The Journal of The Royal Astronomical Society of Canada

Journal

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PROMOTING ASTRONOMY IN CANADA

April/avril 2013
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Inside this issue:

The King's Crown *and the* Crown Jewels

Astrophotographers take note!

This space is reserved for your B&W or greyscale images. Give us your best shots!

Lunar imagers are only too aware of how difficult it is to capture the Moon and its terminator because of the large range of brightnesses across the scene. Victoria's John McDonald solved the problem with this image of the 9.2-day-old waxing Moon on January 20. John used a Williams 105-mm triplet refractor with a Canon T3i operating in video zoom mode at 3× magnification. Exposure consisted of two video sequences at ISO 800, 1/1600 sec. for 39 and 44 seconds to capture the upper and lower parts of the lunar surface.

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Front cover *— Seven nights of imaging gave Howard Trottier this beautiful image of the reflection nebula NGC 7129 and the open cluster NGC 7142. Howard describes the pair, respectively, as the "King's Crown" and the "Crown Jewels." Exposure, in LRGB, totalled 12½ hours using a PlaneWave CDK17 telescope and an Apogee U16M camera.*

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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Canada

News Notes / En manchettes

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Radio telescope to rise in British Columbia

A new radio telescope is being built at the Dominion Radio Astrophysical Observatory (DRAO) southwest of Penticton in British Columbia. At a cost of $11-million, the project represents the first research telescope to be constructed in Canada in more than 30 years.

Known as the Canadian Hydrogen Intensity-Mapping Experiment project, the facility will eventually feature a 100-square-metre collecting area—the size of six hockey rinks—filled with 2560 low-noise receivers built from components adapted from the cell phone industry. The role of the receivers will be to capture and turn radio waves emitted 6-to-11 billion years ago into a 3-dimensional map.

As a starting point, a "pathfinder" telescope—a smaller instrument about 40-by-35 metres in size—is being built to test the electronic components for their environmental suitability and the quality of their sensitivity. This will be followed by the 100-square-metre telescope next to the pathfinder.

The Royal Astronomical Society of Canada

Vision

To inspire curiosity in all people about the Universe, to share scientific knowledge, and to foster collaboration in astronomical pursuits.

Mission

The Royal Astronomical Society of Canada (RASC) encourages improved understanding of astronomy for all people, through education, outreach, research, publication, enjoyment, partnership, and community.

Values

The RASC has a proud heritage of excellence and integrity in its programs and partnerships. As a vital part of Canada's science community, we support discovery through the scientific method. We inspire and encourage people of all ages to learn about and enjoy astronomy.

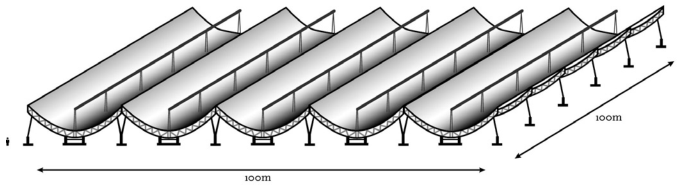

Figure 1 — CHIME, a new radio telescope being built in Penticton, British Columbia, will map the distribution of matter in the Universe as traced by neutral hydrogen gas.

Researchers scheduled to use the new radio telescope include scientists from the DRAO, the University of British Columbia, McGill University, and the University of Toronto.

Increasing number of planetary candidates discovered

The number of planetary candidates discovered in the *Kepler* mission's data to date now totals 2740 potential planets orbiting 2036 stars. The data show a dramatic increase in the number of Earth-size and super-Earth-size candidates discovered, representing a growth of 43 and 21 percent respectively. The new data also increase the number of stars discovered that have more than one planet candidate from 365 to 467. Forty-three percent of *Kepler*'s planet candidates are observed to have neighbour planets. The large number of multi-candidate systems being found implies that a substantial fraction of exoplanets reside in flat, multi-planet systems.

The *Kepler Space Telescope* identifies planet candidates by repeatedly measuring the change in brightness of more than 150,000 stars, in search of planets that pass in front of, or "transit," their host star. At least three transits are required to verify a signal as a potential planet. Scientists analyzed more than 13,000 transit-like signals to eliminate known spacecraft instrumentation and astrophysical false positives—phenomena that masquerade as planetary candidates—to identify the potential new planets. Candidates require additional follow-up observations and analyses to be confirmed. At the beginning of 2012, 33 candidates in the *Kepler* data had been established as planets. Today, there are 105.

The complete list of *Kepler* planet candidates is available in an interactive table at the NASA Exoplanet Archive. The archive is funded by NASA's Exoplanet Exploration Program to collect and make public data to support the search for and characterization of exoplanets and their host stars.

Comets had no role in wipeout of prehistoric humans

Scientists studying the planet Earth have concluded that comet explosions did not end the "Clovis" prehistoric human culture that existed in North America 13,000 years ago. New research evidence now rebuts the theory that a large impact or airburst caused a significant and abrupt change to Earth's climate and terminated the Clovis culture, an event that now requires another explanation for the apparent disappearance of the prehistoric humans.

Archaeologists called the earliest well-established human culture in the North American continent the Clovis culture, which is named after the town in New Mexico where distinct stone tools were found in the 1920s and 1930s. According to researchers, no appropriately sized impact craters from that time period have been discovered, and no shocked material or any other features of impact have been found in sediments. Scientists have also found that samples presented in support of the impact hypothesis were contaminated with modern material, and that no physics model can support the theory.

Researchers from Royal Holloway, University of London, Sandia National Laboratories in Washington, DC, and 13 other universities across the United States and Europe, recently published their results in *Geophysical Monograph Series*.

Scientific cross-field collaborations show results and point to more questions

Living microorganisms including bacteria have been identified in the middle and upper troposphere—a section of the Earth's atmosphere approximately 6.4 to 9.6 kilometres above the planet's surface. Such a finding could have a future research impact on planetary scientists who study atmospheres of distant planets and other space bodies.

Air samples, taken as part of NASA's Genesis and Rapid Intensification Processes (GRIP) program to study low- and high-altitude air masses associated with tropical storms, were captured during a flight of a specially equipped DC-8 aircraft over both land and ocean, including the Caribbean Sea and portions of the Atlantic Ocean. Scientists did not expect to find so many diverse microorganisms in the troposphere, considered a difficult environment for life.

Scientists do not yet know whether these microorganisms routinely inhabit this portion of the atmosphere—perhaps living on carbon compounds also found there—or whether they were simply lofted there from the Earth's surface. Air masses studied over the ocean found mostly marine bacteria; those over land had mostly terrestrial bacteria. The microorganisms likely reach the troposphere through the same processes that launch dust and sea salt skyward, but strong evidence also was found that the hurricanes had a significant impact on the distribution and dynamics of microorganism populations. Atmospheric scientists suspect the microorganisms could play a role in forming ice that may impact weather and climate. As well, the notion of long-distance transport of the bacteria could be applied to disease transmission models.

Top-ten science highlights from *Cassini* for 2012

NASA's *Cassini* spacecraft continues to make history as it uncovers scientific discoveries during its ongoing mission orbiting the Saturnian system. Scientists on the *Cassini* mission have selected ten science highlights that stood out for them as exceptional in 2012. These include the following:

1. Titan subsurface ocean: Spacecraft data showed that Saturn creates solid tides approximately 10 metres in height, which suggests Titan is not made entirely of solid rocky material. An ocean layer does not have to be huge or deep to create these tides. Because Titan's surface is mostly made of water ice, scientists infer its ocean is likely mostly liquid water.

2. Saturn burps and beacons: *Cassini*'s Composite Infrared Spectrometer tracked the evolution of the vortices left behind in the stratosphere after the Northern Storm, a massive storm that started in December 2010.

3. Titan's South Polar vortex: An image showed a concentration of high-altitude haze and a vortex materializing at the south pole of Saturn's moon Titan, indicating seasonal change.

4. Another Pac-Man found!: A second feature shaped like the 1980's video-game icon was recorded in the Saturn system, this time on the moon Tethys.

5. Glittering trails in Saturn's F ring: *Cassini* images showed trails that were dragged out from Saturn's F ring by objects about one kilometre in diameter.

6. Dusty plasma from Enceladus: About 100 kilograms of water vapour per second—about as much as an active comet—were seen to spray out from long cracks in Enceladus' south polar region.

7. Saturn daytime lightning: *Cassini* captured images of last year's storm on Saturn, the largest seen up-close at the planet. Bluish spots indicated flashes of lightning and marked the first time that scientists detected lightning in visible wavelengths on the side of Saturn illuminated by the Sun.

8 Methone: New observation of small moons: The flyby of Methone took place on 2012 May 20 at a distance of about 1900 kilometres, the closest flyby of the 3-kilometre-wide moon.

9. Predators and prey, the ecology of Saturn's ring particles: *Cassini* images have shown a propeller-shaped structure created by an unseen moon in Saturn's A ring.

10. Fresh air at Dione: Cassini "sniffed" molecular oxygen ions around Saturn's icy moon Dione for the first time, confirming the presence of a very tenuous atmosphere.

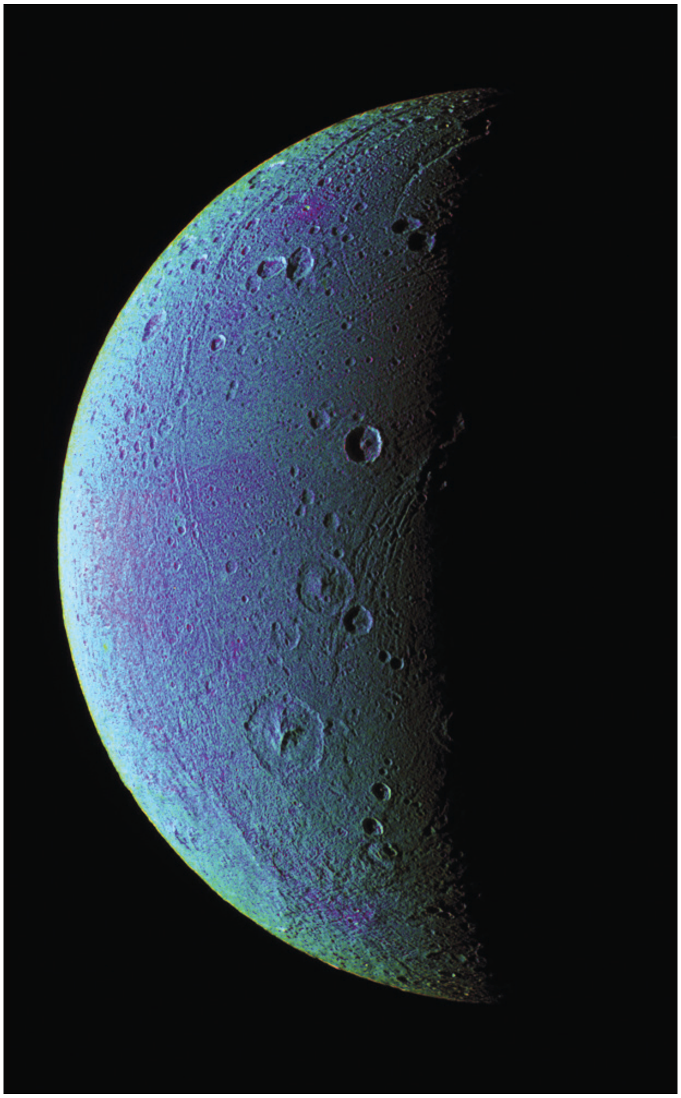

Figure 2 — January 2006 false-colour view highlights tectonic faults and craters on Dione, an icy world. Oxygen ions are sparse—one for every 11 cubic centimetres of space or about 90,000 per cubic metre. Dione has an extremely thin neutral atmosphere.

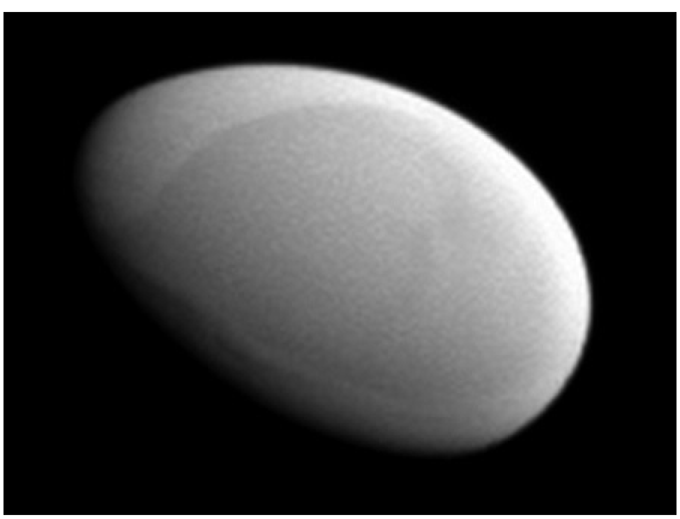

Figure 3 — Saturn's moon Methone, seen here during a Cassini *flyby of the small moon on 2012 May 20.*

Astronomers discover large asteroid belt around Vega

Data from NASA's *Spitzer Space Telescope* and the European Space Agency's *Herschel Space Observatory* indicate what appears to be a large asteroid belt around the star Vega, the second-brightest star in northern night skies. According to astronomers, the discovery of an asteroid belt-like band of debris makes the star similar to Fomalhaut, a first-magnitude star in Piscis Australis. In both cases, the data are consistent with the two stars having inner, warm belts and outer, cool belts separated by a gap. The detection of infrared light emitted by warm and cold dust in discrete bands around Vega and Fomalhaut indicated a new asteroid belt around Vega. It also confirmed the existence of the other belts around both stars.

Vega and Fomalhaut have other similarities: both about twice the mass of the Sun; both burn a hotter, bluer colour in visible light; the two are relatively nearby, at about 25 light-years away; and both are thought to be around 400 million years old (although Vega could be closer to 600 million).

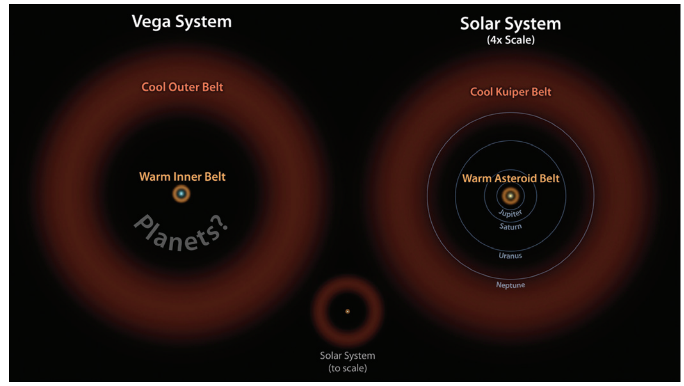

Figure 4 — Asteroid belt around the bright star Vega, as illustrated here, left, in brown.

The data results were presented in January 2013 at an American Astronomical Society meeting in Long Beach, California. ✶

Andrew I. Oakes, a long-time Unattached Member of RASC, lives in Courtice, Ontario.

Research Papers / Articles de recherche

Lemaître's Limit

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Figure 1 — Mgr. George Lemaître. Image courtesy Archives Georges Lemaître

Georges Lemaître gave a theoretical proof, for his 1927 doctoral thesis in astronomy, that the "maximum spherical radius" of our Universe can be computed from first principles to be 14.2 billion light-years (Lemaître 1927a). That estimate, which is known as Lemaître's limit, is based on Lemaître's dynamic-equilibrium theory of the Universe. It is surprisingly close to current estimates of the Universe's age. That age has been firmly established at approximately 14 billion years, based on multiple measurements, including measurements of the extragalactic distance scale by the NASA *Hubble Space Telescope* Key Project (Freedman *et al.* 2001), and of the cosmic microwave background radiation by the NASA *Wilkinson Microwave Anisotropy Probe* in combination with measurements of the distribution of galaxies by the Sloan Digital Sky Survey (Tegmark *et al.* 2004). Recently released final results from the full nine years of measurements by the *Wilkinson Microwave Anisotropy Probe* put the Universe's age at 13.74 ± 0.11 billion years (Bennett *et al.* 2013).

It is surprising that Lemaître's limit has been all but forgotten. Such coincidence, to within 3 percent, between the predicted size and observed age of the Universe ought to be of interest. Yet Lemaître's limit, his dynamic-equilibrium theory that predicted that limit, and other results from his earliest cosmological research are all but unknown to modern science. Only a single reference could be found, on a search of the NASA Astrophysics Data System, to Lemaître's thesis (Lemaître 1927a). By contrast, Lemaître's expanding-Universe theory is well recognized (Lemaître 1927b) and it is for that theory that he is considered a founding father of Big Bang cosmology and why today's standard cosmological model is known as the Friedmann-Lemaître-Robertson-Walker

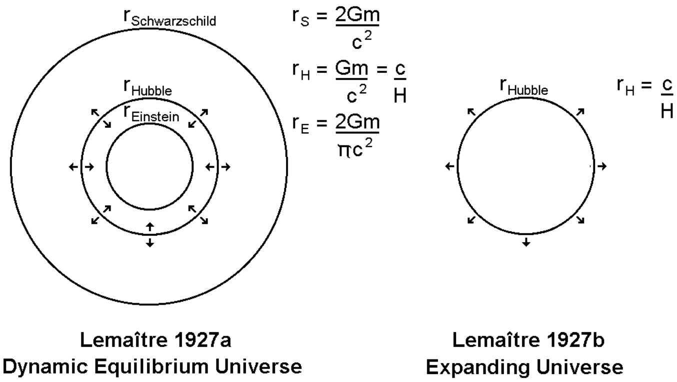

Figure 2 — Two theories of the Universe: one nearly lost to modern physics (1927a), and one that forms the basis of today's standard cosmological model (1927b).

universe. Lemaître was the first to provide solid theoretical evidence for the expansion of the Universe. He even calculated the Hubble constant of expansion, two years before Hubble, which occurred only after Hubble had uncovered observational proof of expansion (Hubble 1929).

Lemaître's limit might come back into modern astronomy, as did the cosmological constant. Indeed, the coincidence it represents between the size and age of the Universe has become more meaningful since the resurrection in the late 1990s of the cosmological constant (also known as vacuum or "dark" energy). That resurrection was based on observations of distant Type Ia supernovae, the same work that earned Riess, Schmidt, and Perlmutter the 2011 Nobel Prize in physics (Riess *et al.* 1998, Perlmutter *et al.* 1999). Verification of the cosmological constant has restored the relationship between the Universe's age in years and its size in light-years. Without the cosmological constant, expanding theories such as Friedmann's estimate the expansion age of the Universe as only 2/3 of the light-travel time required to reach the Hubble expansion radius (Friedmann 1922). The Universe's age could not coincide with Lemaître's limit to better than 33 percent. With the cosmological constant, the Universe's expansion age of 2/3 of the light-travel time is divided by 0.7, the estimated fraction of the Universe's total energy density attributable to the cosmological constant. As a result, age and distance in today's standard model once again equal one another to within 5 percent, *i.e.* to within 0.666/0.7 = 0.95. In essence, the cosmological constant restores the relationship that originally existed, where ages in years and distances in light-years were equivalent and interchangeable. In the earliest expanding theories, including de Sitter's and in Lemaître's dynamic-equilibrium theory, there was a one-to-one relationship between the expansion age of the Universe and the distance light has travelled since expansion began (de Sitter 1917, Lemaître 1927a). Lemaître's limit and the Universe's age coincidence, therefore, is of more interest now than it might have been historically because of the restoration of the cosmological constant.

Differences between Lemaître's dynamic-equilibrium and expanding theories of the Universe are shown in Figure 2. Note the dynamic-equilibrium theory is a hybrid. It incorporates into one theory effectively all of the probable theories possible according to Einstein's general theory of relativity. Those include both dynamic and non-dynamic theories, including expanding and/or contracting theories, as well as static theories. As a result, Lemaître's dynamic-equilibrium Universe includes more than simply the expansion radius of the expanding theories, as the figure shows. It also includes the Einstein radius of the static theory as an inner boundary, and the Schwarzschild radius as an outer boundary. The Schwarzschild's radius, which is the radius of a black hole's event horizon, is usually taken to define the horizons of objects within the Universe rather than the horizon of and exterior limit to the Universe itself. In comparison, Lemaître's expanding theory can be summarized by the expansion radius alone, as shown separately. That radius, described by Lemaître as the de Sitter radius, is now defined as the Hubble radius.

Lemaître's dynamic-equilibrium theory, as a hybrid, incorporates multiple theories, their multiple radii, and their multiple possibilities. Basically, he is offering a sphere-within-sphere theory, similar to the earlier Wright Universe (Wright & Rafinesque 1837). Further, rather than simply an expanding Universe with Hubble's radius and/or a static one with Einstein's, Lemaître's dynamic-equilibrium theory and to a first approximation, Lemaître's limit, offers a Universe with boundaries that limit the expansion radius. In expanding theories, that radius can reach any size up to and including infinitely large values. In the dynamic-equilibrium theory, however, the expansion radius is limited to expanding, (and/or contracting) between inner and outer boundaries, as shown. Those boundaries are defined as noted, inwardly by the Einstein static radius and outwardly by the Schwarzschild event-horizon radius. In other words, the Universe might exist within a black hole. That is no longer a unique or original view. Its origin, however, can be traced to Lemaître's dynamic-equilibrium theory. That theory, though all-encompassing, was nevertheless abandoned by Lemaître after Hubble discovered observational proof of expansion (Hubble 1929). Thereafter, Lemaître pursued his purely expanding theory. In the process, the maximum spherical radius was replaced by one to be determined by observation and all but forgotten.

