomical observations and accompanied him in 1853 on a trip to Europe to purchase instruments for the Shattuck Observatory, then in course of erection. For two years after graduation he taught the classics at Phillips Academy, pursuing at the same time theological studies at the Andover Seminary. In 1857 he went to Hudson, Ohio, as professor of mathematics and natural philosophy at Western Reserve. During several summer vacations he assisted in the governmental survey of the great lakes. Responding to the call of patriotism in 1862, he was for four months Captain of Company B in the 85th Regiment of Ohio Volunteers, which was largely recruited from students.

In 1866 he returned to Dartmouth as professor of natural philosophy and astronomy, thus continuing the family tradition.

The next few years were stirring times in astrophysical research. The spectroscope was just beginning to be applied in the study of celestial objects, with results of surprising interest. The eclipse of 1868 was made memorable by the discovery by Lockyer and Janssen of the method of observing the solar prominences. In spite of heavy duties as teacher, Young applied himself assiduously to solar research. He observed the eclipse of 1869 at Burlington, Iowa, establishing the fact of the gaseous nature and truly solar origin of the corona. Employing what was for those days a very powerful spectroscope, he quite accurately located the position of the green corona line, which was thereafter known as No. 1,474 on Kirchhoff's map of the solar spectrum. It was not until the eclipse of 1808 that the position of the line was more correctly located, by Professor W.W. Campbell observing in India, and was shown not to be represented by a dark Fraunhofer line. At the eclipse of 1869 Young also looked for, but failed to detect, the reversal of the dark lines at the moment of internal tangency of moon and sun. But he realized his expectations at the Spanish eclipse of the next year, when he discovered the "flash spectrum." He describes it in these words: "The moment the sun is hidden, through the whole length of the spectrum, in the red, the green, the violet, the bright lines flash out by hundreds and thousands, almost startlingly; as suddenly as stars from a bursting rocket head, and as evanescent, for the whole thing is over within two or three seconds." This phenomenon was subsequently observed visually in a more or less satisfactory way by different astronomers at other eclipses, but it was not photographically recorded until 1896, when it was caught by Mr. W. Shackelton at Nova Zembla with the prismatic camera.

In the early seventies Professor Young gave much attention to the spectrum of the chromosphere and to the prominences. Many of his delineations of these have become classics from their reproduction in various works and text-books. He devised an improved form of solar spectroscope which served his purpose very effectively. His assiduity was rewarded by his observation of a number of rather unusual solar phenomena: such as the highest recorded prominences, extraordinary velocities indicated by distorted lines, up to 320 miles per second; violent solar agitation associated with magnetic storms. He was the first to attempt to photograph the prominences and attained a partial success (1870). With the wet plates then necessarily employed an exposure of four minutes was necessary with the use of the dark blue line of hydrogen (Hy). This degree of insensitiveness of the films made it undesirable to spend time on such photographs.

In 1876 he made the first use of a grating spectroscope in astronomical work, and measured the rate of rotation of the sun by the displacement of the lines at the east and west limbs.

Professor Young successfully observed the transit of Venus of 1874 at Peking, and went to Russia for the eclipse of 1887, but was prevented from work by clouds. He had clear skies at the eclipse of 1878 at Denver, and in 1900 at Wadesboro, N.C. He also particularly studied the chromospheric lines, and made a list of 190 which he had noted with the spectroscope attached to the Dartmouth nine-inch telescope. The advantage of a high elevation becoming evident, he made an expedition in the summer of 1872 to Wyoming, where with the apparatus taken from Hanover, at an elevation of 8,000 feet, he added another hundred lines to his list. The subsequent increase in these lines, aside from those found in eclipse photographs, has been chiefly due to his own observations at Princeton.

