The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING ASTRONOMY IN CANADA

February/février 2015
Volume/volume 109
Number/numéro 1 [770]

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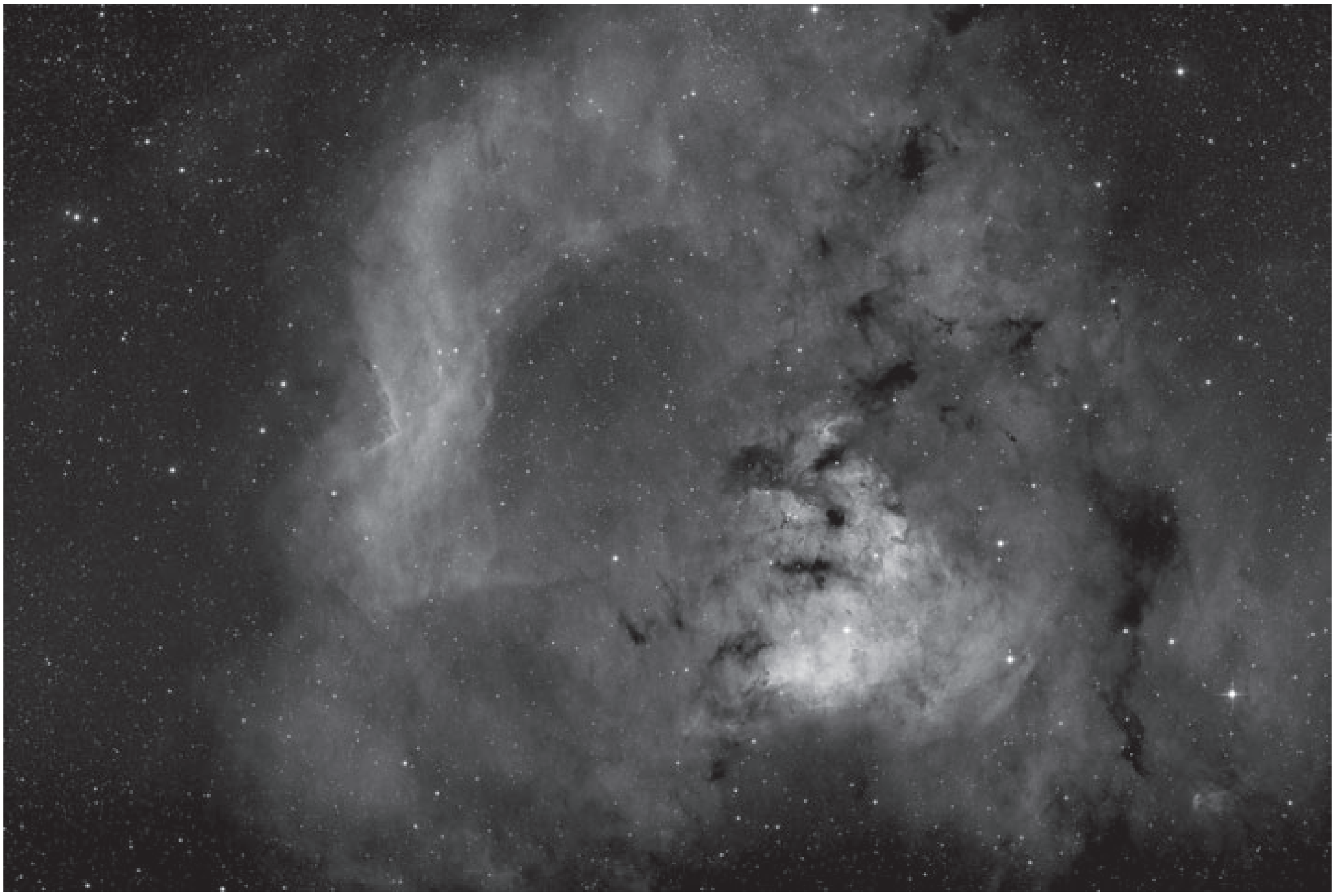
The Iris Nebula: a Study in Blue

The Best of Monochrome

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



James Black is a fan of Hα filters and long-exposure photography, rewarding Journal *readers with this image of NGC 7822 and Cederblad 214, two relatively nearby nebulae in Cepheus. While most images of this area focus on the concentration of dust and gas at the centre of the field (Cederblad 214), this photo shows the surrounding arc of nebulosity (NGC 7822) and its interesting "reef" of emission in the dense cloud of material on the left side. James uses a Takahashi FSQ106ED and a Starlight Xpress SXVR-H36 ccd camera for his photography.*

Free *Journal* Print Version!