Precisely because of its all-encompassing hybrid nature, Lemaître's dynamic-equilibrium theory might well be relevant to today's cosmologists. It incorporates purely dynamic and expanding theories by placing them in dynamic equilibrium. By assuming balance or equilibrium between gravitational attraction and electric repulsion *ad hoc*, just as Einstein did with his first formulation of general relativity but in a static theory, Lemaître is including the cosmological constant in expanding theories. Inclusion of the cosmological constant in today's expanding theory is the reason the Friedmann-Robertson-Walker standard model (before confirmation of the cosmological constant) became the Friedmann-Lemaître-Robertson-Walker model. In contrast to his purely expanding theory (Lemaître 1927b), however, Lemaître's dynamic-equilibrium theory (Lemaître 1927a) also incorporates non-dynamic and purely static theories by framing those as stationary theories. That allows static theories to feature important properties of dynamic theories including expansion and/or contraction, while also still retaining the all-important properties of the cosmological constant. Einstein later disavowed the cosmological constant. He called it his biggest blunder and was relieved to drop it, precisely because it was *ad hoc*, and after learning of Friedmann's expanding theory of 1922 and then of Hubble's observational confirmation of expansion in 1929 (Friedmann 1922, Hubble 1929), was relieved to drop it. Today, however, the cosmological constant is the only physical mechanism that is both understood and observationally confirmed to be able to counter-balance gravity, as originally intended by Einstein and later Lemaître.

All three radii in Lemaître's dynamic-equilibrium theory were established within the first two years of Einstein's earliest formulation of the general theory of relativity in 1915 (Einstein 1915). They were found by Schwarzschild (1916), Einstein (1917, translated 1922, Eq. 124), and de Sitter (1917). Of these, Schwarzschild's radius of the event horizon of black holes is the most recognized. That radius is derived by an equation that is probably the most cited in astronomy after $E = mc^2$, namely $r_S = 2Gm/c^2$. The Schwarzschild radius of the Sun is widely understood to be 3.0 kilometres, based on the Newtonian gravitational constant (6.67380×10^{-8} cm^3/gm sec^2), the speed of light ($2.99792458 \times 10^{10}$ cm/sec)[1] and the Sun's mass (1.988435×10^{33} gm, Gundlach & Merkowitz 2000). Less widely recognized are the other radii, and in particular the fact that both are so closely related to Schwarzschild's radius, as the figure shows. Einstein's static-theory radius is derived by exactly the same equation as Schwarzschild's, excepting only for being smaller by a factor of π. So too, the Hubble expansion radius is derived by exactly Schwarzschild's equation, excepting only for it being smaller by a factor of 2.

Lemaître was the first to establish that all three radii (r_S, r_E, and r_H), then thought separate and unrelated solutions, might actually be three closely related sizes surrounding the same constant mass. The virial mass of expanding theories is the same as the virial mass of static theories, as first noted by de Sitter (1917), then Hubble (1926), and later Eddington (1930) and Einstein (1945). The virial mass is defined as the exact mass a larger body such as the Sun must have to prevent the gravitational escape of a smaller body such as the Earth, *i.e.* to overcome the smaller body's independent velocity of motion. For ultra-massive bodies such as the Universe, with smaller bodies such as galaxies having escape velocities approaching the speed of light, the exact virial mass required to prevent escape is also known as the gravitational mass.

Lemaître's limit is given explicitly in a formula, which is reproduced here in Equation 1[2]. In that formula, Lemaître multiplies three terms together, the Einstein gravitational constant (κ), the square of the maximum virial radius (r^2), and the "invariant mass density" (d), which he writes as $8\pi\, a^2\, d$. Lemaître's limit, defined by that formula, occurs when the product of those terms reaches unity or one, or in other words, when those terms are mathematically in balance, with the Newtonian gravitational constant, G, and the velocity of light, c.

$$\kappa r^2 \rho = \left(\frac{8\pi\, G}{c^2}\right) r^2 \left(\frac{m}{8\pi\, r^3}\right) = \frac{G}{c^2}\, \frac{m}{r} = 1 \qquad (1)$$

The Lemaître limit formula reduces to only two terms; the r^2 term cancels since density equals m/r^3, as shown in (1). Reduced to two terms, the formerly unknown mass/radius ratio of the Universe (m/r), taken as the first term, then becomes known, because it equals a known constant ratio (c^2/G), taken as the second term, as shown in (2).

$$\frac{m}{r} = \frac{c^2}{G} = 1.35 \times 10^{28} \text{ gm/cm} \qquad (2)$$

Based on that constant, universal, and unifying ratio (c^2/G), Lemaître makes only two assumptions. First, our system of units for length, mass, and time holds true for the Universe (note Lemaître uses centimetres, grams, and seconds), and second, that the virial mass-radius relation also holds true. That is, the relation between the virial mass as defined earlier, and the corresponding escape radius from that mass for smaller bodies moving at the limiting velocity of light ($m = rc^2/G$) has universal application. Then, relative to a minimum radius that he defined as 1 cm, Lemaître computed a natural limit for the maximum radius. That limit is reached when the maximum-to-minimum-radius ratio itself reaches the same unifying ratio ($r_{max}/r_{1cm} = c^2/G$), as shown in (3a). Lemaître's limit is reached at a maximum radius of 1.35×10^{28} cm (14.2 billion light-years), when the square of the Universe's virial radius equals its own virial mass in conventional units ($r^2 = m$), and when the virial radius equals the virial mass in natural units ($r = m$, where $c = G = 1$). Only at that limiting boundary radius are the mass, mass/radius ratio, and virial mass-radius relation all linked by the same unifying ratio, as shown in Eq. 3b.

$$m = \frac{m^2}{r^2}\left(1.0\ \frac{cm^2}{gm}\right) = r\,\frac{c^2}{G} = \frac{c^4}{G^2}\left(1.0\ \frac{cm^2}{gm}\right) \qquad (3a)$$

$$m = 1.81 \times 10^{56} \text{ gm} = 9.12 \times 10^{22} M_{Sun}$$

$$r_{max} = \frac{r_{max}}{r_{1cm}}(1.0 \text{ cm}) = \frac{c^2}{G}\left(1.0\ \frac{cm^2}{gm}\right) = \frac{m}{r}\left(1.0\ \frac{cm^2}{gm}\right) \qquad (3b)$$

$$r_{max} = 1.35 \times 10^{28} \text{ cm} = 14.2 \text{ Gly}$$

The unifying ratio, namely c^2/G, is simply the reciprocal of Einstein's constant, κ, without the 8π geometrical factor, since $\kappa = 8\pi G/c^2$, as shown in (1).

Lemaître's limit lives on, though it is now known rather obliquely as the "Newtonian" or classical limit of general relativity. As recently as 2001, a version of Lemaître's limit was used to estimate the maximum radius of the Universe to four-digit precision, finding 13.83 billion light-years (Nowakowski 2001). That estimate, however, assumed vanilla values of the Hubble constant and the total density-to-critical density ratio (H = 100 km/s/Mpc, and $d_T/d_C = 1$). If Lemaître's formula values are employed instead, for a Hubble constant and velocity-distance relation at the limits of the velocity of light, c, and the maximum radius, r_{max} (where $H_L = c/r_{max} = 68.7$ km/s/Mpc), with a total density of double the critical density (where $d_T/d_C = 2$), the result then is Lemaître's maximum radius of 14.2 billion light-years, *i.e.* $14.2 = 13.8 \times [(H_{100}/H_L)/\sqrt{2}]$.

Lemaître's formula, if not the exact limit, evidently has currency in modern physics. Three facts, however, have been all but lost regarding what is nowadays referred to as the Newtonian limit. First, describing that limit as Newtonian or classical is incomplete at best, because it could scarcely have been foreseen, let alone foretold, before the advent of general relativity. Second, Lemaître is the first physicist known to have established its theoretical existence, yet his 1927 discovery and prediction remain unheralded. Third, the exact limit itself has been completely lost to modern physics. That is surprising. Lemaître's limit and observational estimates of the Universe's age, as said, coincide to within 3 percent.

Lemaître's name appears in the abstracts of more than one thousand astronomical papers as of the beginning of 2013, according to the joint NASA Smithsonian Astrophysical Observatory Astrophysics Data System. Yet, of the 45 papers found naming Lemaître in their abstracts in *The Astrophysical Journal*, none cites Lemaître's 1927 thesis. Of the subset of all papers searched naming Lemaître in their abstracts, some 120 papers or 10 percent of the total available, only 1 was found citing Lemaître's thesis, a review by Eisenstaedt (1993). That review divulges the existence of, but not the physics of, Lemaître's limit. Only one other reference to Lemaître's limit could be found in the modern literature, and that only after a pre-print of this JRASC manuscript was circulated on the astrophysics paper e-print archive online (http://arxiv.org/abs/1212.6566). A private communication, from Lemaître biographer Dominique Lambert, reveals that his biography of Lemaître includes seven pages referencing Lemaître's limit (Lambert 2000). Although published *en français*, an English translation is eagerly anticipated this year. Further interest in Lemaître's limit, beyond pedagogical, will depend on future observation-based findings regarding the Universe's size and age.

For astronomers to "discover" whether Lemaître's limit is true or mere coincidence will require, by definition, observational measurements with an accuracy of three sigma or 0.3 percent! Estimates of the Hubble constant, from which the Universe's age and size are derived, are accurate at present to within 3 percent. Those include the most recent results from the Carnegie Hubble Program, co-led by former NASA Key Project co-leaders Freedman & Madore (Freedman *et al.* 2012), and the Supernovae H0 Equation of State team, co-led by Reiss, 2011 Nobel Prize co-winner, and Macri (Riess *et al.* 2011). These programs, however, and others ongoing and planned, are aimed at achieving 1-percent accuracy. Following launch of the NASA *James Webb Space Telescope* in 2018, Hubble-constant estimates of that degree of accuracy might well be achieved. Aiding in that endeavour, within the next decade, giant ground-based telescopes with apertures of more than 30 metres will become available, including the Giant Magellan Telescope, the Thirty-Meter Telescope, and the European Extremely Large Telescope.

More down-to-Earth, poor-man's avenues to high-accuracy cosmological research now exist. Statistical and theoretical analyses can be conducted by anyone, thanks to the vast volumes of data that are already available and openly accessible to all. Examples include analyses of the database of Hubble-constant estimates published from 1927 to 2010 totalling 600 values, compiled by Huchra for the NASA *Hubble Space Telescope* Key Project and available online (Huchra 2010). Earlier analyses of subsets of those estimates led researchers to find a mean of H = 67 km/s/Mpc with a standard deviation of 5 percent (Gott, Vogeley, Podariu, & Ratra 2001), and then with additional estimates H = 68 km/s/Mpc with a standard deviation of only 2 percent (Chen, Gott, & Ratra 2003). An unpublished mean found by this writer based on 365 of the 487 estimates available in 2005, excluding 12 estimates published prior to 1960 and 110 based on non-local distance indicators, including gravitational lens and Sunyaev-Zeldovich effect-based indicators, resulted in H = 68.9 km/s/Mpc. That, coincidentally, is within 0.3 percent of the predicted Hubble constant given earlier based on Lemaître's limit, H_L = 68.7 km/s/Mpc.

Analysis of the NASA/IPAC Extragalactic Database of Galaxy Distances is another way to obtain theoretical yet highly accurate cosmological research. That database features essentially all of the redshift-independent extragalactic distance estimates published since 1980 and upon which most current estimates of the Hubble constant of proportionality between distance and velocity are based. It is co-led by this writer in collaboration with Madore, RASC member and annual contributor to the RASC *Observer's Handbook*, co-founder of the NASA/IPAC Extragalactic Database, former co-leader of the NASA *Hubble Space Telescope* Key Project, and current co-leader of the Carnegie Hubble Program.

In theory, with 60,000 redshift-independent distance estimates available for 12,000 galaxies, the Hubble constant could be found with an accuracy of better than 1 percent, based on having more than 2 orders of magnitude more distance measurements than the Key Project did in 2001, which achieved 10-percent accuracy. That estimate was based on 200 distance measurements for 100 galaxies, as compiled for the Key Project in the first *Hubble*-era database of extragalactic distance estimates (Ferrarese 2000).

One immediate example of armchair results based on "big data" analysis is a statistically derived estimate of the distance to the Large Magellanic Cloud galaxy made by this writer. That distance represents the anchor or zero point of the extragalactic distance scale. Based on analysis of 530 measurements available in the distances database, the accuracy of the calculated estimate is claimed to be 1.2 percent.

For now, reaction to Lemaître's limit depends mostly on one's views. Without question, it involves an unproven coincidence that was abandoned by its originator and has no place in today's standard model. Then again, the same acceptance of expansion in 1929 that caused Lemaître to abandon his dynamic equilibrium theory also caused Einstein to abandon his cosmological constant, since reborn. Might Lemaître's early ideas also be revived in a future standard model? That question is timely. Another recent estimate of the age of the Universe, based on the abundance of heavy-chemical elements observed in an extremely metal-poor K-type giant star, is 14.2 billion years. That was reported by Christopher Sneden, former editor of *The Astrophysical Journal Letters* (Sneden *et al.* 2003), and quoted in the popular press (see *Astronomy* magazine June 2005, p. 46, by Steve Nadis). ✶

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Endnotes

1 U.S. National Institute of Standards and Technology, Committee on Data for Science and Technology recommended values of the fundamental physical constants (Mohr, Taylor, & Newell (2012).

2 That formula originally appeared on page 23 of Lemaître's thesis, at the beginning of Section V, "Interpretation of the results" and shown in his Table V, column 2. The thesis is available on-line through the Massachusetts Institute of Technology (http://mit.dspace.org/bitstream/handle/1721.1/10753/36897534.pdf?sequence=1)

Ian Steer followed an independently pursued avocation as a theoretical cosmology researcher from a non-astronomy background. In 2005, he was contracted by the California Institute of Technology as co-leader of the NASA/IPAC Extragalactic Database of Galaxy Distances. He now collaboratively pursues his vocation – to research, gather, and make publicly available data that astronomers use in extragalactic studies and to estimate cosmological parameters.

Two Astronomers and the Space Race

by Chris Gainor, Victoria Centre
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The death last year of Neil Armstrong has driven home the reality that the space race, which culminated with Armstrong's first step on the Moon, has passed into history. In 2011, we also lost two notable astronomers whose roles in that cosmic competition have been largely ignored.

Sir Patrick Moore, who died at age 89 on December 9, and Sir Bernard Lovell, who passed away August 6, not long before what would have been his 99th birthday, had many things in common: Englishmen who made major marks on astronomy; their skill as musicians; and their love of cricket. While their names today mean little to people outside the United Kingdom, in the 1960s both were well known in Canada, even outside astronomical circles.

Lovell spearheaded the creation of the gigantic 76-metre radio telescope at Jodrell Bank in Cheshire, and in so doing, became one of the founding fathers of radio astronomy. He gained fame and may have saved his astronomy program by using his telescope to track early space vehicles.

Moore was famous in the UK for the 55-year-long run of his monthly BBC television show, *The Sky at Night*. Because this show did not appear on Canadian television, Moore was best known here as a prolific writer on astronomy and space travel. Rare was the Canadian space enthusiast in the 1960s and 1970s who didn't own a copy of at least one of his books. In my case, it was his *Moon Flight Atlas.*

While the claim in one British obituary that Moore was the world's most famous astronomer is debatable, he was probably the world's most famous amateur astronomer. He had come to his interest in astronomy in his childhood, but gave up his admission to Cambridge University to join Bomber Command as a navigator in World War II. After the war, he turned to teaching, observing, and writing the first of his books, which, with various editions and translations, number in the hundreds.

In the 1950s and 1960s, Canada had much stronger political, economic, and cultural links to Britain than it does today. Canadians in those days read more British books and periodicals, and English Canadian broadcasters used British radio and television shows that were never broadcast in the U.S., or were shown there only when they had won popularity in Canada. It was no accident that Moore became well known in English Canada.

Moore had trained in Hamilton, Ontario, for his wartime service, but his postwar visits to Canada were rare—a fact that he regretted when he met a group of RASC members in Toronto in 1985. Although younger Canadian astronomers may not know the name of Patrick Moore, many of them learn the wonders of the deep skies with the help of the Caldwell Catalogue of 109 deep-sky objects that is named after Moore, its creator, whose full last name is Caldwell-Moore.

Figure 1 — Astronomer Sir Patrick Moore with his knighthood, received from The Prince of Wales at Buckingham Palace in London 2001 March 2. Photo: Reuters.

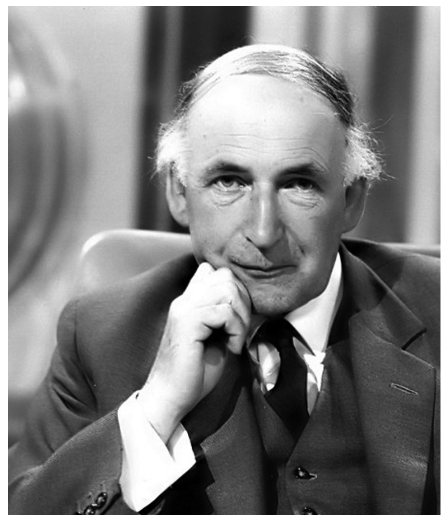

Figure 2 — Sir Bernard Lovell, founder of Jodrell Bank Observatory, led the team that developed H2S radar during WWII and was knighted in 1961 for his pioneering work in radio astronomy at Manchester University. Credit: Jodrell Bank Centre for Astrophysics, University of Manchester

Moore was also involved in the rise of space travel. It has been widely noted that *The Sky at Night* debuted just a few months before the launch of *Sputnik* in 1957. The show benefited from the explosion of interest in space that came with the space race that began with *Sputnik* and ended with Armstrong and Buzz Aldrin's landing on the Moon in 1969. In the year before *Sputnik*, Moore had signed on as the first editor of *Spaceflight* magazine, the flagship publication of the British Interplanetary Society (BIS) and that today remains the English-speaking world's most popular magazine dedicated to space exploration. As an expert on the Moon, Moore encouraged its exploration, and he helped present the BBC's live television coverage of the *Apollo* flights to the Moon. Many astronauts and cosmonauts appeared on *The Sky at Night*, including Neil Armstrong.

After those flights ended four decades ago, Moore continued to the end of his life to feature spacecraft that explored the Solar System and probed the heavens. When *Voyager 1* flew by Saturn and its moon Titan in 1980, I attended the encounter at the Jet Propulsion Laboratory, and a highlight for me was meeting Moore, who was there to gather material for his show and his books.

By the time of that long-ago encounter, Sir Bernard Lovell was nearing retirement. Lovell's passing in August was not as widely noted as Moore's, in part because Lovell has been out of the public eye for decades.

Figure 3 — The Lovell telescope at Jodrell Bank. Image: Mike Peel, Jodrell Bank Centre for Astrophysics, University of Manchester

Lovell was director of the Jodrell Bank Observatory in 1952 when construction began on the Mark 1 telescope, which became the world's largest steerable radio telescope (Figure 3). By the time the telescope was completed in the summer of 1957, it was well over budget and the subject of an investigation by the Public Accounts Committee of the House of Commons. When *Sputnik* was launched that fall, the Jodrell Bank telescope was used to track *Sputnik*'s booster rocket by radar, proving its utility to skeptical politicians and members of the public, including a rich benefactor who paid off the remaining deficit on the telescope's construction.

In those early days of space travel, both Soviet and American space authorities called on Jodrell Bank to track spacecraft sent to the Moon, Venus, and Mars, and the British media became frequent visitors to the radio telescope. In 1961, Lovell was knighted, formalizing the fact that his telescope had become a source of national pride.

Lovell's—and Jodrell Bank's—moment of greatest international notoriety arrived in February 1966 when the Soviet Union's *Luna 9* became the first spacecraft to land intact on the Moon. Not long after *Luna 9* sent back its first data from the lunar surface, the nature of the signal changed and personnel at Jodrell Bank recognized it as being similar to signals used to transmit photos to newspapers (and later used for fax machines), because Jodrell Bank had previously been involved in communications experiments with the *Echo 2* balloon satellite. When Lovell noted the nature of *Luna 9*'s signals to newspaper reporters who had come to Jodrell Bank, the *Daily Express* brought a facsimile machine to the telescope and used it to produce images from the surface of the Moon when the lander transmitted more photos the next day. The *Luna 9* photos appeared in the *Express* and other British newspapers before the discomfited Russians could release them, and Lovell became for a brief time an international celebrity.

Only a small fraction of Jodrell Bank's operating time was used to track spacecraft, however, and Lovell and his team made many contributions to astronomy, from the nature of cosmic rays and meteorites to groundbreaking work on quasars and pulsars. The Mark 1 Telescope was eventually named in Lovell's honour, and continues to operate today. Only two steerable radio telescopes are larger than the Lovell Telescope.

In October 1971, when Lovell visited Edmonton to speak at the University of Alberta, he drew a crowd of more than 800 curious members of the public, including this writer. As in the case of Moore, I believe that Lovell's fame in Canada was related to Canada's closer links to the UK at the time, as well as his association with the exploration of space. Like Moore, Lovell was a prolific author.

In an account of his speech in the Edmonton Centre publication *Stardust,* Lovell expressed the hope that more resources would be put into basic space research similar to what he was doing and less into spaceflight technology. No doubt Lovell's concern about the emphasis on space technology was related to the space race's emphasis on political competition at the expense of science.

The Cold War and the space race between the United States and Russia are over, and today orbiting telescopes and spacecraft that explore the Solar System have taken their places among the tools used by astronomers to do their work. Sir Patrick Moore and Sir Bernard Lovell advanced astronomy not only with their work as astronomers but also through their roles in the 1960s space race that helped vault them both to fame. ✶

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Moon Loops and Dumbbells—The Most Curious Moon of All

by Richard J. Legault, Unattached Member
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Many people think the Moon follows an orbital path that makes loops around the Earth. If you ask them for a crude sketch of the orbits of the Earth and the Moon, many will come up with something more or less like Figure 1, with the Moon making twelve or so loops around the Earth for every one Earth loop around the Sun. As we will see, the idea of Moon loops is very far from the true picture.