In 1877 he accepted a call to Princeton, where much larger instrumental facilities were offered to him, with less confining teaching duties. He gave, however, much time to the organization and equipment of the students' observatory, making it then probably the best in this country. A powerful spectroscope was provided for the 23-inch equatorial of the Halsted Observatory, and with this he made important observations of the chromosphere and sunspots. He discovered in 1883 that the absorption spectrum of the sunspot umbra may be resolved into "countless and contiguous" dark lines, a difficult observation later amply confirmed by others. With the Halsted refractor he also made micrometric observations of planets and satellites. He carried out an extensive program of observations of the transit of Venus in 1882 at Princeton. His admirable work "The Sun," of the International Scientific Series, appeared in 1881 and presented in a clear and interesting manner the known facts and theories of solar physics. It includes many of his own interpretations of difficult points and is the authoritative work on the subject. It is characteristic of his modesty that many of his own discoveries (such as that of the reversing layer) are there given without mention of his own name, and would only be recognized as such by those familiar with the circumstances, who could read between the lines, or by those who happened to consult the index. Several editions of this work appeared, and it was translated into several foreign languages. The last, thoroughly revised, edition was published in 1895.

His "General Astronomy," the first of his important series of text-books, which have been used by more than a hundred thousand students, was issued in 1888. It represents much more than a mere text for students, and has been widely used as a work of reference. The "Elements of Astronomy" and "Lessons in Astronomy" adapted for more elementary students, were published a little later. The "Manual of Astronomy," comprising most of what was in the "General Astronomy," but with more illustrations and with the inclusion of the latest data, ,vas issued in 1902.

The fundamental idea in Professor Young's text-books, popular articles and lectures, was that statements should be accurate as far as they go. He was no special pleader, and in his public utterances always fairly stated both sides of disputed matters, and he avoided controversy in a manner exemplary to younger men. His public lectures were not popular by reason of any eloquence of delivery or of rhetorical skill, but because of their clearness, simplicity and convincing quality of accuracy.

As a teacher he was particularly successful, having himself a splendid grasp of the fundamentals of mathematics and physics, he presented his subject logically, with emphasis on the essentials; and his humor enlivened the class room. It is doubtful if any teacher in this country has enlarged the intellectual horizon of a greater number of undergraduates than has he, in his culture courses in astronomy. "Twinkle" will never be forgotten by any of his students.

Professor Young's eminent services in research and education received recognition in numerous academic degrees, membership in and awards from various learned societies.

He had suffered from Bright's disease for a number of years; but by good care had kept himself fairly comfortable. The loss of his wife seven years ago, after forty-four years of a particularly happy married life, came as a crushing blow to him; and to his sorrow was lately added the death, after a year of distressing illness, of his widowed daughter, who made her home with him.

The retirement from his position at Princeton in the summer of 1905 was made the occasion of a grateful recognition by his colleagues, and the appreciation shown by his friends at that time must have been a source of much gratification to him. He then returned to Hanover, where he lived quietly, until he succumbed to a brief attack of pneumonia on January 3. Two days later he was gathered to his fathers in the old cemetery close to the house where he was born.

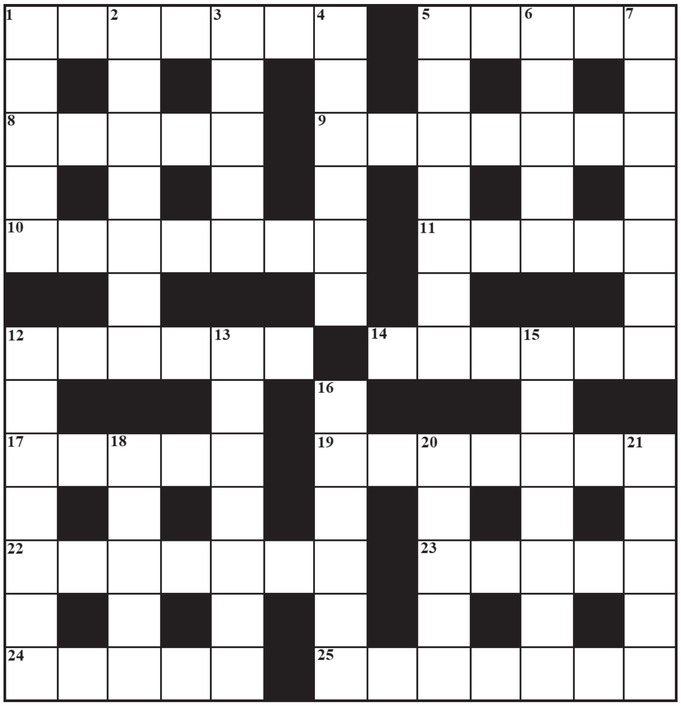
YERKES OBSERVATORY,

January 14, 1908.