The Moon, as many readers of this journal will already know, does not follow an orbital path centred on the Earth. The Moon and the Earth in reality both make orbits around a point known as a barycentre. If you are not familiar with the idea of a barycentre, then what I am now saying about the Moon's orbit and the absence of Moon loops will sound contrary to everything you think you know. However, this is one of those times when you have to make up your mind to just set aside your current understanding and make room for something new. If you are already familiar with a barycentre, read on anyway—I promise that you won't be disappointed.

For several thousand years before Copernicus, everyone was quite sure they "knew" that the Sun, Moon, planets, and stars all went around the Earth. History records that before Copernicus, the general view of the cosmos, with very few exceptions, was geocentric. The Earth was in the middle and everything else revolved around it. Of course, as we now all "know," they were wrong, and it is Nicolaus Copernicus (born Mikołaj Kopernik in Torun, Poland) who is generally credited with showing us that Earth and the planets revolve around the Sun. He got off easy, publishing the idea of a heliocentric (Sun-centred) Solar System very late in his life and passing on shortly thereafter. Galileo Galilei, an outspoken promoter of the Copernican heliocentric view, got into trouble with authorities over it and was forced to recant the idea. He spent the later part of his life under house arrest. Giordano Bruno, another contemporary advocate of the Copernican heliocentric view, was burned at the stake over it. Eventually, in the fullness of time, most people came to understand everything revolved around the Sun instead of the Earth. Except for the Moon, that is—most people continued to think the Moon makes geocentric orbits around the Earth. And for the non-astronomer, that is where things, for the most part, stand today.

The last holdout from the Copernican heliocentric revolution is the Moon. I think the time has come to set aside the idea that the Moon is just an ordinary satellite of the Earth and pursue a little bit further what Copernicus started some 500 years ago. To be sure, Copernicus never said the Moon does not orbit the Earth. However, if he had taken the trouble to follow through on his own ideas and look at things the way many astronomers do now, then I think the results would have made him grin from ear to ear. Don't feel too bad if you don't get this right away. It took me several days of hard thinking to accept it. In the end, I had to draw a very detailed sketch to really get my head around it.

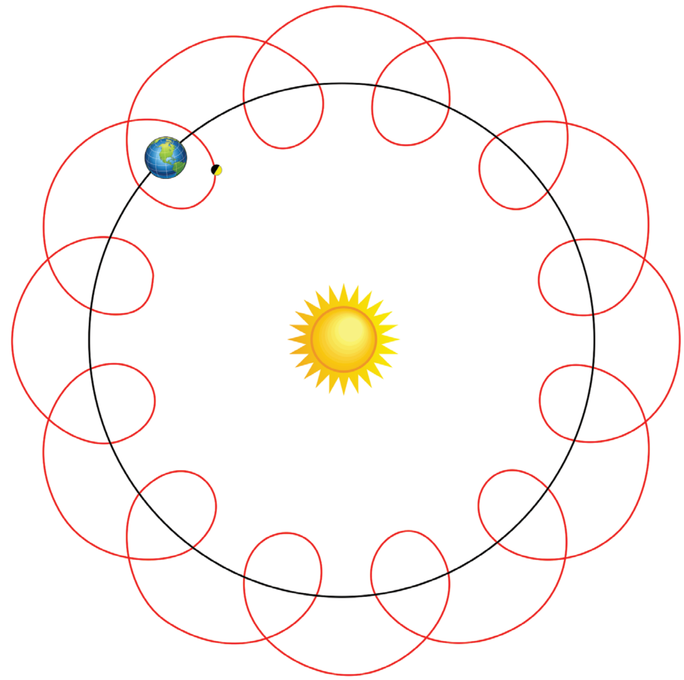

Figure 1 — It is a frequent misconception that the orbit of the Moon around the Sun forms a series of loops with the Earth at its centre.

My perspective on this topic began to change when I stumbled upon some educational lesson notes by Stephen J. Edberg of the Jet Propulsion Laboratory (JPL), California Institute of Technology. Edberg (2005) wants students to question their view about the Moon's orbital path when he notes, "Their observations, or what is "common knowledge," lead them to believe the Moon does loops around the Earth. But is this true?" Edberg's lesson notes are designed for teachers to help students find out whether the impression most people have that the Moon's orbital path makes loops around the Earth is true or false. They also help students to find out whether the Sun or the Earth pulls harder on the Moon and with how much force. The notes give the lesson's objective as:

> *Compute the strengths of the gravitational forces exerted on the Moon by the Sun and by the Earth, and compare them. Demonstrate the actual shape of the Moon's orbit around the Sun. Understand that gravitational forces between bodies and tidal forces generated by those bodies are different, and compare the two.*

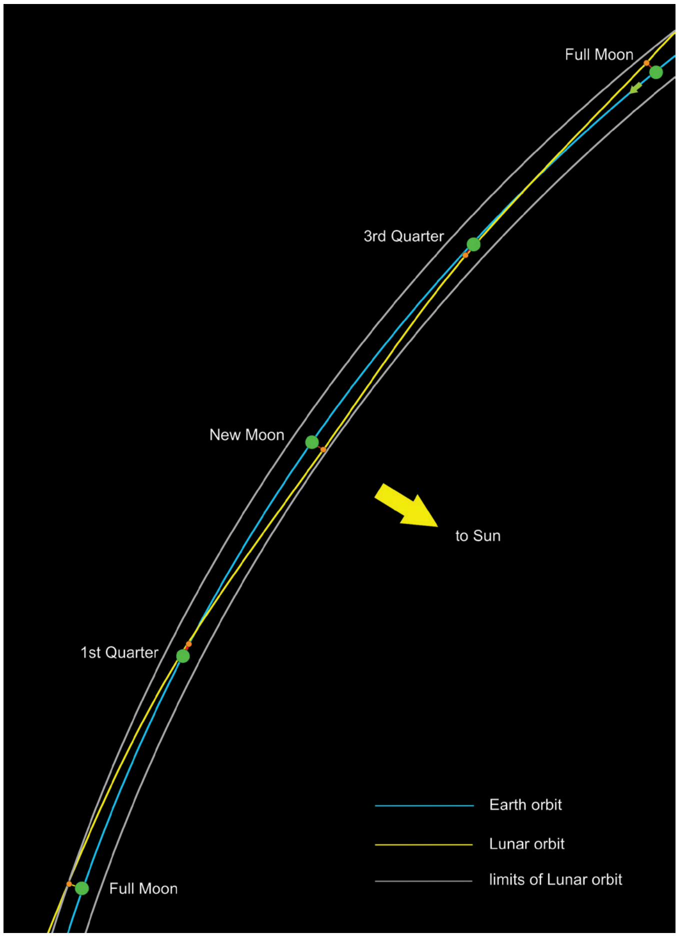

Figure 2 — The actual orbit of the Moon is similar to this schematic (it is not possible to draw a continuously concave orbit at this scale).

In brief, Edberg's lesson shows that the actual path of the Moon's orbit makes no loops around the Earth and in fact, "the path is always concave, to a lesser or greater degree, towards the Sun." At first, I did not agree with this at all. So out of curiosity and plain pig-headedness, I made my own sketch of the Moon and Earth's actual orbital paths. I came up with Figure 2. To my utter astonishment, I found Edberg was right.

Figure 2 shows, with two white curves, a segment of the wide ellipse within which the Earth and Moon move together as they orbit the Sun in a counterclockwise direction (as viewed from above the North Pole). I show them on the sketch in several positions as they move inside this elliptical band. The yellow line shows the path of the Moon, and the blue line, the path of the Earth. The yellow line never makes any loops around the Earth. Each path is in fact some sort of polygon shape with curved corners and curved edges. I call them *ellipse-ogons*. Any segment of these ellipse-ogons is always curved toward the Sun and never the other way. The two paths are in fact two intersecting ellipse-ogons. The intersection points show the Earth and Moon at what we call the first and third quarter Moons (times when you see a half Moon in the sky). The points where the two ellipse-ogons show the widest gaps are the times when you see either a full Moon or no Moon (*i.e.* new Moon). Note especially that the Moon's path never makes loops around the Earth. There are no Moon loops around the Earth![1]

I think we need to let go the idea that the Moon is an ordinary typical planetary satellite that makes closed loops around its primary. A better idea is to consider the Earth and Moon as a single entity—a binary planet. A good image of this would be to visualize this single entity as a sort of lopsided dumbbell the way I've drawn it in Figure 2, and imagine this dumbbell tumbling around on its annual path around the Sun. The dumbbell is lopsided because the Earth ball on one end is much bigger than the Moon ball at the other end. In fact, the Moon's mass is about 1/81 of the Earth's—lopsided indeed. The tumbling point, or pivot point of the dumbbell, in the jargon of astrophysics, is called a barycentre. This point is the centre of gravity of the lopsided dumbbell and lies on a line connecting the centres of the two balls. The barycentre of the Earth-Moon dumbbell is located, on average, about 1,710 km below the surface of the Earth (about 72 percent of the distance outward from the centre of the Earth to its surface). It is not correct to say the Moon orbits the Earth; they both circle the barycentre. If the Earth were smaller and the Moon bigger, the barycentre would be in empty space between the two balls, and the tumbling dumbbell image would be more obvious. So, from now on forget Moon loops and think tumbling dumbbell.

By way of references and acknowledgements, Edberg's lesson notes refer to an essay entitled "Just Mooning Around" by Isaac Asimov, which I looked up and found on the Internet. Reading that essay struck a chord of memory with me, which to my wife's dismay, set me on a flurry of searching and emptying out all the closets in the house. Sure enough, after an afternoon of searching and digging, out came my spine-broken dog-eared copy of *Of Time, Space and Other Things* (Asimov 1975). I must have packed it away, unable to part with it and other treasured tomes of my tender youth, every single time I moved from one address to another over the last 37 years.

And there it was, on page 87, Chapter 7, Isaac Asimov's essay entitled "Just Mooning Around." It had been originally published in 1959 in *The Magazine of Fantasy and Science Fiction*, to which Asimov made regular non-fiction contributions. The essay describes in Asimov's inimitable style and with great precision, exactly how our Moon is so different from all the other moons then known in the Solar System. He states as a matter of scientific fact that in all the Solar System our Moon is unique (Asimov 1975, pp. 97-98):

> *The Moon, in other words, is unique among the satellites of the Solar System in that its primary (us) loses the tug-of-war with the Sun. The Sun attracts the Moon twice as strongly as the Earth does.*

Asimov demonstrates this claim by using fundamental Newtonian physics to formulate a measuring tool he calls the *tug-of-war ratio* (TOW). Suppose we picture a tug-of-war going on for each satellite, with its planet on one side of the gravitational rope and the Sun on the other. In this tug-of-war how well is the Sun doing?

Asimov's tug-of-war ratio (TOW) formula is designed to be equal to a value of one (1) when the pull of a planet on its satellite is exactly equal to the pull of the Sun. If the ratio is bigger than one, then the planet's pull is stronger; if the ratio is smaller than one, the Sun's pull is stronger. The formula is:

$$\text{TOW} = \frac{\text{Mass of Planet}}{\text{Mass of Sun}} \times \left(\frac{\text{Planet's Distance to the Sun}}{\text{Satellite's Distance to Planet}} \right)^2$$

Asimov calculated this value for all the 31 satellites and planets in the Solar System for which the required data was then known, and found only one case of a value less than one: the Earth-Moon pair. It had a tug-of-war ratio of 0.46. In other words, the Sun pulls 2.2 times harder on the Moon than the Earth does. It was the one and only known case, at the time, of a moon that was pulled more strongly by the Sun than by its planet.

I compared Asimov's results for the Moon with Edberg's lesson notes. Edberg gives the force of the Sun's pull on the Moon as 4.3×10^{20} newtons and for the Earth on the Moon as 1.98×10^{20} newtons. This gives a ratio of 0.46 and compares exactly with Asimov's derivation. Both Asimov and Edberg also insist on the uniqueness of the Moon's orbit in that the curvature of any given segment of the Moon's path is *always* bent toward the Sun, *never* the other way, and the Moon's path *never* makes loops around the Earth. I also found this point about curvature stressed in several other sources. The oldest reference I could find was published in 1912 in none other than the venerable *Journal of the Royal Astronomical Society of Canada* (Turner 1912). All of this information adds weight to the notion that perhaps we need to think a bit more carefully about our geocentric notions about the Moon. The Moon's orbit is not geocentric. It is *barycentric.*

However, considering that the Sun pulls 2.2 times harder on the Moon than the Earth does, plus the fact that the Moon's actual path always curves around the Sun and never makes any loops around the Earth, I'm satisfied to say the actual orbital path of the Moon is definitely more centred on the Sun than on the Earth. So there you have it—a heliocentric Moon. I'm not entirely sure professional astronomers would agree with all of this. Nevertheless, wherever they are, I'd like to think that Copernicus, Galileo, and Bruno are all grinning with delight.

Asimov does not stop there. He goes on to state that the Moon is definitely too far away from the Earth to be a true natural satellite of the Earth and that it is also much too big to ever have been captured whole by the Earth. He then asks, "But, then, if the Moon is neither a true satellite of the Earth nor a captured one, what is it?" Asimov postulates that both the Earth and the Moon may have both originally condensed as separate planets at the time of formation in the early Solar System in a uniquely bounded combination of masses and orbital distances from the Sun that led to their becoming in effect a binary planet. "Can there be a boundary condition in which there is condensation about two major cores so that a double planet is formed?" he asks (Asimov 1975, p. 98).

Current thinking on the Moon's origin is of course, a little bit different. The most widely accepted theory today for the origin of the Moon is based on the idea of a collision of a Mars-sized object with the Earth, very early on in the planetary evolution of the Solar System. The collision would have caused the Moon to be formed from material from both the Mars-sized object and from material blasted away from the Earth by the super-colossal collision.

This collision theory of Moon formation has been supported in recent years with work published by Edward Belbruno. He is a mathematician of exceptional and practical brilliance and at the forefront of the deepest understanding of orbital physics and gravitational interactions today. I think his work has gone far beyond conventional Newtonian approaches by applying the newest ideas of the mathematics of Chaos Theory in this domain. His ideas and work are now legendary in the discipline, as he is regarded as the only person who could have, and actually did succeed in retrieving and salvaging an off-course satellite mission of multi-million-dollar proportions that would otherwise have been utterly lost in space and had to be written-off.

Belbruno is of the view that as the Earth accreted from the original solar gas and dust cloud, a similar accretion could have begun at the L_4 Lagrangian point of Earth's orbit and been held there by only a very weak stability boundary occurring at a point of very finely balanced attraction by the combined masses of the Sun, the Earth, and the object. Computer modelling of this situation indicated to Belbruno (2007, pp. 119-128) that because of the very weak stability at this location, it would have taken only the teeny-weeniest tweak of acceleration to destabilize the body's orbit and set it on a very slow trajectory that would result in exactly the same kind of collision that others had earlier proposed would be required to properly account for the formation of the Moon. If Belbruno's views are correct, then I have to applaud Asimov's uncanny insight in posing the right question by asking, "Can there be a boundary condition in which there is condensation about two major cores?"

Regardless of the process with which the Moon was originally formed, Asimov's conclusion that our Moon is unique in the Solar System as the only moon that loses the tug-of-war with the Sun, is a very interesting property that I thought would be worth updating based on later discoveries of additional moons in the Solar System. Asimov, working in 1959, had limited data. Maybe by now astronomical science had found other moons with similar properties to provide counter-examples to show that our Moon is not all that unique.

Using data published on NASA's Web site for 169 known planetary satellites in the Solar System, and data from Wikipedia for 10 more in orbits around smaller bodies, I calculated Asimov's tug-of-war ratio for all 179 of them, and I found:

- Only six moons other than our Moon have a tug-of-war value less than one.
- Of the six moons with a value less than one, all have extremely eccentric orbits (*i.e.* very elongated ellipses) with eccentricity factors above 20 percent and all have orbits inclined by over 125 degrees (or over 70 percent) to their respective planet's planes of orbit around the Sun. These extremely large eccentricities and angles of inclination indicate the objects were very likely asteroids captured whole in near passes by the planets they now orbit.
- The six other moons with a tug-of-war value under one are, in any case, very different from our Moon, which has a very low eccentricity of less than 6 percent and an inclination of only 5.2 degrees (or 2.9 percent).
- The highest ratio of 448,681 is for Neptune's moon Naiad.
- The average ratio is 18,896 and the standard deviation is 61,747.

I formulated my own amateurish *Curiosity Score* to try to rank all 179 moons based on simply adding together three ratios: tug-of-war, eccentricity, and inclination. This score would be meaningless in terms of physics; it is like adding together apples and oranges, all you get is fruit salad. I wanted a curiosity salad. I needed a simple number that combined all these factors together to help me do ranking to find the moon with the lowest overall combined score for Tug-of-War, eccentricity, and inclination to allow me to declare one of them the champion and the most curious moon in the whole Solar System. Are you ready?

> *Our Moon not only has the lowest overall Curiosity Score of 0.539, it is the only one in the entire population of 179 moons in our Solar System with a Curiosity Score of less than one.*

You don't have to take my word for this conclusion. You can easily check my results by building your own table of planetary satellite data. Just copy the data from the sources provided in the References section into a spreadsheet. Use Asimov's formula for the TOW ratio. Use this one for the Curiosity Score:

Curiosity Score = TOW + Eccentricity
+ Inclination Percentage

The Inclination Percentage is calculated as Inclination in degrees divided by 180. An inclination of 50 percent would be perpendicular to the relevant plane.

I think I now have to bow to Asimov's canny insight and conclusion that our Moon is indeed the most unique and most curious natural satellite in the entire Solar System. Not bad for a guy who was, after all, a mere chemist.

Acknowledgments

I wish to acknowledge the contribution of Tenho Tuomi, a fellow member of the RASC with whom some of the moon-loop ideas were discussed. ✶

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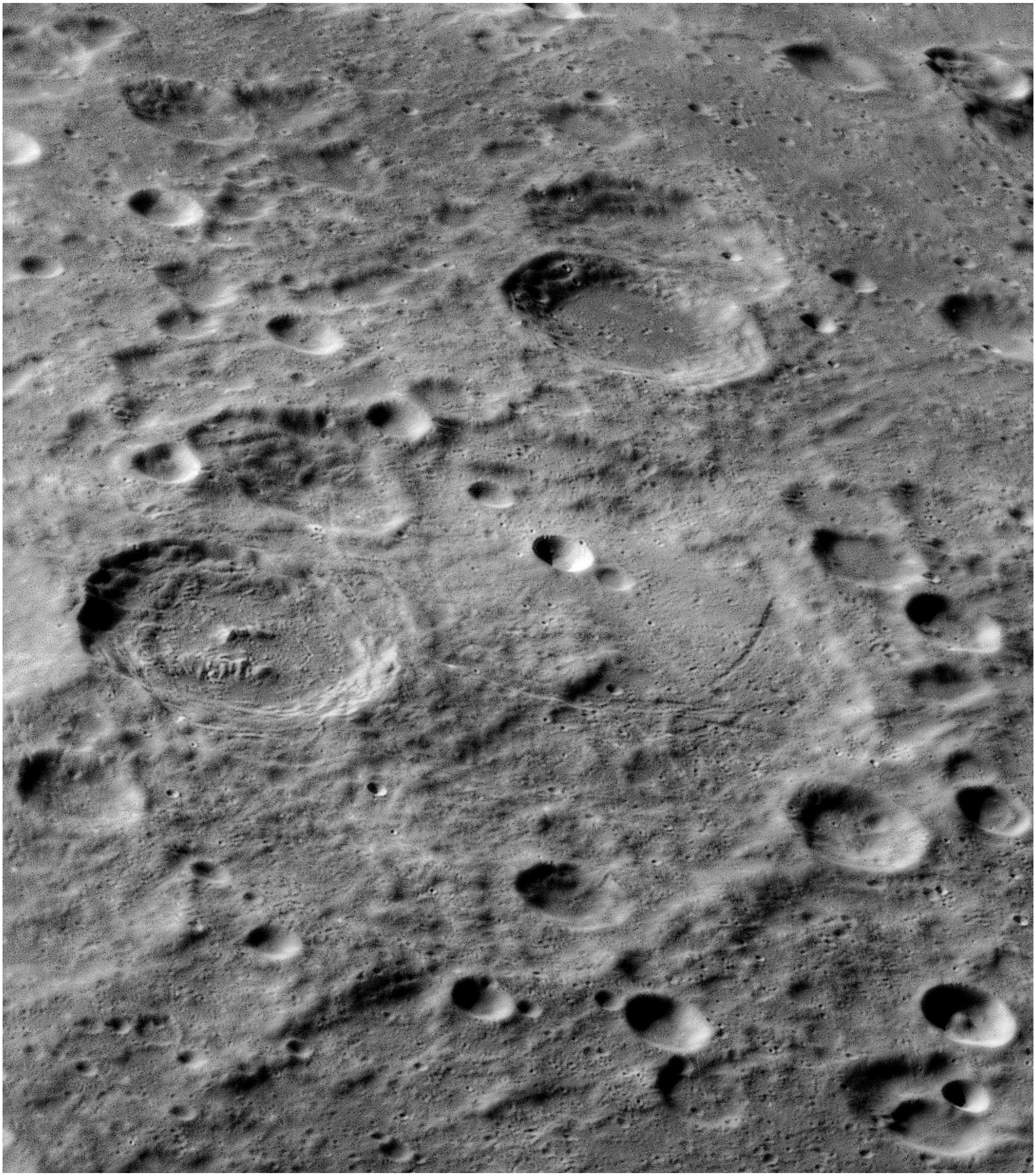
Endnotes

1 This is not to say that there are no Moon-loops *on* the Earth. Quite the contrary, my wife Lynn happens to think she lives with one.

Richard J Legault, born 1954 March 20, lives in Ottawa. He has a B. Com. (hon.) from the University of Ottawa (1978). He spent 30 years in the Public Service of Canada, 3 more operating a financial management consultancy, and is now retired. Astronomy, of the naked-eye kind, and SETI are two of several hobbies that his wife, Lynn, thinks he takes more seriously than is good for her health.



Mike Wirths captured Janssen (on the right) and Fabricius from his favourite hill overlooking the Pacific at his Baja Dark Skies Inn in Mexico. Janssen, with its criss-crossing rilles, and Fabricius, with its "E" shaped central mountains, are only the most noticeable features in this detail-packed image. Janssen is a 190-km-wide impact crater, large enough to be classified as a walled plain. It's an ancient surface, severely eroded and partly filled with debris from numerous impacts. Fabricius is a fresher-looking 80-km wide crater embedded in the wall of Janssen, but its slumping terraced walls, multiple central peaks, and a tiny rille of its own display a wealth of high-magnification detail.

A Chance to Recreate a Historic Telescopic Observation

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

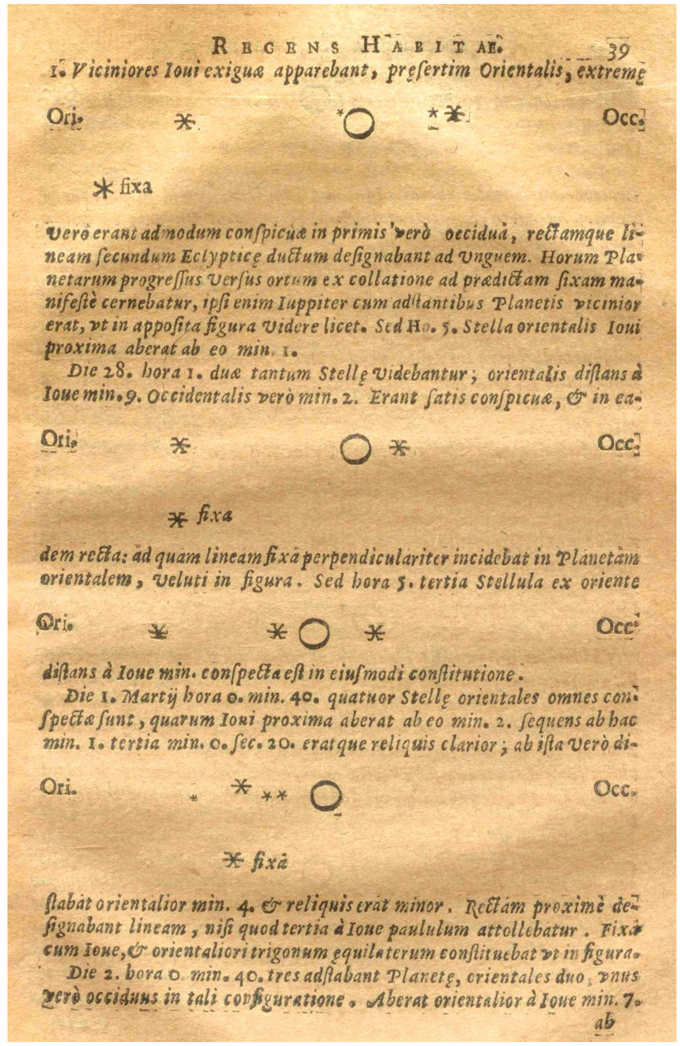
The year 1609 was an extraordinary one for the history of astronomy. The story is well known: the many International Year of Astronomy 2009 events celebrating the 400th anniversary of that year serve as a recent reminder. In 1609, word of Hans Lippershey's new invention—the telescope—spread rapidly through Europe and eventually made it to the attention of Galileo in Padua, Italy.

During the autumn of 1609, Galileo began to build telescopes and turn them skyward. He systematically recorded his observations of the Moon, stars, star clusters, and finally Jupiter (the telescopic study of Venus, the Sun, Saturn, *etc.* would come later). His observations continued into the new year and, by March 1610, he published his conclusions in the revolutionary *Sidereus Nuncius* (aka *The Starry Messenger*).

It wasn't until the early evening of 1610 January 7 that Galileo directed his attention to Jupiter. At first, he noticed three stars peculiarly close to Jupiter and in a line parallel to the ecliptic. He thought it curious that these three stars, so close to each other, would be lined up in such a manner. (This instant and intuitive observation is by itself a fine example of his gift.) Within a week, he saw a fourth star. In the next two months that followed, Galileo would decipher the true nature of Jupiter and the four new moons he discovered orbiting it.

I draw attention to specific observations Galileo made starting early on the night of 1610 February 26 (Figure 1). He noticed a fixed star just to the east of Jupiter. He noted, "...On this night I decided for the first time to observe the progress of Jupiter and his adjacent planets along the length of the zodiac by reference to some fixed star."[1] Galileo observed this progress for five consecutive nights. The evening of 1610 March 2 marks the very last observation Galileo made before publishing *Sidereus Nuncius*. His sketch from that night shows the star just to the south of Jupiter, about 8 minutes of arc directly below the westernmost visible moon (Figure 2). Even though his telescope offered a very narrow field of view, the star was easily in the same field as Jupiter.

It is worth analyzing these last observations a little more closely. Galileo felt at least some pressure to publish. Word of the telescope had spread through Europe. Others, if it weren't already happening, could make their own telescopes, make observations, and draw their own conclusions. His last series of notes and sketches summed up quite tidily what he had observed in the preceding two months.


RECENS HABITAE. 39

1. Viciniores Ioui exiguæ apparebant, presertim Orientalis, extreme

vero erant admodum conspicuæ in primis vero occidua, rectamque lineam secundum Eclyptice ductum designabant ad vnguem. Horum Planetarum progressus versus ortum ex collatione ad prædictam fixam manifestè cernebatur, ipsi enim Iuppiter cum adstantibus Planetis vicinior erat, vt in apposita figura videre licet. Sed Ho. 5. Stella orientalis Ioui proxima aberat ab eo min. 1.

Die 28. hora 1. duæ tantum Stelle videbantur; orientalis distans à Ioue min. 9. Occidentalis verò min. 2. Erant satis conspicuæ, & in ea-

dem recta: ad quam lineam fixa perpendiculariter incidebat in Planetam orientalem, veluti in figura. Sed hora 5. tertia Stellula ex oriente

distans à Ioue min. conspecta est in eiusmodi constitutione.

Die 1. Martij hora 0. min. 40. quatuor Stelle orientales omnes conspectæ sunt, quarum Ioui proxima aberat ab eo min. 2. sequens ab hac min. 1. tertia min. 0. sec. 20. eratque reliquis clarior; ab ista verò di-

stabat orientalior min. 4. & reliquis erat minor. Rectam proximè designabant lineam, nisi quod tertia à Ioue paululum attollebatur. Fixa cum Ioue, & orientaliori trigonum equilaterum constituebat vt in figura.

Die 2. hora 0. min. 40. tres adstabant Planete, orientales duo, vnus verò occiduus in tali configuratione. Aberat orientalior à Ioue min. 7.

ab

Figure 1 — Galileo's sketches and notes published in Sidereus Nuncius. *1610 February 27, 28, and March 1 clearly illustrate the night-to-night eastern progression of Jupiter and its moons. Opere di Galileo Galilei (1656), vol. 2, p.39; courtesy of the Thomas Fisher Rare Book Library, University of Toronto.*

The final few days of sketches clearly demonstrate the following:

- Jupiter has four moons, they never stray very far from the planet, and they are aligned along the ecliptic.
- Jupiter and its moons progress eastwardly relative to the fixed star along the ecliptic as predicted.
- The fixed star in no way affects the movement of the Jovian system even though it is seen closer to Jupiter than some of its moons.

At this conjuncture, it is possible to suggest that Galileo had reached the conclusion that there was little to be gained by collecting further observations. He decided that now was the time to publish.

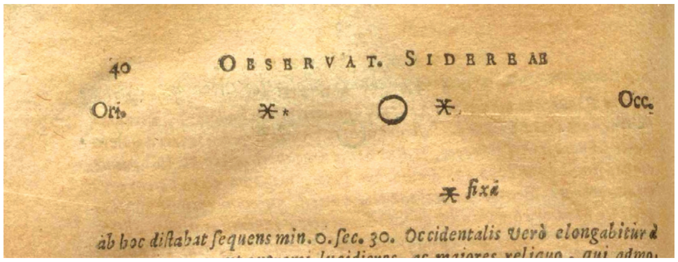


Figure 2 — This is the very last observation in Sidereus Nuncius. *The star is shown just to the west of Jupiter.* Opere di Galileo Galilei *(1656), vol. 2, p.40; courtesy of the Thomas Fisher Rare Book Library, University of Toronto.*

Figure 3 — Simulation from 1610 March 1 shows Jupiter and the star SAO76962 (highlighted) as Galileo would have seen it. The circle roughly illustrates the field of view of Galileo's telescope (created with Stellarium software).

Modern sky software allows us to easily simulate the sky the way it appeared from both Galileo's time and location (Figure 3). Using the software, the fixed star he sketched can be identified and it is also possible to check the accuracy of Galileo's sketches, especially the positions of Jupiter's moons.

The 7.1-magnitude star in Taurus he sketched is now placed just south of the 78-degree mark of the ecliptic (precession has moved this star more than 5.5 degrees along the ecliptic since Galileo's time). The star is SAO76962[2] at RA 05h 06m 40.9s, Dec +22° 30′ 38.6″.

A curiosity exists with regard to SAO76962 and Jupiter that occurred on the night of 1610 January 10. That evening, the star was in his FOV just north of Jupiter, yet Galileo did not sketch or make note of it. This fact is even more puzzling since on this night Galileo was trying to confirm, among other things, the retrograde motion of the planet. It appears that he missed an opportunity to record a vital observation that would take him almost another two months to obtain. Did Galileo simply overlook it, or was the star just on the threshold of visibility for his equipment? It is improbable to suppose that he noticed the star but simply ignored it.

Today, the telescopic views that Galileo experienced still delight viewers. Amateurs, me included, spend a part of many nights each year observing Jupiter, its complex features, and the continuous dance of its moons. Others enjoy surveying, photographing, or sketching the Moon during its changing phases. Who among us, the first time we looked at these objects, didn't express marvel at what we were seeing in the eyepiece? Recall, at public events, the reaction of most passersby at seeing the Moon or Jupiter for the first time through a telescope. Even though everyone has seen thousands of images of these objects over the course of their lifetime, the detail seen can still surprise the first-time observer. What must it have been like for Galileo and others, without any forewarning, to see these sights through a telescope for the first time?

In the early evening of 2013 April 29, the star SAO76962 will be seen once again, slightly to the east of Jupiter as it was some 403 years ago. Two days later, on May 1 and continuing through to May 2, the star will be just south of Jupiter. The orientation of the star and the planet over these four evenings will be nearly identical to that recorded by Galileo (Figure 4).

Jupiter has an orbital period of 11.86 years. So, approximately 34 orbits around the Sun will have been made by Jupiter since Galileo viewed this pairing. (There is a minor discrepancy between the actual date of its 34th completed revolution and the date it is actually observed due to parallax caused by the event being seen from the Earth.)

To view the event all one has to do is find Jupiter on the dates listed. The star will become immediately apparent through a telescope. Jupiter will be quite low in the west in the evening as twilight ends, so it would be advisable to observe from a place that has a good western horizon and be prepared to observe as soon as the sky becomes dark enough. Some major Canadian centres in northern latitudes will have to deal with

Figure 4 (right) — Simulation showing the same star near Jupiter on 2013 May 2. Galileo's approximate FOV is shown by the red circle, for perspective (created with Stellarium *software).*

twilight and a lower altitude for viewing, so a larger-aperture telescope may be necessary.

Consider recreating the event as Galileo witnessed it. The Galileoscope, which was specifically designed for IYA 2009, would be an excellent choice. Galileo probably used about 20x for his observations with his aperture stopped down to less than 30 mm, so just about any telescope can be set up to view the event. Recognize that a modern telescope's field of view will be far superior. Remember, Galileo's view would have been very challenging. So, if you are considering a re-creation, your expectations and those of others should be put in perspective.

Regardless of what equipment you choose to use, plan to record your observations by sketching, imaging, or even by writing in a journal. Better still would be to observe over multiple nights to see firsthand the motion of Jupiter among the stars just as Galileo did so many years ago. ✶

Endnotes

1 Translation from A. Van Helden (1989), *Sidereus Nuncius* or *The Sidereal Messenger*, p.81.

2 Other catalogue designations include; HD 32811, HIP 23784. The star is labelled on map 14 of *Sky & Telescope*'s popular *Pocket Sky Atlas*.

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Clark Muir enjoyed astronomy while growing up in Ontario. Since joining RASC about 20 years ago, he has been interested in amateur telescope making, the history of astronomy, celestial navigation, and most of all, observing.

Rectifying a 227-Year-Old Error: Stellar-remnant Nebulae

by Michael Harwood, Physics Teacher, H.B. Beal Secondary School, London, Ontario.

From 1782 to 1802, William Herschel carried out an extensive deep-sky survey. In his *Catalogue of One Thousand New Nebulae and Clusters of Stars*, he divided all nebulae into five classes, the fourth class being that of planetary nebula. These are described as "Stars with burs, with milky chevelure, with ſhort rays, remarkable ſhapes, &c." (Herschel, 1786, p. 492). He appears to have linked the nebulae to planets because of their milky appearance—having just made the remarkable discovery of Uranus five years earlier. For the past 227 years, astronomers have continued using this unfortunate and inaccurate term, even though William Huggins showed that planetary nebulae consist of hot gases by analyzing the spectrum of the Cat's Eye Nebula in 1864.

Since then, astronomers through the centuries have had to include notes such as the following by Balik (2007) whenever they communicate with the public:

> *The name "planetary nebula" is a misnomer. The name arose over a century ago when early astronomers looking through small and poor-quality telescopes saw these objects as compact, round, green-colored objects that reminded them of the view of Uranus. However, "planetary nebulae" are not made of planets, and no planets are visible within them.*

It is time for this error to be corrected.

I first encountered the problem with "planetary nebula" in May 2011, when I was teaching astronomy to a Grade 9 science class. While explaining the life cycle of stars to the students, I realized it didn't make sense to call the glowing cloud of gas expelled at the end of a red giant's life a planetary nebula, since it had nothing do with planets. After a couple of days of cogitating and poring over different types of nebulae, I coined the phrase "stellar-remnant nebula."

Stellar-remnant nebula is a more suitable name because

- it describes the origins of the nebulae more accurately
- the name parallels that of supernova-remnant nebulae
- one doesn't have to immediately explain that it has nothing to do with planets

It is encouraging that the term "stellar remnant" is already associated with planetary nebulae in astronomical literature. For example, in the textbook, *An Introduction to the Sun and Stars*, Green and Jones state, "[i]t thus seems to be the case that through most of the life of a star, severe mass loss occurs only when a planetary nebula is shed, with the resulting stellar remnant becoming a white dwarf, or when a massive star ends its life as a Type II supernova." (Green, 2004, p. 129)

Previous use of the term "stellar-remnant nebula"

On 2013 January 6, I created a Wikipedia page for "stellar-remnant nebula" that pointed to "planetary nebula" and then I also added the following bolded text to the entry for planetary nebula: "A planetary nebula**, more correctly known as a stellar remnant nebula,** is an emission nebula …." After updating the Wikipedia page for planetary nebula, I realized that a search needed to be done for any prior usage of the term. Employing Google, Yahoo, and Google Books searches, I discovered that this term has only ever been used very few other times, not always correctly.

For example, in a blog posted on 2010 March 23, astrophysics student Philip Stobbart used the term "stellar-remnant nebula" to refer to NGC 7822 (Stobbart, 2010). Alas, NGC 7822 is actually a giant molecular cloud of over 40 light-years in diameter that serves as a nursery for new stars to be born (Nemiroff, 2011). The name stellar-remnant nebula is not applicable to this object, as it already has a perfectly satisfactory name.

Is it unreasonable to expect that the astronomical community will adapt to this new name for planetary nebulae? Other significant corrections have occurred in the past: William Herschel's original name for Uranus: *Georgium Sidus* was rejected within eight years of his naming it. Some corrections have taken longer: the reclassification of Pluto occurred 76 years after its discovery in 1930.

Alternative names and abbreviations

Are there any other names that would be better than stellar-remnant nebulae to describe planetary nebulae? The only one I've come across in my research is the suggestion that "ejection nebula" be used instead of planetary nebula (Balick, 2007). However, the term "ejection nebula" is more general than "stellar-remnant nebula" and could be used to describe nebula that are ejected by various processes, rather than those that specifically cause planetary nebulae to form. Thus stellar-remnant nebula remains the more accurate term. The term "ejection nebula" also does not seem to be in common use in astronomical literature: an online search indicated only a few instances of the phrase. A typical example is the paper on the arXiv database entitled *Discovery of a Luminous Blue Variable with an Ejection Nebula Near the Quintuplet Cluster* (Mauerhan, 2010). The Pistol Nebula, a part of the Quintuplet Cluster, is an emission nebula created by a star so massive and luminous that it is throwing off enough material to create a pistol-shaped arc, which may be why the authors of the above paper are introducing a new category of nebulae.

The final remaining issue is deciding how to abbreviate "stellar-remnant nebula." Existing related abbreviations are the following (List of Astronomy Acronyms, n.d.):

PN	Planetary Nebula
SN	Supernova
SNe	plural
SNR	Supernova remnant (nebula)

Some possible abbreviations along with potential problems that they might have:

SR	perhaps not informative enough and can be confused with possible abbreviations the term "stellar remnant".
SRN	too similar to SNR and easy to confuse.
STR	(STellar Remnant) existing abbreviation for "street".
SLR	(SteLlar Remnant) existing abbreviation for "Single Lens Reflex" (camera).
STN	(STellar remnant Nebula) existing abbreviation for "station."
StRN	(STtellar Remnant Nebula) there are very few mixed case astronomical abbreviations.

It will be left to the astronomy community to decide on which to accept. ✶

Notes

For more information on the history of planetary nebula, see http://www.jenedo.info/histres.html

http://neilenglish.net/planetary-nebulae-through-history/

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Michael Harwood is a high-school physics teacher and a new member of the London Centre. In earlier years, he was a computer programmer for Dynix Library systems in Waterloo. He notes that his "… interest in astronomy is part of my wide-ranging interest in all areas of science and nature."

Figure 1 — Messier 94 is the brightest member in a group of about 20 galaxies lying at a distance of about 15 M ly in Canes Venatici. It is notable for its double-ring structure, the fainter of which is just visible in this 10-hour 20-minute image from Kerry-Ann Lecky Hepburn. Kerry-Ann used an 8″ Astro-Tech Ritchey-Chrétien telescope with a QHY-8 CCD camera.

Figure 2 — Last November, André Paquette stored up enough 27 million-year-old photons to give us this image of the edge-on galaxy NGC 891 in Andromeda. André works from his Barred Owl Observatory in Carp, Ontario. It is speculated that NGC 891 resembles our galaxy if it could be seen edge on. This photo was caught with a 14″ Celestron Edge HD at ƒ/11 using an Apogee Instruments Alta U16M camera. Exposure was 4.75 h in red, 4 h in green, and 5.5 h in blue; subframes ranged between 15 and 30 minutes.

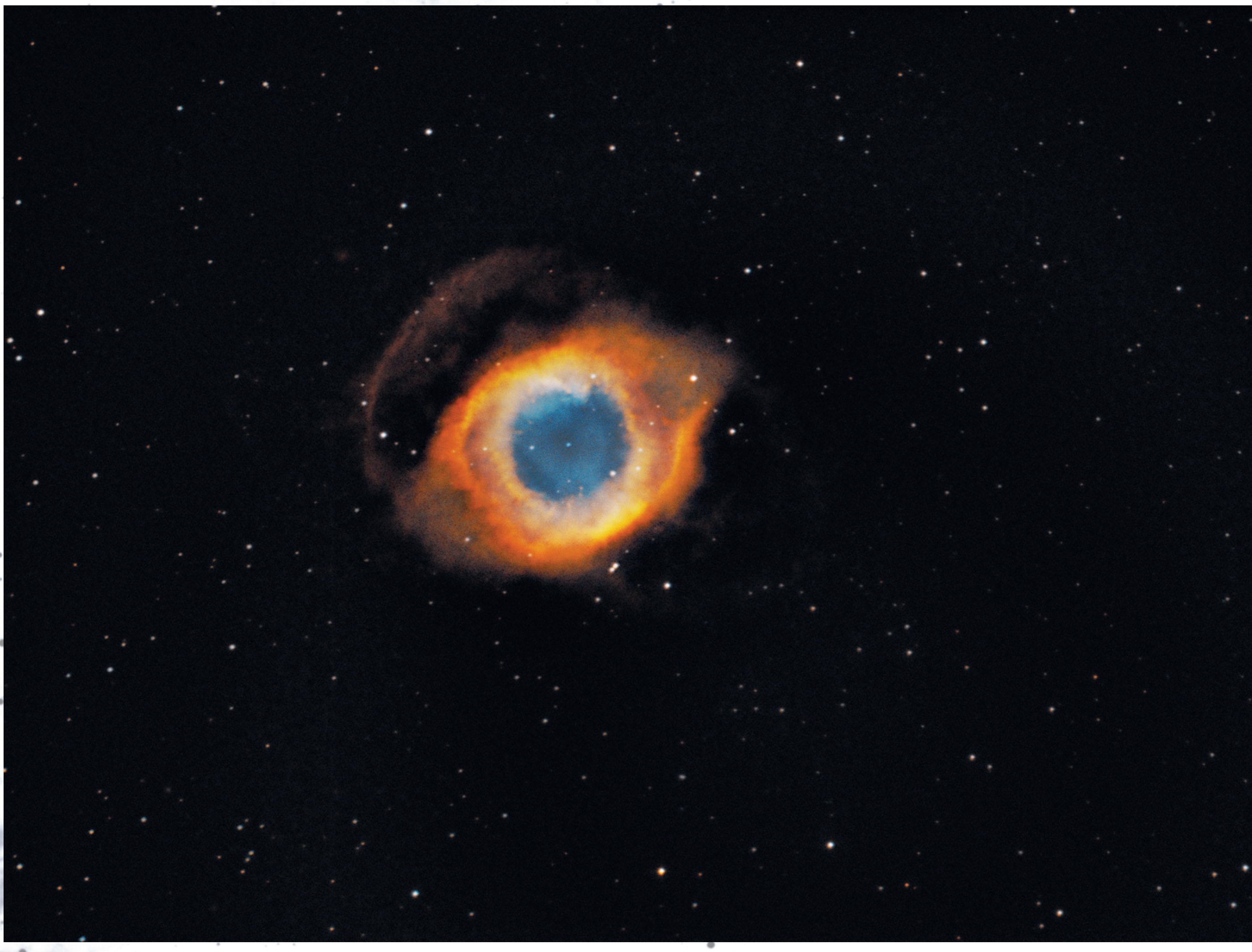

Figure 3 — Dalton Wilson captured this colourful image of the Helix Nebula (NGC 7293) last August from his observatory at Didsbury, Alberta. Dalton used an AstroTech 8" Newtonian, a QSI 583WS camera, and Astrodon Hα and OIII filters. Exposure in the two filters totalled nearly 7 hours. The Helix Nebula lies at a distance of 522 light-years in Aquarius.