[Edwin B. Frost joined the staff of Yerkes Observatory in 1898 and became its director in 1905.] ✶

Astrocryptic

by Curt Nason



ACROSS

1. Misguided hope of seeing Pluto's moon in a southern constellation (7)
5. Planetary scarps formed from super rotation (5)
8. See-through diagnostics emitted from AGNs (1-4)
9. Gray or Roberts is a star contributor to a handbook (7)
10. Rotation somehow led to forming a galaxy in Sextans or Draco (7)
11. Asteroid sampled in retrograde through the Sun Nebula (5)
12. Indigenous trickster was sly to return to Earth (6)
14. Like General Relativity: not just but well supported (6)
17. Without the Spanish, Liberal is left in the balance (5)
19. A number turns it green on March 17 (7)
22. Strike out with ten men around the horseman's shoulder (7)
23. Two-faced rounder of Saturn (5)
24. Surrounded by Mars in Greece, I look up for a sign (5)
25. Was it used to measure stars near Nebecular Major? (7)

DOWN

1. Mariners relied on a constellation for directions (5)
2. Capacity for calcium-oxygen exchange to cause limb darkening (7)
3. Pried apart nodes (5)
4. Mount maker backs for sex with royal (6)
5. Charioteer backed around Bach composition of the Queen's Knee (7)
6. Nebulous seafood in emission from a false comet (5)
7. Where neutrinos were detected in south of France with an odd red gem (7)
12. Dove into business degree following parts of college and university (7)
13. Elementary drawers could destroy craters (7)
15. Carbon-based heart, for example, set with intensive care (7)
16. Scottish ancestor or painter of stars? (6)
18. Steady State cosmologist involved in carbon dispersal (5)
20. High-speed plane returns at a star in Gemini (5)
21. Lord of the Roses configured a huge mirror (5)

Answers to previous puzzle

Across: **1** MIKE PAUL CHRIS (2 def); **8** GEMINID (2 def); **9** LOUIS (L+anag); **10** ATLAS (hid); **11** NEPTUNE (pen(rev)+tune); **12** MUSCAE (M+anag); **14** RONCHI (anag-c); **17** TOPSPIN (top+spin); **19** FORUM (F(anag)M); **21** NORMA (anag); **22** LORENTZ (Lo+rent+z); **23** CHANDRASEKHAR (anag)

Down: **1** MAGMA (anag); **2** KEMBLE'S (2 def); **3** PINES (Pi+NES); **4** UNDINA (Sunday-say+in a); **5** CALYPSO (2 def); **6** RYUGU (an(Y)ag); **7** SYSTEM 1 (systemic-c); **12** METONIC (an(rev)ag); **13** ALPHARD (Alpha+RD); **15**CORINTH (2 def); **16** ANTLIA (2 def); **18** PARKA (2 def /anag); **19** FORCE (hid); **20** MIZAR (M+Izar)