Figure 4 — David Jenkins sent the Journal *this superb image of Jupiter showing the transit of Ganymede on December 5 last year. David used a Lumenera SkyNyx 2-2 CCD on a 12-inch Meade RCX-400 at f/24. He used the best 300 images from each of the RGB colour channels.*

Peter Millman and the Revitalization of the Meteoritical Society

by Howard Plotkin, University of Western Ontario and London Centre
(hplotkin@rogers.com)

Abstract

In 1962, Peter M. Millman was elected President of the Meteoritical Society. He used his office to help revitalize the nearly moribund society by healing personal divisions, re-establishing the society's journal, *Meteoritics*, and encouraging international membership. In 1963, he held the society's annual meeting in Ottawa, the first time it had met outside the U.S. A highlight of the meeting was a special symposium he organized on Current Research on Terrestrial Meteorite Craters. The symposium played an important role in showcasing the contributions being made by Canadian scientists in the search for Canadian impact structures and the development of criteria for their authentication. Millman himself played a key role in this development. At present, 30 meteorite craters have been authenticated in Canada.

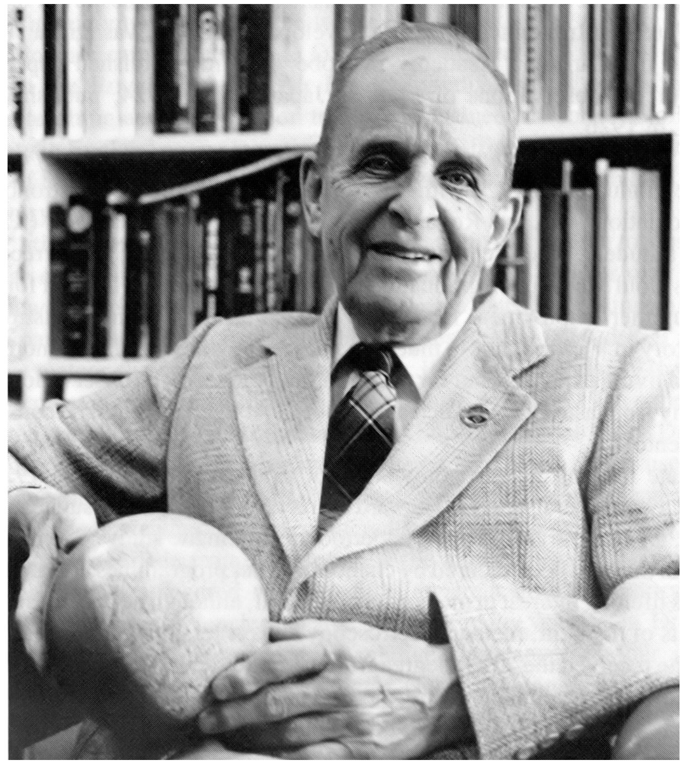

Figure 1 — Peter Mackenzie Millman (1906–1990), shown here in retirement. (After Halliday 1991, p. 67.)

Background

Peter Mackenzie Millman (1906–1990) was an exceptional scientist, with a broad range of interests and talents (Figure 1). As a postgraduate student at Harvard University in the early 1930s, he undertook a systematic study of meteor spectra under the direction of Harlow Shapley (1885–1972), the Director of the Harvard College Observatory (Tors and Orchiston 2009). This began his lifelong interest in meteors, and he became involved in all aspects of the field. Following stints as a staff member at the David Dunlap Observatory of the University of Toronto and as Chief of the Stellar Physics Division at the Dominion Observatory in Ottawa, Millman transferred to the National Research Council early in 1955. There, he became Head of the Upper Atmosphere Research Section, and oversaw the council's active meteor program.

He strongly felt that advances in meteor science should be brought to the attention of both other scientists and the general public alike. To this end, he wrote a regular column, "Meteor News," for the *Journal of The Royal Astronomical Society of Canada* (JRASC) beginning in January 1934. The column appeared in the JRASC through 1940, but lapsed during wartime, not starting up again until 1952. Altogether, more than 120 of his columns appeared in 25 volumes of the *Journal*. He also wrote a weekly newspaper column for the *Toronto Star* between 1940 and 1971, covering all aspects of meteor astronomy.

Millman was persuaded by John A. Russell (1913–2001), an astronomer at the University of Southern California and the Secretary of the Meteoritical Society, to join the society in 1957 (Marvin 1993, p. 280). His scientific abilities and his dedication to the society quickly led to his election as a councillor, a position he held from 1958 to 1962. Moreover, his skill as a writer brought him to the attention of the society's editor, Frederick C. Leonard (1896–1960), an astronomer at the University of California, Los Angeles, who had co-founded the society in 1933, was its president from 1933 to 1937, and served as editor for 26 years, from 1933 to 1959. In early February 1959, Leonard (1959a) wrote Millman, informing him he would like to end his stint as editor and would be delighted to pass it on to him. Millman (1959a) did not jump at this, but offered to serve as a kind of liaison officer between the Meteoritical Society and the JRASC, looking over any articles that Leonard thought suitable for publication in the *Journal*, and forwarding them to its editor.

Leonard (1959b) happily agreed to this, but continued to pursue his earlier idea: "Nothing would please me more than to be able to resign the editorship of the M[eteoritical] S[ociety] and to turn it over to you!" Moreover, he stated he would like to see the JRASC become the official publication organ of the Meteoritical Society. The society's first publication, *Contributions of the Society for Research on Meteorites* (the name was changed to *Contributions of the Meteoritical Society* when the society changed its name in 1946), was published as a section of the journal *Popular Astronomy* from 1933 to 1951. When *Popular Astronomy* ceased publication in 1952, the society instituted its own journal, *Meteoritics*, early in 1953. But, the paucity of first-rate articles to fill the new journal led to it ceasing publication in 1956 with the appearance of Volume 1, Number 4. With an increasing membership, the society now needed some sort of outlet for its publications once again.

Leonard's suggestion that the JRASC might fill this role was not as unusual an idea as might seem at first blush. For one thing, the Society was becoming truly international with an increasing number of non-U.S. members. Publication of the Society's articles in a journal published outside of the U.S. would nicely reflect that. And for another, the JRASC was then serving as the official publication medium of another organization, the American Association of Variable Star Observers. Millman (1959b) felt that the greatest difficulty to this idea was the fact that the *Journal* could only allow 18 pages per year (3 pages in each bi-monthly issue) for the Meteoritical Society's publications. Leonard (1959c) was dismayed, pointing out that the society had been allotted about 100 pages per year for its publications during the 18 years it published in *Popular Astronomy*.

In light of the JRASC page limitation, Leonard thought that the *American Journal of Science* might then be the best outlet for Meteoritical Society publications. Leonard (1959d) turned away from Millman, his first choice for editor, to the only other person he had been considering for the job, Dorrit Hoffleit (1907–2007), a former vice-president of the society, then at the Yale University Observatory. Since she was physically close to Philadelphia where the *American Journal of Science* was published, Leonard thought that this would greatly help facilitate editorial matters between editor and publisher. Hoffleit was duly nominated and elected to that position at the 22nd annual meeting of the society in September 1959.

But Millman's expertise in all aspects of meteorite science and the important role he played in other scientific organizations brought him to the attention of others in the Meteoritical Society (Halliday 1991). He was, for example, a dedicated member of the RASC for 65 years, having joined the Toronto Centre in 1925, had served as Librarian 1936–1946, President of the Ottawa Centre 1945–1950, National President 1960–1962, and Honorary President 1981–1985, and had served as a member or chairman of many other societies as well. In September 1961, Russell (1961), now the president of the society, wrote him a flattering, courting letter:

> *It is my understanding that in the past, the wishes of the President concerning his successor have at least been given special consideration. To the extent to which this may still be the case my wishes would be to have you!... No one is more widely respected in the field or would be of greater benefit to the Society.*

As a further incentive, Russell wrote that if it would help influence him in his decision and if he would find it more convenient to host a meeting of the society than to travel to one, he would seek Council approval for a meeting in Ottawa. Millman agreed to have his name placed in nomination, and was elected president of the society at its 25th annual meeting in September 1962.

Millman's Presidency of the Meteoritical Society

When Millman started his term as president, the Meteoritical Society was at a low point in its history. As Ursula Marvin (1993, p. 261), a Smithsonian Astrophysical Observatory meteoriticist who has written a masterful history of the society, explained, "Throughout the 1950s the Society was widely regarded as a small, disorganized and essentially moribund organization." Two of the society's most combative personalities, Harvey H. Nininger (1887–1986), a meteorite collector/dealer who had co-founded the society with Leonard, and Lincoln LaPaz (1897–1985), the Director of the Institute of Meteoritics at the University of New Mexico, engaged in heated, bitter disputes that carried over into society meetings, turning its membership into hostile factions. Although Nininger and Leonard had maintained a close professional and personal relationship for more than two decades, various events took place that led to tensions between them. Worse yet, Nininger became convinced that Leonard had switched his allegiance to LaPaz (Plotkin and Clarke 2008; Marvin 1993).

The final straw leading to the complete breakdown of relations between Nininger and LaPaz came as a result of the recovery of the Norton County meteorite. Following a spectacular fireball that exploded over Kansas on 1948 February 18, both men went to the area where they thought the meteorite's strewn field might be and asked farmers there to be on the lookout for fragments. Although over a hundred smaller fragments were quickly found, it was not until six months later, on August 16, that a farmer found the main mass, weighing nearly a ton, at the bottom of a 3-m-deep hole. Both men rushed to the farmer's field the same day. Shortly after Nininger and a helper climbed down the hole to begin to retrieve the meteorite, LaPaz and Leonard arrived. Both Nininger and LaPaz claimed rights to the meteorite. Since neither would yield, an auction was arranged by the absentee landlord, which was won by LaPaz through a joint bid from the University of New Mexico and the University of Nebraska.

The following month, when the Meteoritical Society held its annual meeting at the Institute of Meteoritics, Leonard gave an account of the finding and recovery of the meteorite with no mention of the role Nininger had played. Nininger strongly protested this omission in the account he gave. The following year, at the society's 1949 annual meeting, a colleague of LaPaz at the Institute of Meteoritics presented a paper on the meteorite that also made no mention of Nininger's role. Nininger was furious, and delivered a paper of his own in which he accused LaPaz—falsely—of waiting till he, Nininger, had located the approximate site of the fall before beginning his search.

The antagonisms between the two headstrong men, Nininger and LaPaz, were at this point so serious and disruptive that they were threatening to destroy the society. Something had to be done. Following the adjournment of the 1949 meeting, a special session of the society's council was convened. It claimed that Nininger had misused his membership "to turn a meeting of the society into a vehicle for unwarranted slander," and passed a resolution authorizing the president to give Nininger the opportunity to resign from the society, or else steps would be taken to enforce his resignation in accordance with the provisions of the society's constitution. Three days later, Nininger officially resigned from the society he had helped found. These events nearly wrecked the struggling society (Plotkin and Clarke 2008; Marvin 1993).

When Millman assumed his presidency of the Meteoritical Society some 13 years later, he endeavoured to utilize his considerable skills in negotiation and personal diplomacy to revitalize the weakened state in which he found the society. A golden opportunity presented itself in April 1963, and he seized the opportunity. Millman had heard that a new scientist at the Smithsonian Institution, Roy S. Clarke, Jr., was assuming some responsibility for meteorite work and arranged to pay him a courtesy visit. Clarke was then a chemist in the Division of Mineralogy and Petrology (later that year, the Department of Geology was reorganized, and the Division of Meteorites was created), but was becoming increasingly involved in the museum's meteorite program. At the time of Millman's visit, he was overseeing matters in the absence of Associate Curator Edward P. Henderson (1898–1992), who was en route to Australia with Brian Mason (1917–2009), the Curator of Mineralogy at the American Museum of Natural History in New York, on a meteorite- and tektite-collecting program. Clarke (1998) recounts that Millman told him he should come to the annual meeting of the Meteoritical Society that he was organizing for later in the year in Ottawa (he did), and talked of plans for strengthening the society. During their meeting, Clarke received a phone call from the museum guard saying that Nininger had unexpectedly shown up, and wished to come up and pay him a visit.

Millman was delighted to hear this, and used the chance meeting to encourage Nininger to let bygones be bygones, rejoin the society, and attend the Ottawa annual meeting. Clarke (1998) recalls that Millman explained to Nininger that the society's members would no longer be partisan, would be delighted to see him return, and would welcome him warmly. Nininger replied that he would consider rejoining if Millman would officially invite him to do so. Millman (1963a) did, with a formal letter written "on behalf of our Council and on behalf of myself, personally." In his letter, he stated:

> *I am most happy to send you a cordial invitation to renew your membership in the Meteoritical Society...I have also done quite a bit of thinking about what happened in the past history of the Meteoritical Society and I agree with you that I cannot see that there would be any point in rehashing old matters which neither of us approve of and which I am quite sure most, if not all, of the current members of the Meteoritical Society know nothing about. Such things are best forgotten and allowed to sink quietly into the limbo of the past.*

In a letter to the secretary of the society, Millman (1963b) explained "I am doing my best to promote good fellowship among all those working in meteoritics and I am glad to see that time is healing some of the old sores which didn't help our Society in the past." This was not lost on Russell (1963), who wrote:

> *This is a matter that I am sure rests upon the consciences of a number of old members of our Society. Regardless of what the initial circumstances were, the time has long passed when reconciliation is in order...I congratulate you for taking the step that many of us have thought of but none of us has had the courage to act upon in the past.*

Nininger rejoined the Meteoritical Society shortly thereafter, 30 years after he had co-founded it with Leonard.

The 1963 Meeting of the Meteoritical Society

With council approval, Millman arranged for the 26th annual meeting of the Meteoritical Society to be held in Ottawa October 7–8 at the invitation of the Associate Committee on Meteorites of the National Research Council. This was the first time the society held its annual meeting outside of the United States (Figure 2). On Sunday, October 6, some 50 members and guests of the society enjoyed a field trip to the Holleford meteorite crater, a short distance north of Kingston. The Holleford crater had only recently been discovered from Canadian Air Photo Library photographs in 1956. Stereoscopic photographs in the Library revealed a relatively shallow circular depression about 2.35 km in diameter and about 30 m deep, with some indication of a raised rim.

The discovery of this crater was a result of a systematic search of aerial photographs for suspected Canadian meteoritic impact structures undertaken by C.S. Beals (1899–1979) of the Dominion Observatory. At the observatory, Beals had earlier come under the influence of Millman, who brought to his attention Ralph Baldwin's (1912–2010) book *The Face of the Moon* (1949), a manuscript that became the "manifesto" of the impact revolution (Hoyt 1987, p. 360). Both Millman and Beals agreed with Baldwin that the lunar craters had meteoritic rather than volcanic origins. Together, they thought it

Figure 2 — Participants of the 26th meeting of the Meteoritical Society, 1963 October 7–8, Ottawa. (After Millman 1964, p. 44.).

should be possible to locate meteorite craters in Canada like those that pockmarked the lunar surface (Halliday 1991). Beals made such a search a major program at the Dominion Observatory (Hodgson 1994). As historian of science Richard Jarrell (2009, pp. 230-231) points out, the observatory was in a unique position to take the lead in such a program:

> *The Dominion Observatory, with Beals's blessing, had several advantages: it had a long history and expertise in gravity, magnetic and seismological research and it was a Division of the Department of Mines and Technical Surveys (which also controlled the Geological Survey of Canada). Over the following twenty-five years, most of the impact structures discovered and studied lay in the Canadian Shield, about which the Survey had firm knowledge.*

Millman had become keenly interested in meteorite craters in Canada following the discovery of the 3.4-km-wide Chubb Crater (later named Ungava Crater, then New Quebec Crater, and now Pingualuit Crater) in the northernmost region of Quebec and the pioneering expeditions there led by V. Ben Meen (1910–1971) of the Royal Ontario Museum of Geology and Mineralogy in 1950 and 1951 (Plotkin and Tait 2011). On the basis of Royal Canadian Air Force photographs, Millman (1956) undertook a topographic profile study of the crater that helped support Meen's contention that it had been formed by meteoritic impact. He also spent six days in July 1951with a group of scientists from the Dominion Observatory and the Geological Survey of Canada investigating the 3.8-km-wide Brent Crater in northeast Ontario, which had been noted the previous year on aerial photographs taken by a private company for the Canadian Government (Millman *et al.* 1960). The investigation that he and his colleagues carried out at the Brent Crater, employing gravity, seismic, and magnetic methods as well as a diamond-drilling program, became a model for all later impact crater studies.

As a result of his interest in Canadian meteorite craters and the Dominion Observatory's program of searching for them, Millman decided to include a special symposium entitled "Current Research on Terrestrial Meteorite Craters" at the 1963 Meteoritical Society meeting. Invited papers were presented by Eugene Shoemaker (1928–1997) of the U.S. Geological Survey on "Cryptovolcanic Structures in the United States"; E.C.T. Chao of the U.S. Geological Survey on "Petrographic Evidence of Impact Metamorphism"; Jack Green of North American Aviation, Inc. on "Morphological Distinctions Between Impact and Volcanic Craters"; M.J. Innes of the Dominion Observatory on "Recent Advances in Meteorite Research at the Dominion Observatory"; and Kenneth L. Currie of the Geological Survey of Canada on "On the Origin of Some 'Recent' Craters on the Canadian Shield." Of these five papers, the last two were of special significance to the program of searching for meteorite craters in Canada.

Innes (1907–1980) reviewed the Dominion Observatory's meteorite crater research program, with special attention paid to the New Quebec Crater and the 13-km-wide Deep Bay and 39-km-wide Carswell Lake Craters in northern Saskatchewan. Innes (1964) explained that since the principal characteristic of impact is that it is almost entirely a shock event, the resulting deformation alters the physical properties of the rock in the vicinity of the impact. Studies undertaken by him and others at the New Quebec Crater revealed well-defined negative gravity anomalies symmetrical with the crater. Innes interpreted this as being due to low-density fragmental material underlying the crater floor. Within a short time, research at a few other craters showed that such negative anomalies were general diagnostic features of meteorite craters.

Concerning the Deep Bay Crater, Innes stated its impact origin was clearly indicated by the intense fracturing and shattering of the granitic rocks in its vicinity and by the diamond-drilling program carried out there, which revealed intense deformation with a breccia zone underlying the sedimentary rock. Studies at the Carswell Lake Crater revealed a negative gravity anomaly similar to what was observed at the New Quebec Crater. Additionally, fragments of gneiss displayed radiating and striated surfaces characteristic of shatter cones, believed to be formed by high-velocity shock waves. Like negative gravity anomalies, the presence of shatter cones came to be seen as a diagnostic feature of meteorite craters.

Currie (b. 1934) was not as convinced of the meteoritic origin of terrestrial craters as Beals and Innes were. Currie (1964) noted that comparisons of the New Quebec Crater, the 26 km-wide Clearwater East and 36 km-wide Clearwater West Craters in northern Quebec, and the 100 km-wide Manicouagan Crater in Quebec showed that all four craters occurred on topographic highs of recent origin;

that the immediate areas of the craters were uplifted, and their edges showed signs of subsidence; and that the subsidence had been accompanied or followed by igneous activity. What was problematical, however, was what to make of all this. He felt that none of the craters could be explained either by the "classic" meteoritic impact hypothesis, or by analogy with known volcanic areas. Since no other known geological explanation could satisfactorily explain them, what was needed, he felt, was a deeper insight into the nature of geological processes than was presently available.

In addition to the crater symposium, two other papers presented at a later session were also devoted to Canadian meteorite craters: "A Comparative Structural and Petrographic Study of Probable Canadian Meteorite Craters" by Michael R. Dence of the Dominion Observatory, and "Sudbury Structure as an Astrobleme," by Robert S. Dietz of the U.S. Coast and Geodetic Survey. Dence (1964) examined data for ten circular structures in the Canadian Shield. He divided the 10 craters into two groups: 7 with diameters between 2 and about 20 km were in a group of "simple" craters, and 3 structures with diameters greater than 30 km were in a group of "complex" craters. All ten structures displayed a high degree of circularity, with the most obvious variations among them due to factors of size, age, and degree of erosion. The only major structural variation was the presence or absence of a central uplift of the basement gneisses; this was only present in the three complex craters.