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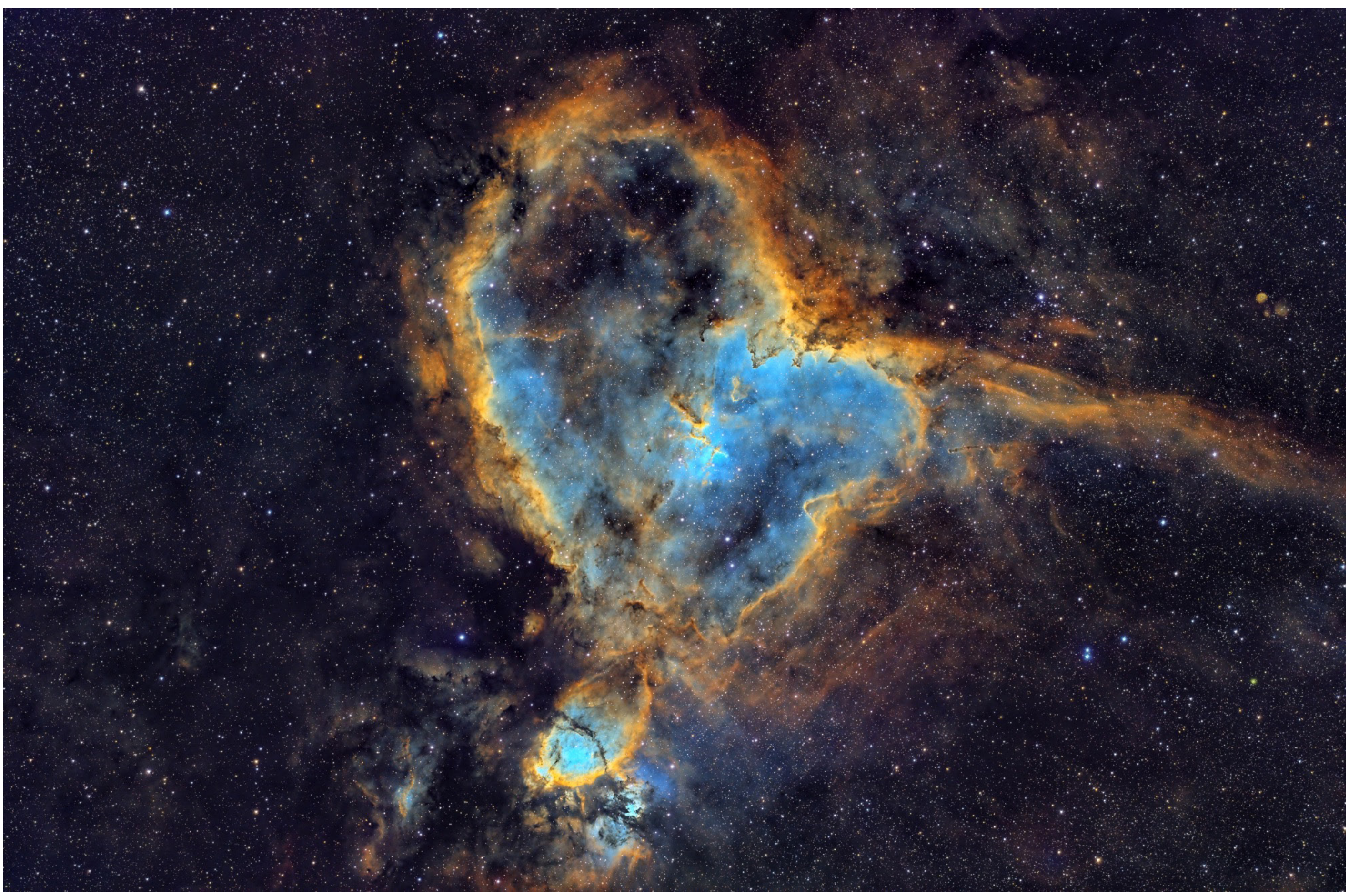
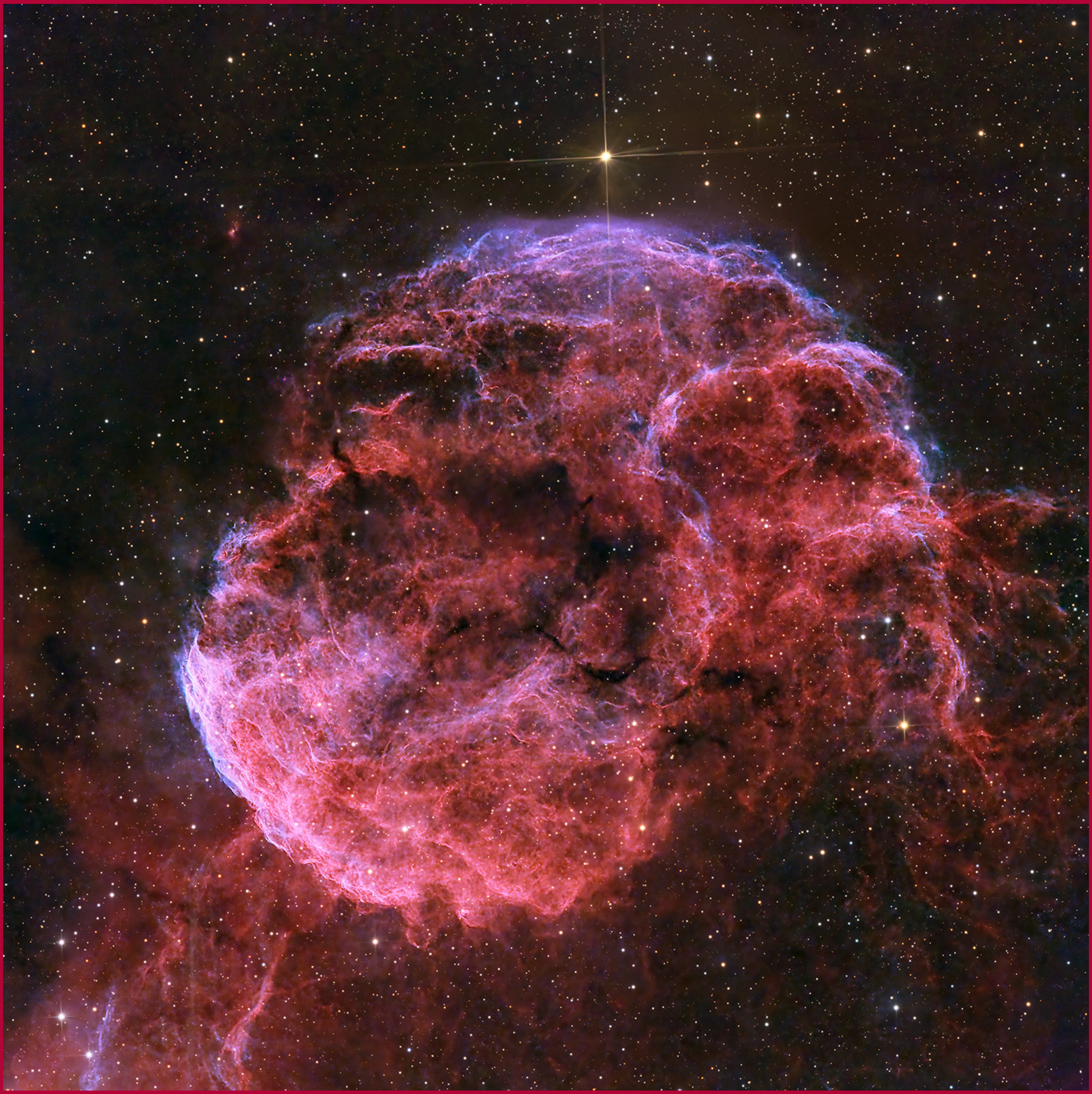
- Discovery through the scientific method

Great Images

by Malcolm Loro



The heart wants what the heart wants. Malcolm Loro imaged the Heart Nebula, an emission nebula 7,500 light-years away and located in the Perseus Arm of the galaxy in the constellation Cassiopeia. Malcolm used an Astro-Tech AT92 apochromatic refractor with Starizona Apex ED 0.65× L reducer on an iOptron GEM equatorial mount. He used a ZWO ASI2600MM Pro monochrome camera along with Antlia EDGE 4.5nm $H\alpha$*, OIII, and SII filters, with N.I.N.A. The final image was processed in PixInsight. Total integration time was 11 hours and 5 minutes.*



Journal

Scott Johnstone once again provides us with a beautiful image, this time of the Jellyfish Nebula (IC 443) from his backyard in Delaware, Ontario. He used a Sky-Watcher Quattro 150P with a coma corrector ƒ/3.45 on a Sky-Watcher HEQ5-pro mount, and an ASI 533MC pro cooled to –10 °C. He also used L-eXtreme and UV/IR filters. Total integration time was 9.75 hours.