Dence pointed out that all ten structures yielded a family of characteristics, including gravity, magnetic, and seismic characteristics, that was explainable by a model consisting of a basin of disrupted country rock. Surface investigations and diamond drilling at the crater; investigations of microscopic textures of rocks, including fracture cleavage in quartz and the breakdown of feldspar to glass, indicative of shock loading; evidence of fused material, seen as the ultimate result of shock metamorphism; and the presence of shatter cones in the larger craters confirmed this model in all important respects, and supported the craters' origins by meteoritic impact.

In the last of the Ottawa meeting papers that had special significance to Canadian meteorite craters, Dietz (1964) fleshed out the bold and entirely original idea he had presented a year earlier at the western national meeting of the American Geophysical Union, that the Sudbury structure, which he thought was a crater about 50 km across but is now recognized as having a diameter of about 250 km, was caused by the impact of a meteorite. Dietz termed the heavily eroded structure an "astrobleme" (from the Greek, meaning "star wound"), and thought it had been formed by the impact of a 4-km-wide meteorite some 1.7 billion years ago. His evidence for this was the upturned collar of rim rock surrounding the basin, and its great size, which could not easily be accounted for by explosive volcanism; the presence of shatter cones; and especially the presence of widespread and deep brecciation, indicative of intense impact-shock melting.

Dietz went on to offer the "tenuous" suggestion that the copper-rich, nickel-iron sulphide ore mined at Sudbury (about 30 percent of the world's nickel ore) is of meteoritic parenthood. He speculated that an incoming nickel-iron meteorite, upon hypervelocity impact, had smeared out as a liquid lining coating the explosion cavity, and was injected into tension cracks in the country rock wall. The impact also triggered a deep magmatic event, and the highly fractured condition of the crust beneath the impact site provided easy access for the magma generated in the deep crust to rise to the surface. Dietz's hypothesis had gained widespread attention but predominantly negative responses from geologists and geophysicists when it had been presented the previous year (Marvin 1993, p. 281). When Ursula Marvin suggested in the fall of 1962 that he be invited to Harvard to give a talk on the subject, the students threatened to boycott; Dietz was not invited (Bourgeois and Koppes 1998, p. 154, n. 147). At the Ottawa meeting, Dietz's idea received a much more positive response.

Besides these presentations, other activities at the Ottawa meeting included an open house at the Dominion Observatory, the viewing of the meteorite collection at the Geological Survey of Canada, and a picnic supper at the Springhill Meteor Observatory, a National Research Council site 32 km south of Ottawa that had begun operations in the summer of 1957(Millman 1964). By all accounts, the meeting was a huge success.

Conclusion

As President of the Meteoritical Society, Millman endeavoured to make it the foremost forum for research in meteoritics. To this end, he helped oversee the re-establishment of the society's journal, *Meteoritics*. The society was then in a position to contribute $1000 towards the publication costs, and the Barringer Crater Company assisted by covering the deficit (Russell 1962). The society's Editor, Dorrit Hoffleit, assumed the editorship of the renewed *Meteoritics*, and the new issue began with Volume 2, Number 1, dedicated to Leonard, who had died in June 1960. Millman solicited contributions from leading scientists, and kept in close contact with the journal's editor on the quality of submitted papers. As well, he encouraged international membership in the revitalized society.

The 1963 meeting of the Meteoritical Society in Ottawa was important for many reasons. After Millman persuaded Nininger to rejoin the society he had co-founded, Nininger attended the Ottawa meeting and presented a paper on "Meteoritical Increment as Viewed Through 40 Years of Field Work," and became a regular participant at meetings for many years thereafter. As Millman had hoped, this played a major role in helping to heal divisions among the society's membership that had festered for years, and had threatened to destroy it. In 1967, Nininger received the Leonard Medal, the Meteoritical Society's highest award.

Millman saw to it that most of the important papers presented at the Ottawa meeting were published in the society's rejuvenated journal, *Meteoritics*, and he continued to solicit papers for it from the leading scientists of the field. He also made endeavours to strengthen the society by inviting influential international scientists to its meeting. For the Ottawa meeting, for example, Millman (1963c) wrote the First Secretary of the Embassy of the Union of Soviet Socialist Republics to extend an invitation to E.L. Krinov (1906–1984), the Chairman of the Committee on Meteorites of the USSR Academy of Sciences. Unfortunately, Krinov was not able to attend.

Perhaps most importantly, the symposium that Millman organized at the Ottawa meeting on "Current Research on Terrestrial Meteorite Craters" showcased the important contributions being made by Canadian scientists towards meteorite crater research in Canada. In many ways, such a program was a natural one for Canadian scientists to undertake because of their long-standing work in geological, geophysical, and mapping studies. Canadian astronomers and geophysicists successfully joined forces in the search for meteorite impact craters on the Canadian Shield, and developed valuable criteria for their authentication. At present, 30 Canadian meteorite craters have been authenticated (Earth Impact Database 2006). ✶

Acknowledgments

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Second Light

A New Way to Measure Black-hole Masses

by Leslie J. Sage
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Astronomers have good reasons for thinking that all (or almost all) giant galaxies with spherical components—such as the bulge of the Milky Way—contain supermassive black holes with masses ranging from a few million solar masses to ten billion or so solar masses ($M_{\odot}$). But actually measuring their masses is complicated. Normally it is done by determining the "velocity dispersion" of stars near the centre of the galaxy (or sometimes using ionized gas). These optical observations find the range of velocities of stars using spectral lines in the stars' atmospheres. But they are tricky and time consuming to do. Timothy Davis of the European Southern Observatory and his colleagues have now demonstrated that it is possible to determine the black-hole mass using the motion of molecular gas (see the 2013 February 14 issue of *Nature*—it was published online on January 30). They observed the nearby lenticular galaxy NGC 4526 (observed by Joan Wrobel and myself 25 years ago in one of the first studies of molecular gas in galaxies other than spirals).

Not that this isn't tricky, too. It took them over 100 hours of observing time using the Combined Array for Research in Millimeter-wave Astronomy (CARMA), and they had to achieve a resolution of 0.25 arcseconds (20 pc at the 16.4 Mpc distance of NGC 4526). They used the emission from the carbon monoxide molecules that trace the dense molecular clouds from which stars form. From the data, they generated what astronomers call a "position-velocity diagram" (Figure 1) and then compared that to a range of computationally generated diagrams that went from no central black hole to a black hole with a mass of 1.2 billion $M_{\odot}$. They found that the best fit was to a black hole with a mass of 450 million $M_{\odot}$.

While it is clearly impractical to devote hundreds of hours to each galaxy, the Atacama Large Millimetre/submillimetre Array is in the final stages of construction in the high desert of Chile (https://science.nrao.edu/facilities/alma). This extraordinary instrument will soon be able to make the same observation in just five hours in a galaxy seven times farther away, or repeat the NGC 4526 measurement in about ten minutes. The technique therefore holds the promise of being able to determine black-hole masses across a range of galaxy types and masses using a single instrument. Davis and his colleagues estimate that this can realistically be done for hundreds of galaxies.

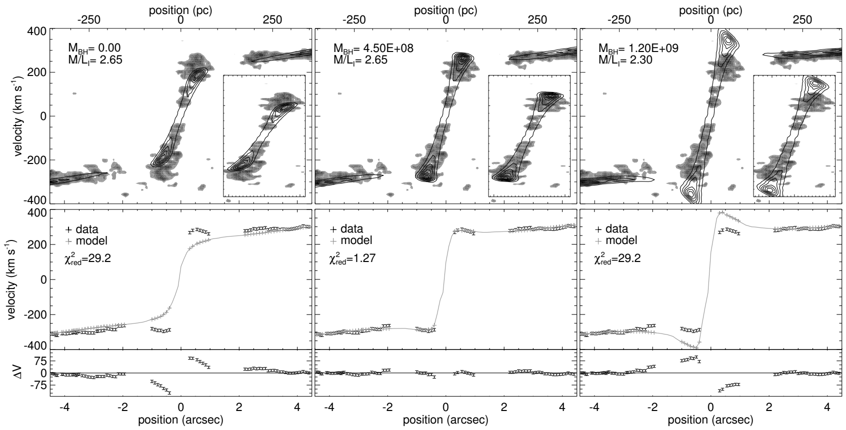

Figure 1 — In the upper three panels, the model position-velocity diagrams are shown with the black contours, while the CARMA data are in grayscale. In the lower three panels, the "residuals" (data minus model) are shown. The panels show the model with no black hole (left), the best fit (centre), and black-hole mass of 1.2 billion $M_{\odot}$ (right). Figure courtesy of T. Davis and Nature.

It has become clear in the last ten or so years that galaxies and their central black holes evolve together in a complicated way. When a lot of gas is falling into the black hole, enormous amounts of energy are radiated away in "active galaxies"—the most extreme example of which is a quasar. Davis is hopeful that once black-hole masses are available for a wide range of galaxies, the mechanics of this co-evolution will become clearer.

That is not to say that there are not problems associated with this technique. It is based upon the assumption that the gas is in uniform rotation around the centre of the galaxy, though we know that this is not always the case. Galaxies with gas rotating opposite to the stars or with counter-rotating components (molecular and atomic gas) are known, though not common. In some galaxies, the gas is rotating in a plane perpendicular to the stars. In these cases, it is not at all clear that the gas is truly reflecting only the gravitational influence of the black hole. Moreover, we know that near the centre of the Milky Way, some of the gas is turbulent with distinct non-circular motions. With these concerns—and others—in mind, I have to admit that I was skeptical when I first saw this paper. The point that this could be done seemed obvious, even trivial, but over time and with the addition of specific information about exactly what ALMA could do, I came to see the merits of the technique, and now I'm writing about it.

Science is great—facts and rational arguments can change minds! ✶

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

Cosmic Contemplations

The Untold Secrets of Making Your Own Monochrome DSLR

by Jim Chung, Toronto Centre
(jim_chung@sunshine.net)

My 16-year-old son stayed up all night doing whatever teenagers do these days with their friends online, and we subsequently opened our Christmas presents at 6 a.m. so that he could snatch a few hours of sleep before going out for brunch with my cousins. I didn't expect to see the new Leica Monochrom DSLR under the tree—and fortunately I didn't. Certainly, this $8,000 monochrome Kodak-sensored camera from the world's premier manufacturer topped this holiday season's wish list for astrophotographers everywhere.

The launch of the Leica Monochrom was greeted with derision by many amateur photographers who viewed it as an unnecessary backward step in development. Everyone knows that you can easily convert colour images into B&W with a simple desaturation command in *Photoshop* and most cameras even have this feature built in. At a price point $1,500 more than the conventional Leica M9 (on which the Monochrom is based), this was merely another limited-production niche product for the Leica collector, the poser who encases the camera behind glass never to see the light of a single photon. Astrophotographers familiar with the Canon 20Da and the current 60Da were much more charitable. We appreciated that a manufacturer was passionate enough to offer a model with an infrared cut-off filter (ICF) whose transmission profile had been subtly altered to pass hydrogen-alpha wavelengths. As astrophotographers, we also appreciated the many virtues intrinsic to monochrome imaging, namely increased sensitivity and resolution, particularly in special applications such as narrow-band deep-sky photography from urban centres.

DSLRs are typically one-shot colour cameras, and they accomplish this feat by having the CCD/CMOS sensor overlaid by a colour filter array (CFA) known as the Bayer layer. The technique was proposed by Bryce Bayer (pronounced BYE-er) in 1976 while working for Eastman Kodak, but sadly, he failed to gain the recognition due him when he died this past November. Red, green, and blue filters are laid in a checker-board style pattern so that colour information can be sampled by the sensor. There are twice as many green filters as red or blue, because the green channel doubles as the luminance channel. The green colour is the spread of wavelengths at which the monochromatic rod cells and the colour-perceiving M and L cone cells in the human retina

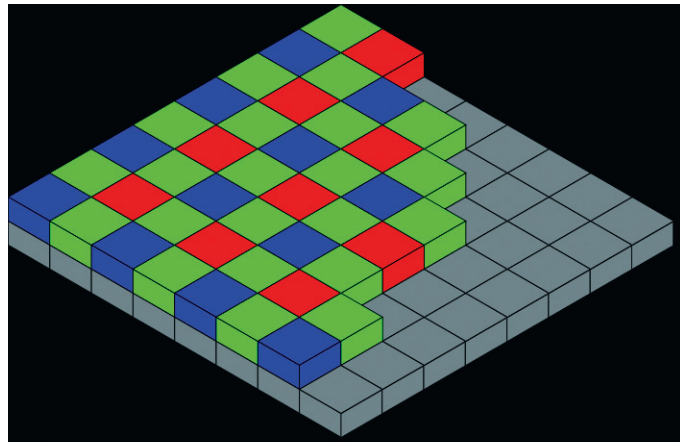

Figure 1 — Bayer Layer revealed, ubiquitous in 21st-century technology.

respond best. Since each pixel records data from only one of three colour channels, it cannot render true colour on its own, so the image is reconstructed with a demosaicing algorithm that interpolates the RGB value of each pixel based on the information gleaned from its neighbours. The green luminance channel provides the fine detail information that is overlaid onto the RGB image. Since the Bayer layer is rotated 45° (Figure 1), each green or luminance channel is sampled every $\sqrt{2}$ pixel spaces in either horizontal or vertical direction. In other words, your brand-new 18-megapixel DSLR is capable of a resolution some 2–3× less than advertised.

Figure 2 — Moiré distortion pattern caused by the Bayer layer.

It gets worse! The demosaicing algorithm can be fooled by finely patterned objects such as the weave on clothing (Figure 2), because the signal is severely undersampled by the Bayer layer. This is known as aliasing, an effect that causes different sampled signals to become identical or aliases of one another, resulting in a distorted image when the image is reconstructed. The resulting distortion is also known as a moiré pattern. According to the Nyquist-Shannon sampling theory, this problem can be avoided by sampling at twice the

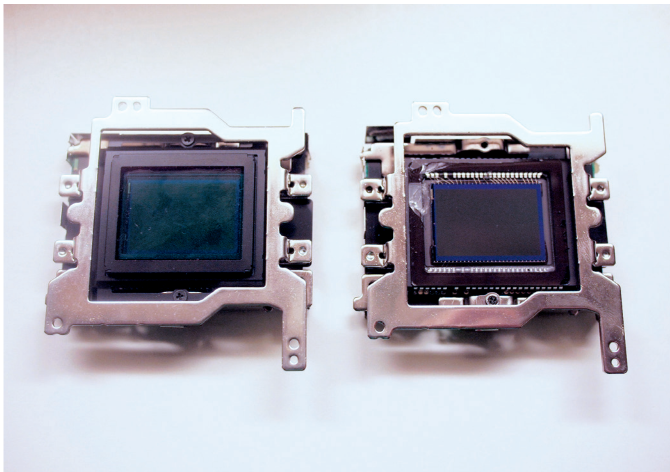

Figure 3 — Canon 10D CMOS sensors with ICF and AA filters, and without.

frequency or resolution of the maximum resolution of the entire image. Since we are already undersampling because of the Bayer layer, the maximum signal must be reduced and this is accomplished by utilizing a blur filter known as an antialiasing (AA) filter, usually found bonded to the ICF. This typically reduces resolution by 15–20 percent. The Leica Monochrom has no Bayer layer and hence no need for an AA filter, so its 18-MP sensor now has a resolution similar to a conventional DSLR with a 36- to 54-MP sensor. In practice, this is most apparent in narrowband astrophotography. The loss of the CFA automatically increases sensor sensitivity by more than one full aperture stop, but the ability of each pixel to record data during narrowband applications raises the final image's resolution enormously. In a typical DSLR, only the red pixels see Hα so 75 percent of the pixels record no data and you are essentially forced to resize your final image to one-fourth of its native resolution.

If you're like me, you can't afford to buy a Leica Monochrom. You could try to pick up 1 of 100 Kodak DCS760M DSLRs, made in 2001, on eBay, but they still go for $5,000. Or, try the 39-MP Phase One Achromatic medium-format digital back for $43,000, but you still need a compatible Hasselblad or Mamiya body.

A company based in New Jersey (www.maxmax.com) has been offering monochrome conversions of Canon DSLRs for the past two years. The procedure is not for the faint of heart and requires a clean room. Success is still variable enough that the company will not convert your camera for fear of destroying your sensor but rather sells preconverted units. The final thin sensor cover glass is removed and a 5-µm surface layer of the sensor removed with a proprietary substance to strip both the microlens and CFA (Figure 3) while not damaging the very thin gold wires (Figure 6) that connect the sensor to the substrate board's IC legs. A monochrome-converted Canon T3i goes for $2,000 and a Canon 5D Mk 3 for $6,500.

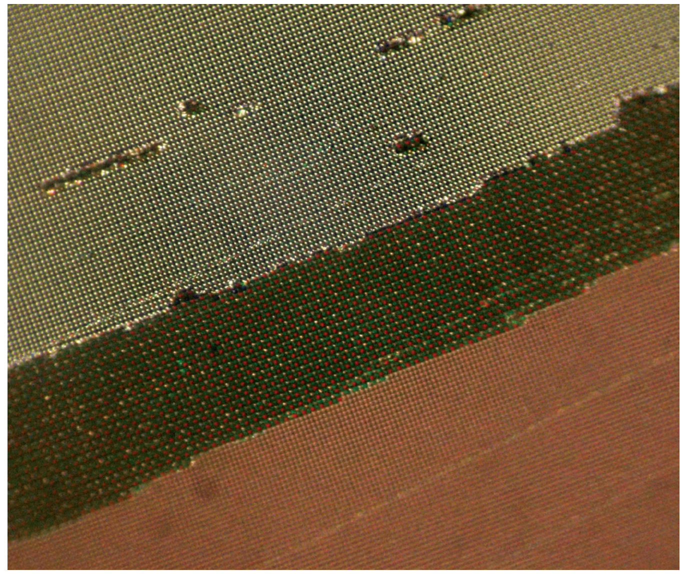

Figure 4 — 100× magnification image of Nikon D40 sensor surface.

It will be no surprise to regular readers that there is a third way, and that is to make your very own monochrome DSLR for under $200.

To keep the price economical (and failures financially bearable), I looked to the very first generation of DSLRs introduced only eight years ago. This would be the Canon 300D/10D and the Nikon D40/D50/D70 with 6.3-MP sensors. Canon makes their own CMOSs while Nikon uses CCDs made by Sony. These are very competent cameras that are typically lightly used and camera bodies without lenses can be found on Kijiji for a little over $100. Non-working bodies as a source for parts can be had for less than one-third of that amount.

Now the process requires a degree of mechanical aptitude, access to chemical reagents, and some specialized equipment. Dismantling the camera to free the sensor is the first step,

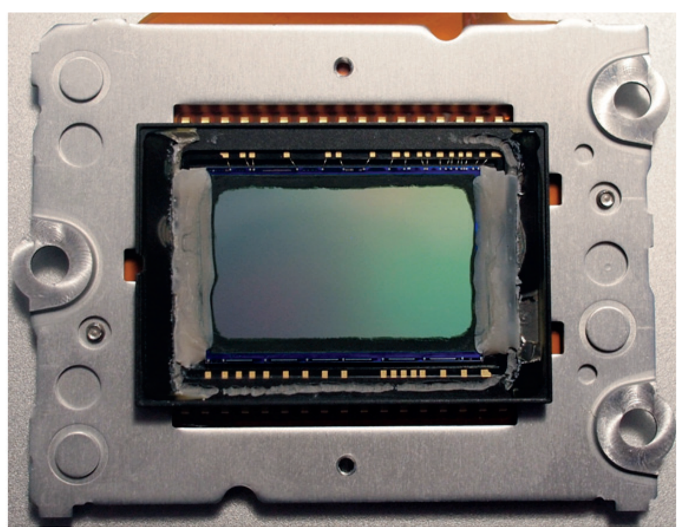

Figure 5 — Appearance of first successfully stripped D40 Sensor.

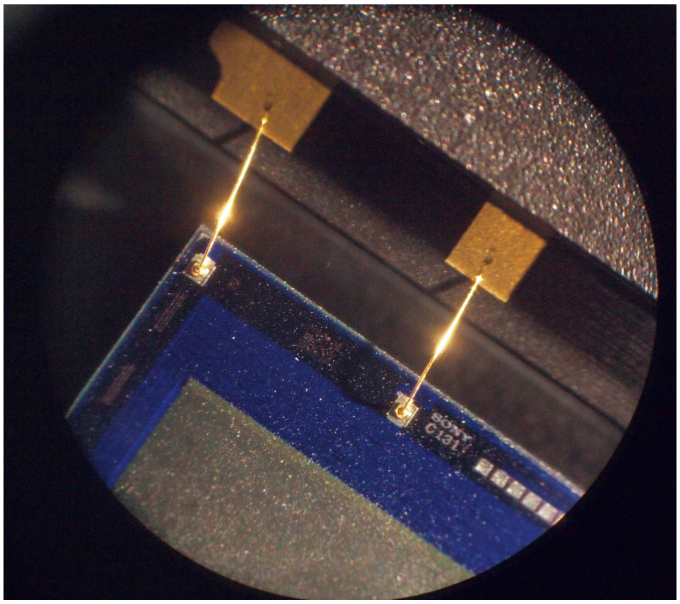

Figure 6 — Fragile gold connecting wires on D40 CCD sensor at 100× magnification.

and www.lifepixel.com provides some excellent video tutorials on how this can be done for several camera models. I would not attempt this without reference to somebody who has done it before because it's easy to damage the components if done out of order, and some desoldering is required. Since I'm a Canon owner with lots of lenses and accessories, I made my first attempt on some Canon 10Ds. Removing the thin sensor cover glass is very difficult, because it is epoxied onto the sensor housing and can only be removed by cutting it off. My day job allows me access to a 200,000-rpm electrically driven precision-cutting carbide drill and I performed this under 4× magnification wearing a pair of Carl Zeiss loupes to prevent damage to the sensor's fine gold-wire connections. There is some speculation that the microlens layer is made from polycarbonate plastic, so I immersed the sensor chip for several days in some chlorinated organic solvents such as chloroform (CHCl3) or dichloromethane (CH_2Cl_2) and then later in some toluene/methylethylketone mix that can be commonly sourced as lacquer thinner. The first two chemicals are very volatile and carcinogenic and should be handled inside a chemical fume hood. In lieu of such a facility, I sealed a glass Tupperware container within a large Ziploc freezer bag and placed that in one of my bathrooms with the door closed and the fan running overnight. I actually found an old Web thread from 2005 where two amateurs were able to dissolve away the CFA and microlens on a Nikon using heated chloroform, but this is very dangerous considering the low flash point of the reagent. I sourced the chloroform and dichloromethane from the University of Toronto Medstores (www.uoftmedstore.com) and prices were startlingly inexpensive, I just had to promise not to use them on my patients!

The solvent baths had absolutely no effect on the Canon 10D sensor, so, following another thread lead, I attempted to gently remove the CFA/microlens layers with a mild commercial abrasive paste sold to remove scratches and insect carcass remains from motorcycle helmet visors. Using a very soft rubber cup turning at 60 rpm, I was able to see layers being slowly ground away, but there was no way to control ablation depth, and I destroyed six sensors with no positive results using some less abrasive automotive clear-coat polishers, a razor blade, and some diamond-impregnated silicone polishing tips. The sensors passed the power-up diagnostics but produced no data. I destroyed the next sensor, which was from a Nikon D40, because Nikon secures their CCD chip to the substrate with only a spot of adhesive (Canon's method is much more robust). I was attempting to rub away the CFA/microlens layer with a cotton-tipped applicator (like a Q-tip), when I tore the CCD chip right off all its gold wire connections. Working with another sensor, I injected viscous, flowable bis-GMA light-cured dental resin material on either side of the CCD chip to secure it from movement and was able to slowly remove the CFA/microlens layer by gently rubbing with the same cotton-tipped applicators and microbrushes that I use on a daily basis, after subjecting the Nikon sensor to the same prolonged solvent bath. I confirmed the efficacy of this method by viewing the results under 100× microscope magnification (Figures 4 and 5). I was delighted to see the modified sensor produce an image when reinstalled back in the camera body.

The data from the raw Nikon files must be converted to a .tiff image file without undergoing demosaicing. This is conveniently done by an open-source program called *dcraw*, which is able to convert almost any camera raw file format in existence, including long-unsupported legacy models, by reverse engineering the myriad of encryption methods. The program operates from the command line and is written in C

Figure 7 — Nikon D40 with 135-mm lens, f/4, ISO 800, 1/80th-second shutter speed. Left: normal Bayer layer converted to grayscale. Right: camera with Bayer layer and microlens removed.

so it can be compiled on many platforms. I used *Terminal* in MacOS X to access its *Unix* command line:

./dcrawU –D –T *.NEF

to output the pure RAW data of any Nikon raw file without any demosaicing or scaling into a .tiff file.

Figure 7 is a photo of a box of crackers in my kitchen from a distance of about 4 m with both a normal Nikon D40 and the monochrome modified D40. There is significant improve-

Figure 8 — Check out the Hα cloud detail in only one hour of integration using ridiculously short subexposures!

ment in sharpness and reduced noise in the monochrome D40 as well as increased sensitivity of about a half aperture stop. The microlens layer serves to increase sensor sensitivity by focusing and concentrating light that would otherwise fall on non-photosensitive areas of the sensor, however, removal of the pigmented Bayer layer more than compensates for the loss of the microlens layer. The conventional D40 exhibits "colour noise" that manifests as abnormally coloured blemishes, which become even more apparent when converted to grayscale. Presumably this noise has its origins in errors in colour interpolation. The significant lack of this noise in the monochrome D40 means that it can be operated at higher ISO levels without sacrificing dynamic range; this is seen in performance tests of the Leica Monochrom as well. Such a benefit is especially good news for astrophotographers, as they are currently limited to shooting between ISO 400-800 to preserve that all-important dynamic range.

The older Canon and Nikon DSLRs are known for producing significant dark noise and amp-glow artifacts that are detrimental to long-exposure astrophotography. The next generation of Nikons switched to CMOS sensors manufactured by Sony, which have much better noise behaviour, as well as useful features such as Live View. I was successful at converting a Nikon D90 and was surprised by two unexpected benefits of this model. The CMOS chip has a much larger border than the CCD, allowing removal of the entire Bayer layer without straying too close to the gold-wire connection (Figure 6). The Nikon D90 also features a piezoelectric dust-vibrating glass window that is placed in front of the ICF/AA filters and that now acts as a *de facto* replacement sensor cover glass, preventing further intrusion of exterior contaminants. The very early results of a Nikon D90 conversion can be seen in Figure 8.

Current Nikon models offer CMOSs sourced from Sony, NEC, and Toshiba, but since I am familiar only with Sony's fabrication methods, I would restrict the use of this conversion method to the Nikon D2X, D90, D5000, D7000, D5100, D800, and D600. Most of these models are higher end and/or feature full-format sensors. The D7000 has a self-diagnostic shutter-speed monitor that uses an IR LED for timing, which may cause image fogging in long exposures. The D5100 model has emerged as a surprisingly economical ($450 CDN) camera with a swivel-mounted screen and 18-MP sensor that has been shown to have better noise performance of even the Canon 5D Mk3. I am happy to confirm that it can also be successfully converted to monochrome photography. ✶

Jim Chung has degrees in biochemistry and dentistry and has developed a particular interest for astrophotography over the past four years. He is also an avid rider and restorer of vintage motorcycles, which conveniently parlayed into ATM (amateur telescope maker) projects. His dream is to spend a month imaging in New Mexico away from the demands of work and family.

Through My Eyepiece

Through My Eyepiece: Music of the Spheres

by Geoff Gaherty, Toronto Centre
(geoff@foxmead.ca)

I just realized that I have never written here about music, which is odd because music has always been as much a part of my life as astronomy. I discovered classical music just around the time that I discovered astronomy, in my mid-teens. What hooked me was a series of live broadcasts by the Concertgebouw Orchestra under guest conductor Eugene Ormandy on Sunday afternoons, which I discovered when driving home from our cottage in the Laurentians. I was particularly taken by their performance of Sibelius' *Symphony Number 1*, which became one of my first classical record purchases.

When I joined the Montreal Centre in 1957, I discovered that many amateur astronomers shared my love of classical music. Klaus Brasch, Ken Chalk, George Wedge, and I often attended concerts together, especially summer concerts by the Montreal Symphony at the Chalet atop Mount Royal. An especially memorable event was the Montreal Symphony's first performance in the newly completed Place des Arts on 1963 September 21, where Zubin Mehta conducted Mahler's *Symphony Number 1*, a favourite of ours. If you look closely, you can see us four RASCals sitting at the right end of the last row of the third balcony.

Back at that time, I often used my new Sony transistor radio, bought to receive WWV and CHU time signals, to listen to music while at the eyepiece. I'd tune into WQXR in New York City, which came in quite clearly in the early evening. At the time it was one of the best classical music stations in the world.

Nowadays I never listen to music while observing. I find it distracting. I prefer the quiet and the natural sounds of the night: birds in the trees nearby and distant cows and coyotes.

In fact, I listen to very little music at any time. I *play* music with friends every week. We named our group Cassiopeia because there are five of us. I play lute—a modern reproduction of a lute made in Venice in 1595—and recorder, and the others play recorders, harp, and viola da gamba. We mostly play dance music from around the time of Galileo. Did you know that Galileo's father was an eminent composer and lutenist? I have a facsimile of one of Vincenzo Galilei's books of music published in 1584.

For the International Year of Astronomy, Toronto's baroque orchestra Tafelmusik put together a wonderful collage of words, music, and images on astronomical themes called *The Galileo Project*. (www.tafelmusik.org/watch-and-listen/playlists/playlist-galileo-project-music-spheres)

I'm particularly fond of the music written in the decades around 1600. This was a time of tremendous innovation in both astronomy and music. Astronomy became a true science in those decades, and baroque music has its roots in the same period.

Many astronomers have a strong interest in music, and many musicians have a strong interest in astronomy. The most famous is, of course, Sir William Herschel. Herschel came to England as a member of King George's company of musicians, and initially established himself as a music teacher in Bath. Later he got interested in astronomy, and started making telescopes and using them to explore the sky, becoming one of the greatest observational astronomers of all time.

I have a CD of some of Herschel's music. How can I put this politely? It's very pleasant music, but it's a good thing he quit his day job. Astronomy was his true calling.

The recent obituaries for Sir Patrick Moore reminded me that Patrick was a prolific and talented composer and pianist.

One of the reasons I don't listen to music much today is that I've absorbed so much music in my lifetime that it is always playing in my head. Every time I look at Jupiter through my telescope, the slow section of "Jupiter" from Holst's *The Planets* plays in my head, as fresh now as 50 years ago. Of course, *The Planets* is really astrological music rather than astronomical.

A recent discovery of mine is a march, *The Transit of Venus*, written by John Phillip Sousa to commemorate the 19th-century transits (http://en.wikipedia.org/wiki/File:Transit_Of_Venus_March.ogg).

Returning to my own band's favourite period, one of the dances we play was published in 1599 by Anthony Holborne—an almain entitled *The Night Watch*. Unlike Rembrandt's sombre painting of the same name, Holborne's dance is a cheerful upbeat ditty, the sort of thing to which I'd expect the celestial spheres to move. (www.youtube.com/watch?v=BN-WOGXYc-c) ✶

Geoff Gaherty received the Toronto Centre's Ostrander-Ramsay Award for excellence in writing, specifically for his JRASC column, Through My Eyepiece. Despite cold in the winter and mosquitoes in the summer, he still manages to pursue a variety of observations. He recently co-authored with Pedro Braganca his first iBook: 2012 Venus Transit.

Rising Stars

Nutwood Observatory: Where the Elk, Wild Birds, and Astronomers Roam

by John Crossen
(johnstargazer@xplornet.com)

What do a 2000-acre wildlife sanctuary/dark-sky preserve, teaching astrophotography, playing guitar in a 1960's pop group, starting a computer company, and holding a Ph.D. in physics have to do with each other?

If your name is Brian McGaffney, they are all integral parts of your life—a life that is exploring many aspects of science, especially astronomy.

Brian's interest in astronomy began early in school, where he built his own telescope in Grade 6. From grinding the mirror to final assembly in the optical tube and mount—Brian did it all. But, why stop there? A few months later, an interest in astrophotography clicked in when Brian took his first images of the Moon through the telescope.

But, astronomy is the mother of all sciences, so it wasn't long before Brian's growing list of interests encompassed numerous other disciplines. In high school, he won first place at the Ontario Science Fair with an experiment in electricity that, according to Brian, set the hair of one of the teachers on fire. His blazing interest in electronics and "how things work" eventually culminated with Brian starting up and operating a very successful computer company called Nortek Computers in North Bay, Ontario. Though he sold the company a decade later, Brian still does consulting work with the new owners. There were a few more ports-of-call on his ever-extending life journey.

Like many astronomers, Brian also had an interest in music. Following in the footsteps of Sir William Herschel, Brian May, Sir Patrick Moore, and Wayne Parker, he took up guitar and wound up in one of Toronto's top recording bands of the mid-60s. Today he keeps his musical interests alive in a small home-engineered recording studio.

On yet another creative front, Brian is an accomplished astro imager. His work has graced the pages of the *Journal* numerous times, and he frequently conducts imaging classes in Canada and the U.S. But his real gift to the astronomical community is a 2000-acre nature sanctuary and dedicated dark-sky preserve called Nutwood Observatory. Located just south of Bancroft, Ontario, the huge expanse of land is home to a herd of 70 elk, wild turkeys, the occasional wolf, and numerous birds. During the summer months, the population expands to include astronomers, astronomy clubs, and campers.

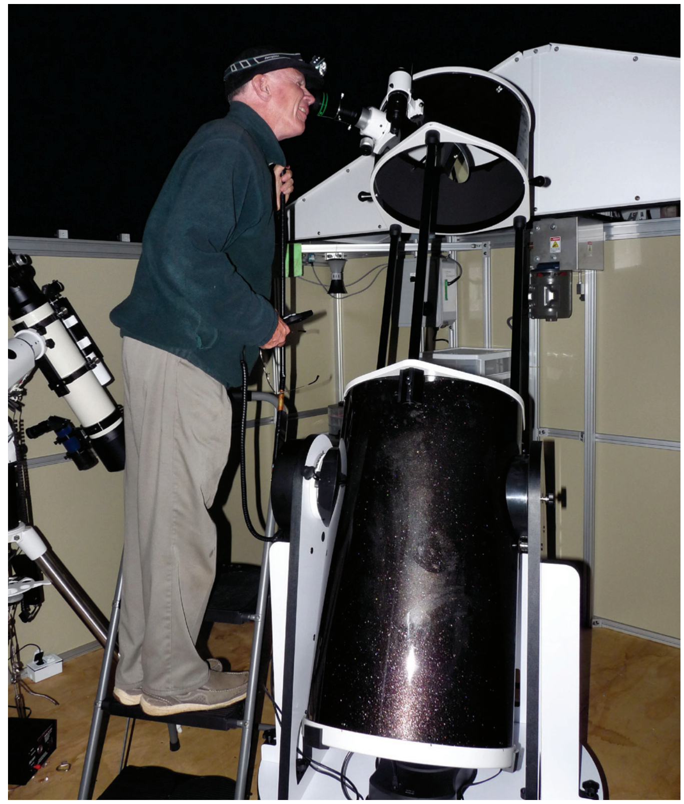

Figure 1 — Brian McGaffney enjoys "the view from the top" of the 16-inch SkyWatcher in the public observatory, where he gives sky tours on clear, warm nights.

The property is situated at an altitude of 730 metres, and if the dark sky is your calling, it is rated at 21.0 on the Unihedron sky meter with a 360-degree field of view. The observatories, as well as the observing areas, are situated in the most remote part of the reserve. During the day, there are trails for hiking, and the local flora and fauna make school field trips a fledgling botanist's delight.

From May 1 to October 30, a 12′× 12′ roll-off observatory is open to the public for regular observing nights. Naturally, your tour guide is Brian, who uses a number of different telescopes during guest visits. The public observatory is very well outfitted, with equipment ranging from a dedicated solar scope to a bino-equipped refractor, an SCT, and a giant 16-inch Dobsonian.

For the convenience of astronomers, he has built observing pads along with washrooms, running water, fire pits, and plenty of room for camping. It isn't unusual for campers to report elk wandering up and lying down near their campfires. It's a moment a family won't soon forget, especially the kids.

Brian invites astronomy clubs to visit the property for their annual star parties and promotes his own "Star Fest" during

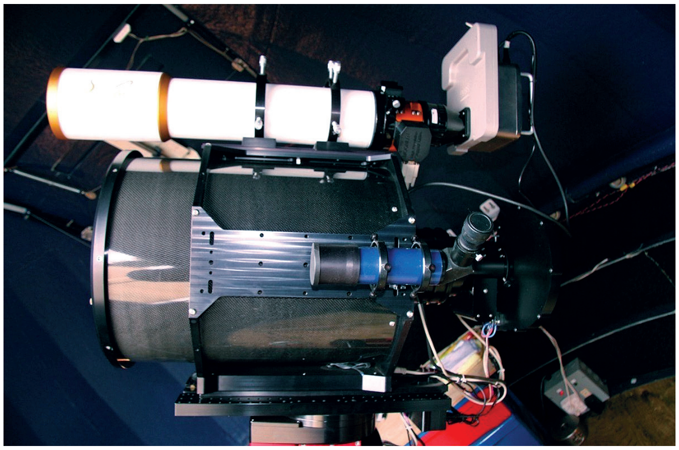

Figure 2 — The 14-inch Ceravolo Astrograph is outfitted with internal heaters and all the right stuff for a long night of imaging.

the summer months. He has all the facilities, and is happy to include a sky tour at the public observatory whenever the weather permits. Brian's outreach work also extends to schools in Toronto, North Bay, and Bancroft. He is a frequent guest speaker at local Shriners' youth groups and libraries, not to mention a Q&A link on his Web site. But, there's still more: astro imaging in the 12-foot dome.

Beneath the motorized dome are a 14-inch Ceravolo Astrograph and all the essentials for astrophotography. This is where Brian's imaging, creative, and technical skills come together, often with breathtaking results. Along with the raft of other electronic necessities, the imaging observatory is equipped with a network control router to forward data to his imaging students.

Nutwood Observatory is much more than a private sanctuary for an accomplished astronomer and imager. Brian wants as many people as possible to share his passion for the night sky and love of nature. Visit www.nutwood-observatory.com for a cyber-tour. To Brian, this is a dream come true. For light-polluted city dwellers, it is a welcome resource to be treasured and visited often. ✶

John Crossen has been interested in astronomy since growing up with a telescope in a small town. He owns www.buckhornobservatory.com, a public outreach facility just north of Buckhorn, Ontario.

Astronomical Art & Artifact

The Prehistory of the Society's Seal

by R.A. Rosenfeld, RASC Archivist
(randall.rosenfeld@utoronto.ca)

Abstract

An earlier article in this series explored the iconography of the direct ancestor of the Society's present seal introduced in 1905, and claims about its artistic parentage (Rosenfeld 2009). The saga of how the Society got its seal actually began in the closing years of the 19th century. The impassive muse who seals our fate was not the only contender a century ago, and certainly not the most novel. This episode can be read as a triumph of safe conservatism over innovation.

> *"Past research has identified tattoos as a way that people demonstrate their affiliation with or dedication to a group. Common uses for this type of tattooing include gang members...and modern primitives"* (Bloch 2011, 64).

Symbols of institutional identity, from grants of arms, badges, and seals to logos, "graphical identities," and "brands," can play a significant role in shaping a successful corporate ethos, forging living members into the very body and blood of their institution. Wear the badge, aspire to the ideals, become the symbol. Seals also perform a legal function, symbolizing authentication, assent, and sanction, but their dry impress does not preclude their possessing emotional associations. The perception that no institution can be fully formed without its symbols can almost seem instinctual. C.A. Chant, the undisputed Augustus of the Society throughout the first half of the century just past, wrote in 1905 that: "For a number of Years the Society has had under consideration the selection of a design for an official seal..." (TRASC 1905, 23). The story of the process can be partly traced in our surviving records, both in manuscript (MS) and print. A few of the competing models for the Society's seal can even be reconstructed, and they display some quite novel conceptual elements and are boldly in advance of the design that has marked us for over a century.

They also reveal something unsettling about our Victorian records, when one compares the account in the MS sources against the account in the printed sources.

Foraging and Gathering

The earliest printed reference to the desirability of the Society having a seal is found in the *Transactions of the Astronomical and Physical Society of Toronto* for 1895, reporting the minutes of a regular meeting of January 22:

> *Dr. Smith referred to several matters of business which it would be the special province of the Council to consider, and suggested that the question of designing a suitable seal to be attached to the Society's official documents, and which it was necessary for a corporate body to adopt, be discussed as early as possible* (TAPST 1895, 1). [1]

Curiously enough, no mention is made of the seal in the manuscript minutes of the same meeting (APST Minutes 1895, 156-157).

A committee was duly struck during the council meeting of 1895 March 12:

> *The Vice-Pres. [E.A. Meredith, or J.A. Patterson], Mess. Harvey, Stupart and Lumsden were appointed a committee to devise a suitable seal for the Societ[y]'s official documents* (APST Minutes 1895, n.p.).

The paper trail then runs cold. It would appear that Dr. Smith's attempt to impress upon his fellow members a measured sense of urgency in the matter of the seal was rewarded with a two-year silence. The lack of a paper trail may be deceptive, or it may be the telling product of inaction (such instances are, alas, not unknown in our history).

In the MS minutes for the Society meeting on 1897 March 30 we read that:

> *Mr. Arthur Harvey referred to a minute of Council under the Presidency of Dr. Larratt Smith authorizing the adoption of a seal for the Society's official documents and offered to donate the body and stand of the apparatus for making impressions, as soon as a design would be decided on by the Committee* (APST Minutes 1897, 332).

In the published version, this appears as:

> *The Secretary reported having received from the Vice-President, Mr. Arthur Harvey, the necessary apparatus for a seal to be used by the Society on official documents. A Committee had been appointed at a council meeting previously held, to consider the execution of a suitable design* (TASP 1898 10).

The accounts are not in full agreement. The published version does not allude to the council's authorization to "adopt" a seal,

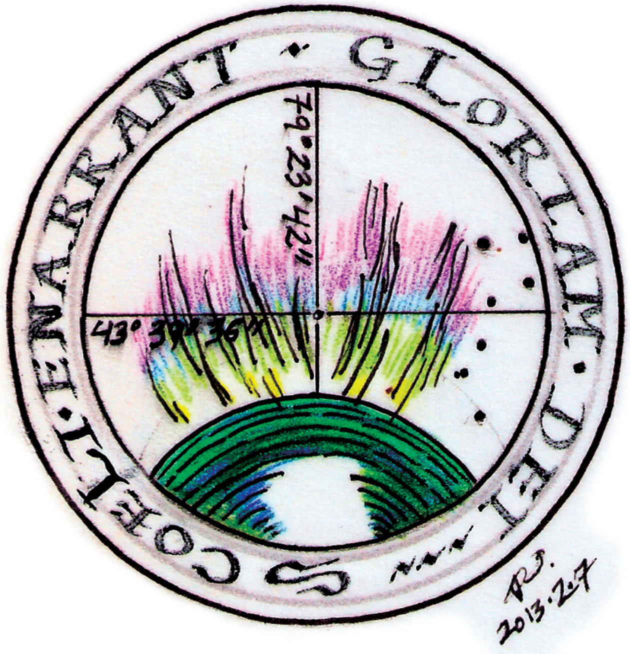

Figure 1 — Dr. E.A. Meredith's proposal for the Society's seal. The design is well-balanced, and the use of the aurora borealis is imaginative. Some would now object to the use of a biblical verse, and the indication of the geographical location of Toronto would doubtless also have its objectors. It did seem like a good idea in the 1890s. Redrawing by R.A. Rosenfeld based on Meredith's rough uncoloured sketch.

the nature of the "apparatus" cited in the published version is specified in the MS version, and what was stated as an offer in the MS version is reported as a gift received in the published account. What is clear from both MS and print versions is that the committee had seemingly transitioned from studied somnolence to a semblance of engagement.

The next notice appears in the MS minutes for 1897 October 12:

> *The assistant secretary [Thos. Lindsay] stated that he had received from Mr. Arthur Harvey a design for a seal for the society's official documents. It was decided to wait until the members of the committee had sent in designs when the matter of selection would be left to the council* (APST Minutes 1897, 375).

This information is omitted from the printed version of the minutes (TAPST 1897, 70), bringing to mind the inclusion of seal information in the printed version of the minutes of 1895 January 22 that was omitted from the MS version (see above).

The wording might imply that the members of the committee had among their duties the invention of possible designs for the seal, rather than the duty to act as a clearinghouse for designs submitted by members at large. Arthur Harvey, as a member of the committee, may have been obliged to submit

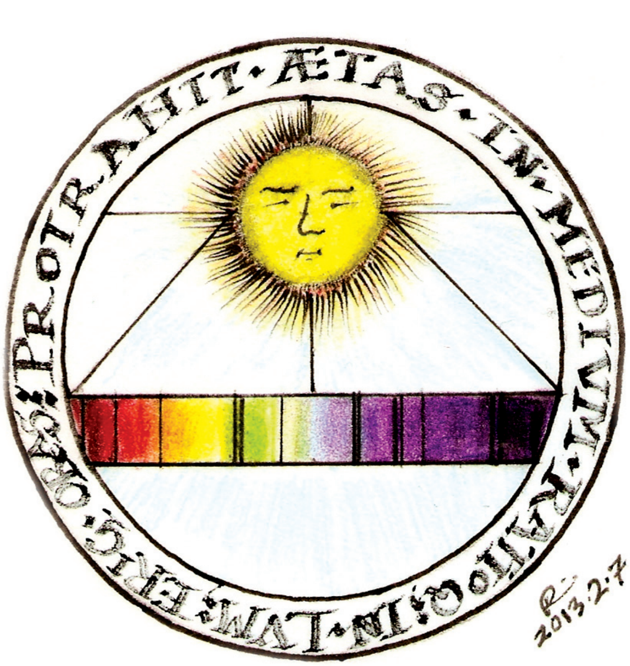

Figure 2 — A speculative reconstruction of Arthur Harvey's design for the Society's seal. The only definite detail known about his design is that it included a spectrum, a characteristic that made it very forward looking for the time. The reconstruction is by R.A. Rosenfeld in late-Victorian style. The inscription is from Lucretius De natura rerum, *V. 1452-1453, and can be rendered "Time brings every thing before our eyes, and reason raises it up into the borders of light."*

a design, and he may have been the first to do so. He was playing in a field that was tilted in his favour. It will be recalled that he had offered to donate the materials from which the seal would be constructed (his offer may have been to pay for the materials, rather than a direct donation of the materials themselves). His generosity doubtless engendered a sense of gratitude among his fellows, which may have unwittingly (or wittingly?) lent his design an unfair advantage over those of his competitors.

One of those competitors was councillor E.A. Meredith, of whom it was reported (1897 October 28):

> *The assistant secretary [Thos. Lindsay] stated that he had received from Dr. E.A. Meredith a design for the Society's seal. The committee would await a design from Mr. Lumsden and would then be able to bring forward a report* (APST Minutes 1897, 379).

(In yet another instance of disagreement of sources, no mention is made of this item in the printed version; TAPST 1897, 84). A page in Meredith's hand dated 1897 October 16, with a description and sketch of his design, survives (Figure 1):

> *Rough Design for a seal for the Astronomical & Physical Society of Toronto. The Meridian passing through the Pole Stars[!] should be marked with the Longitude of Toronto and the parallel of Latitude with the Latitude. This Wo[uld] seem to shew the locus of the Society. The coloured bank is Meant as a ~~OE~~ bank of Cloud from Which stream ~~Aur~~ Aurora borealis. It would be easy to put in some other Northern Constellation if thought advisable* (APST Minutes 1897, loose sheet).

Meredith's design is notable in several respects. Its inclusion of Polaris, a meridian, and parallel of latitude could refer to the fundamental geodetic nature of so much professional astronomy in Canada at that time and in the past. It was reasonable to incorporate into the design the specific latitude and longitude of the city in which the Society was founded, perpetuated, and hoped to thrive, but with the passage of time leading to a national Society with regional nodes, it now seems terribly parochial. Along with Polaris, two further evocative features of the northern skies iconographically symbolize the "Canadian" celestial identity: one is the northern lights, and the other is Ursa Maioris (the latter is also present on the current version of our seal). The aurora borealis was also a topical research interest of the time, in and beyond Canada. The proposed legend, "COELI ENARRANT GLORIAM DEI" ("The heavens declare the glory of God"), is from a Psalm verse that would have been familiar to every member of the late-Victorian Astronomical & Physical Society of Toronto, whether they were atheist or believer (*Biblia vulgata* 18:2; KJV 19:1). Most Society members of the time would have fallen into the latter category, which is probably the reverse of the situation at present.

Arthur Harvey's design doesn't appear to survive, although there is a very intriguing reference to its iconography in the damaged and not entirely legible minutes of the council meeting of 1897 November 20:

> *Seals presented by Mr. Harvey & Dr. Meredith & ////// Smith /// as to Prices & Sketches. Moved by Mr. Pursey sec[onded by] J.R. Collins that Mr. Harvey's Spectrum Sketch be///// Thank Dr. Meredith for his design & file.* (APST Minutes 1897, loose sheet).

If Arthur Harvey's design incorporated a representation of a spectrum, it exceeded Meredith's composition as an astronomically innovative visual marker of institutional identity, given spectroscopy's centrality to astrophysics, the "New Astronomy" (Figure 2). Few of those in the "active" category of Society membership—equivalent to today's "regular" members—were contributing to that science in any meaningful way, although some owned star spectroscopes (A.F. Miller, also on council, was an exception; Broughton 1994, 137). It was a different matter among the Society's Honorary Members, such as Sir William Huggins, Professors J.E. Keeler, E.C. Pickering, Hermann Vogel, G.E. Hale, Samuel Pierpont Langley (Secretary of the Smithsonian Institution, whose 1888 book *The New Astronomy* popularized the term), the Rev'd T.H.E.C. Espin, "uncle" Johnny Brashear (the premier maker of commercial Rowland gratings), and Miss Agnes M. Clerke (the premier chronicler of the "new astronomy," who learned

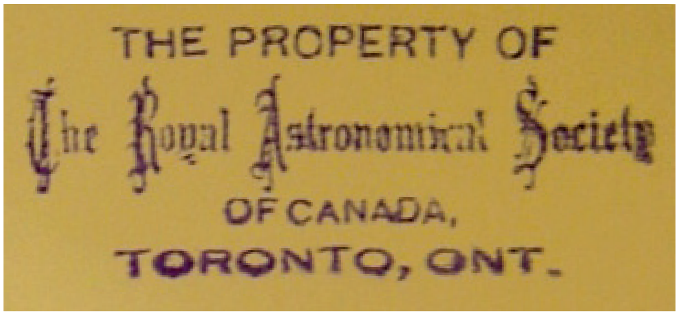

Figure 3 — A narrow escape. While a fine stamp for the 1900s, if Andrew Elvins and Thomas Lindsay had had their way, a similar stamp would have become our seal in the 1890s. It cannot be said to have much going for it in the way of evocative or inspirational astronomical imagery.

her spectroscopy under Sir David Gill at the Cape). Perhaps Harvey's design meant to honour those distinguished in astrophysics who honoured the Society by accepting honorary membership. Had Harvey's seal with a spectrum been adopted, it would have been a visual sign of the Society's commitment to the idea of "cutting-edge" astronomy, if not to the actual promotion of its meaningful practice among the rank and file membership.

The country had to wait for the opening of the Dominion Observatory before it saw the planning of a professional spectroscopic program of any significance conducted within its borders (Hearnshaw 1986, 172, 192). That year, 1905, was incidentally the same year the Society adopted the direct ancestor of its present seal, which incorporates no direct iconographical reference to astrophysics.

Is the "Smith" in this document Larratt W. Smith, and did he submit a sketch for a seal? What of George Lumsden's design mentioned in the MS minutes of 1897 October 28th? No enlightenment is forthcoming from the record of 1897 November 20.

Too few members were at the regular meeting of 1897 November 25 to discuss, or decide on any course in regard to choosing a seal based on the Committee's recommendation (APST Minutes 1897, 385; this item is also missing from the published version. The poor turnout may have been because it fell on Thanksgiving, a public holiday. It should be noted that the Committee's recommendation is not clear from the document of 1897 November 20). And, with that notice of inaction bred by general member apathy, we have heard the last of Dr. Meredith's and Arthur Harvey's proposed designs for the Society's seal. It cannot be said that we can reconstruct with certainty the reason why the project of a seal for the Society died out yet again. After the passage of nearly two years (1899 October 17), the matter was resurrected:

> *Mr. W.D. Musson opened up the subject of a device for the Society's seal. He described an engraving of Urania, a copy from one at the Vatican, which was particularly beautiful and reported a motto as given by Prof. Huntingdon "Mens agitat molem" ["Mind moves matter," from Virgil, Aeneid 6, 727].*

The President [G.E. Lumsden] reviewed other attempts at fixing on a device and thought it would be well for several members to bring forward what they thought would be appropriate and have the whole matter thoroughly debated" (APST Minutes 1899, 545; yet again the item is omitted from the published version in TAPST 1899, 60).

Musson's introduction of Urania, the Greco-Roman muse of astronomy, as a suitable subject for the seal of our Society, is the first mention of the triumphant principal iconographic feature of the RASC seal, which drove all other contenders from the field in 1905.

Society members may, or may not have heeded the president's advice. At the council meeting of 1900 February 3 it was decided to bring the subject before the members at "its next [regular] meeting [on 1900 February 20]" (TAS 1900, Report from Council February 3, n.p.). What transpired at that meeting was surprising in light of much that had gone before:

> *Mr. Elvins moved seconded by Mr. Lindsay that the stamp now in use be used as the Society's seal. After a brief discussion it was ruled that a motion was not necessary and the matter of the seal was allowed to stand* (TAS Minutes 1900, 12; omitted from TTAS 1900, 5-6).

This is surprising, because the Society's stamp bears no astronomical symbols or motto whatsoever; unlike the designs previously offered for consideration, it is devoid of potentially inspirational and imaginatively representational imagery (Figure 3). Its only advantages were that it already existed, was then in use, and seems to have been uncontroversial. The latter may be the key to understanding what happened, and what was not reported in either the MS or print versions of the minutes. It is possible that the choice of design from among those offered proved divisive, and Elvins and Lindsay wished to be peace-makers by presenting an interim solution they hoped would be neutral and equally unsatisfactory to all concerned, and therefore grudgingly acceptable. How else is the strangely timid proposal to be explained? However plausible, without further documentary evidence, this must remain mere speculation.

The next development is nearly a replay of what had gone before. At the meeting of 1900 October 16:

> *Mr. Arthur Harvey presented a design for a seal for the Society. The President [G.E. Lumsden] stated that he was prepared to receive others from members who wished to offer designs and that they would be duly considered* (TAS Minutes 1900, 71; omitted from TTAS 1900, 32-34).

and at the meeting of 1900 October 30:

The president reminded the Society that designs for a seal would be gladly received for consideration" (TAS Minutes 1900, 73; omitted from TTAS 1900, 34-35).

By now, the reader will not be surprised to learn that the president's request for more designs apparently fell on deaf ears. The next iteration of the regular non-periodic seal quest occurred on 1903 March 3:

> *The question of a suitable device for an official Seal was discussed and the members were asked to bring designs of same to be presented at the Meeting of Mar[ch] 17th* (RASC Minutes 1903, March 3, n.p.).

On that date:

> *Various designs of Seals were posted in the library [the RASC's library in the Canadian Institute] and the question of the adoption of a suitable device left over to a suitable meeting* (RASC Minutes 1903, March 17, n.p.).

That meeting never apparently happened, but by 1905, the Society, under the leadership of C.A. Chant, had apparently had enough of the regular non-periodic seal quest, and decided to put an end to the interminable indeterminacy by engineering the Society's choice of a seal. That story is told elsewhere (Rosenfeld 2009).[2]

Are Safe Choices Salutary Legacies?

Nineteenth-century seals of astronomical institutions often featured classical subjects. Urania was a popular feature, with her celestial globe, rule, and dividers. The past she evoked could be seen to embrace earlier astrometric enterprises, from Ptolemy's catalogue in the *Almagest* to the great stellar cataloguing projects of the age of Argelander, Airy, and Auwers. This was difficult and demanding micrometrical and meridian work. It was the "old" positional astronomy to which the recently developed astrophysics was the "new astronomy." The RASC and its immediate predecessors had a clear choice; populate its prospective seal with symbols of the old astronomy or the new. In designing its seal, the Society could have "gone boldly where none had gone before," graphically signalling its allegiance to innovative astrophysical work with an image of the aurora borealis as A.E. Meredith proposed, or better yet, a solar or stellar spectrum as Arthur Harvey urged. It could have followed the modernizing lead of its Honorary Members Huggins, Hale, Langley, and their peers. Instead, it chose a symbol of the old astronomy, the way of Newcomb and Christie, prestigious, exacting, and unexciting—the safe seal of Urania.

Canadian astrophysics, the work of J.S. Plaskett, Andrew McKellar, and C.S. Beals among others, did develop under Urania's aegis. Do symbols matter? What difference would a spectrum have made on our seal? Does an institutional graphic identity have any bearing on what, and how people do astronomy as members of that astronomical institution?

What of the sources from which this narrative has been constructed? It is regrettable that so much is missing, particularly sketches of the various designs. It is unsettling that there are major gaps and discrepancies between the MS and printed versions of the Society's minutes. Which record is the "right" one? Why is the record in the two media so different? It would seem that it is impossible to write the history of the RASC from either set of minutes alone. For this, Urania can hardly be blamed. ✶

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Endnotes

1 Brief biographical accounts of most of the figures mentioned in this study can be found in Broughton 1994, which is now available online at www.rasc.ca/looking-history-rasc.

2 I wish to thank Roy Bishop for alerting me to Helen Hogg's statement in the foreword to the 1990 *Observer's Handbook*, that C.A. Chant's daughter Etta was responsible for the design of the Society's seal. Thus far I have been unable to find any documentary support for this statement in our Archives; email of 2012 January 17 from R.L. Bishop to R.A. Rosenfeld.

R.A. Rosenfeld is the RASC's Archivist. He was trained as a palaeographer and codicologist at the Pontifical Institute of Mediaeval Studies, and specialized in the technologies of written communication ca. AD 500-1500. He won second prize in the Boeing-Griffith Observatory Science Writing Contest for 2008, and the 2009 Ostrander-Ramsay Award for excellence in astronomical writing (Toronto Centre, RASC), and received a Certificate of Appreciation from the IAU for contributions to IYA2009. In 2012, he won the Society's Simon Newcomb Award and the President's Award.

Rendezvous with the Stars!

54th General Assembly of the Royal Astronomical Society of Canada
June 27 - July 1, 2013

Come explore Thunder Bay, Canada's gateway to the west while attending the 54th General Assembly of the RASC. With features like the Sleeping Giant, Kakabeka Falls, Old Fort William (with the brand new David Thompson Observatory), and situated on the largest inland lake in the world, there is lots to see and do.

The GA is taking place on the beautiful campus of Lakehead University, located in the heart of Thunder Bay and on the banks of the McIntyre River. Most activities will be in the Advanced Technology & Academic Centre (ATAC) building. While you are there, don't forget to visit Mars! The Lakehead University Virtual Reality Environment (LUVRE) recreates stereoscopic 3D environments – as if you were really there.

Accommodations

Lakehead University will play host to us for the weekend. Guests can choose from a shared apartment-style room or a traditional dorm style accommodation.

Tours

There are four tours to select from.

Tour #1 – Friday June 28 – Fort William Historical Park with the David Thomson Observatory. From the fur trade to 21st century tech in one day!

Tour #2 – Monday July 1 All Day – Slate Islands – featuring shatter cones from meteor impacts (limited availability and weather permitting). Requires travel by boat.

Tour #3 – Monday July 1 AM – Ouimet Canyon, Eagle Canyon, Amethyst Mines, Terry Fox Monument. After viewing spectacular scenery, visit the spot where Canadian hero Terry Fox ended his run.

Tour #4 – Monday July 1 PM – Kakabeka Falls and Founders Museum.

More information at www.rasc.ca/events

Night Sky Photo Workshop

We will be hosting a three part night sky photography workshop, that will be instructed by Dennis Mammana. His photos capture the heavens in ways rarely seen, and incorporate the celestial with the terrestrial to provide a unique perspective for the viewer.

Speakers

Dr. Sara Seager from MIT will be our first keynote speaker after the Wine and Cheese. She will deliver a talk entitled – *Exoplanets and the Search for Habitable Worlds.*

The Ruth Northcott Memorial Lecturer will be **Dr. Raymond Carlburg**. He is the Canadian lead on the Thirty Meter Telescope from University of Toronto, and will be delivering a talk about the background of the project, why Canada is involved and it's current state of development.

Our banquet speaker will be **Dennis Mammana**. Dennis was an invited photographer with the IYA The World at Night (TWAN) project, and his talk will be entitled – *One People, One Sky.*

Society News

by James Edgar
(james@jamesedgar.ca)

By the time you read this, National Council meeting NC131 will be part of our history. These are momentous times, as we move along the continuum of changing our governance model. Not that we began the process ourselves; it came about as a result of changes to the Canada Corporations Act. That change spawned the Canada Not-for-profit Corporations Act (CNCA), which governs how we operate in the eyes of the law.

We weren't too far off base. Where we were lacking was in accountability—the government essentially asked "who elects the board of directors of your corporation?" Our board of directors is National Council, and it has been for many decades. The problem is that the Representatives on National Council aren't elected at all, in many cases. Some are appointed, some are elected by Centre executives, some just volunteer because nobody else would do it! The CNCA requires that the membership elect the board of directors, and the directors are accountable to the membership.

During our transition to operating under the new act, we had to declare that we wish to continue operating, that our board of directors will be a specified number (or a range), and what we intend to do as a not-for-profit corporation. The declaration is in the form called Articles of Continuance, which is published in the member's section of the Web at www.rasc.ca/system/files/private/Articles_of_Continuance_text.pdf. We filed the appropriate form and received the expected Certificate of Continuance. See www.rasc.ca/system/files/private/Cert_Cont_20130108.pdf. These documents were also filed with the Canada Revenue Agency. This means we have fulfilled our reporting obligations to the federal government. What remains is to formally approve the new By-Law #1 and the Policy Manual.

NC131 should have completed those last steps as far as National Council is concerned. The Society membership also has to pass those same documents before they become official. That will be at the Annual General Meeting on June 30 at the Thunder Bay GA. See you there! ✶

Astrocryptic Answers

by Curt Nason

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10 T	E	L	S	T	A	R	■	11 H	O	Y	L	E
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12 L	O	U	I	13 S	E	E	D	W	A	14 R	D	S
E	■	■	■	H	■	R	■	■	■	E	■	■
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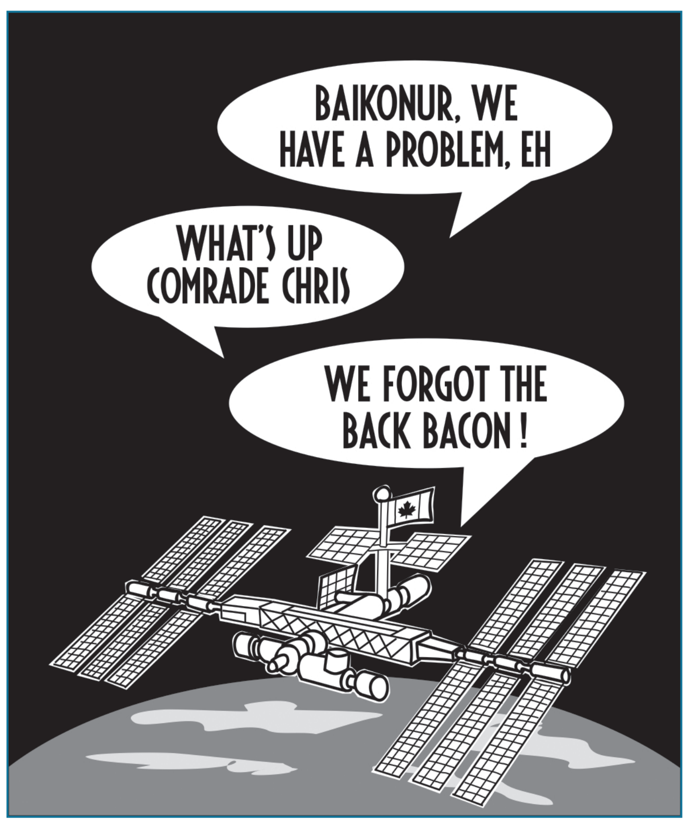
It's Not All Sirius

by Ted Dunphy



THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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The most current contact information and Web site addresses for all Centres are available at the Society's Web site: www.rasc.ca

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Journal

Great Images

Charles Banville returns to Journal *pages with this image of the waxing gibbous Moon-Jupiter conjunction on 2013 January 21. The photo was taken from West Bay Walkway in Esquimalt, B.C., using a Canon EOS 5D with a 24-mm ƒ/1.4 lens and an exposure of 1/10 sec. at ISO 800. The Moon and Jupiter performed this ballet for several months in a row this past winter.*