All RASC members are receiving a print version of this issue of the *Journal*. It has been several years since the print version has been an option of membership. Since then, *Journal* Editor Jay Anderson and Production Manager James Edgar have turned the *Journal* into an admirable and valuable publication. All members receive a link to an online version via email, but we know not everyone reads it! There is valuable information in each *Journal*. We are hoping that all members will consider spending the $21 (average cost) on a subscription to the print version of the *Journal*. A real bargain @ $3.50 an issue!

To order a print version of the *Journal*, call the Society Office at (888) 924-7272 during business hours.

Note: the printed *Journal* can always be donated to your local school or library, doctor's or dentist's office.

Randy Attwood, FRASC
Executive Director

Journal

February/février 2015 | Vol. 109, No. 1 | Whole Number 770

Royal Astronomical Society of Canada

Société Royale d'Astronomie du Canada

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Front Cover — These clouds of intense blue dust and gas lie 1300 light-years away in Cepheus, spanning a diameter of about six light-years. The blue colour comes from the reflection of light from hot, blue stars by the dust grains in the nebula. A much larger area of surrounding dust and gas appears as an extensive brownish cast extending across much of the image. Dalton Wilson captured this impressive image of the Iris Nebula from Didsbury, Alberta, using an Astro-Tech 10″ RC with an Astrophysics CCDT67 reducer and a QSI583wsg camera. Exposure was 6×900s in L and 13×300s in each of RGB.

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.

The *Journal* of The Royal Astronomical Society of Canada is published at an annual subscription rate of $93.45 (including tax) by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Applications for subscriptions to the *Journal* or membership in the RASC and information on how to acquire back issues of the *Journal* can be obtained from:

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Toronto ON M9A 1B7, Canada

Email: nationaloffice@rasc.ca
Web site: www.rasc.ca
Telephone: (416) 924-7973
Fax: (416) 924-2911

Canadian Publications Mail Registration No. 09818
Canada Post: Send address changes to 203 – 4920 Dundas St W, Toronto ON M9A 1B7

Canada Post Publication Agreement No. 40069313
We acknowledge the financial support of the Government of Canada through the Canada Periodical Fund (CPF) for our publishing activities.

Canada

 ISSN 0035-872X

President's Corner

by James Edgar, Regina Centre
(james@jamesedgar.ca)

The Board of Directors has taken some time off at the end of the year, so no meetings are planned until January 2015. As I write this in early December, it seems a good time to reflect on the past year, its successes and failures. More of the former and less of the latter, if you please!

- One very great success was the election process of 2014. We managed to find nine willing and talented people to stand for the Board of Directors. Kudos to the Nominating Committee for their challenging and rewarding activity.

- We had it on the agenda last January to review the Society's funds and to decide if a change was important or necessary. We're still working on that!

- It is generally agreed that not including committee chairs and publications editors as part of the Council was a missed opportunity (read "bad idea!"). That has been corrected; the Honorary President and Past President are also now part of Council.

- While it isn't official, the suggestion to change the name from National Advisory Council to "Council" is gaining traction. This may be made into a motion at the next Council meeting and become a voting item to revise the By-Laws at the Annual General Meeting in July. (See? I'm doing it already.)

- The Board has established a set number of meetings throughout the coming months, and will invite specific committee chairs (or delegates) to attend a Board meeting to discuss their individual committee's activities, needs, and future plans.

- The Society has subscribed to WebEx, a video communication platform for use by the Board, Council, or committees to conduct meetings electronically—if not face-to-face. This is the next best thing!

- The Board revisited the 2014-2016 Strategic Plan to consolidate and more sharply define our long-term goals. One such goal was to initiate a sponsorship program—done! Another was to publish a guide to the total solar eclipse of 2017—coming soon (thank you, Jay Anderson, for your offer to guide this through!). A third goal was to increase our donations—it's happening. And, we wanted to more closely collaborate with the people at *SkyNews*—and we did. The *Getting Started in Astronomy* booklet is one of the first things to come out of this joint effort, as we continue our dialogue.

- We began selling Value Packs of promotional items on the eStore.
- We searched for and found a capable Executive Director in Randy Attwood to replace the hard-working Deborah Thompson, who moved on to a different career.
- The Board voted to approve sponsorship of the Clear Sky Chart; we're now the top sponsor!
- The Board and Council have agreed to relax the provisions of the Public Speaker Program to allow reimbursement of speaker's fees up to a maximum of $500.

There are many other small things that go on through an entire year, but these are some of the highlights—good and not so good. Every day and in every way, we try to get better and better.

On a different note, we welcome three new faces to our *Journal* team: Michele Arenburg (Halifax) as Editorial Assistant; Blake Nancarrow (Digital Universe) and Eric Rosolowsky (Dish Cosmos) as Contributing Editors.

Clear skies! James ✶

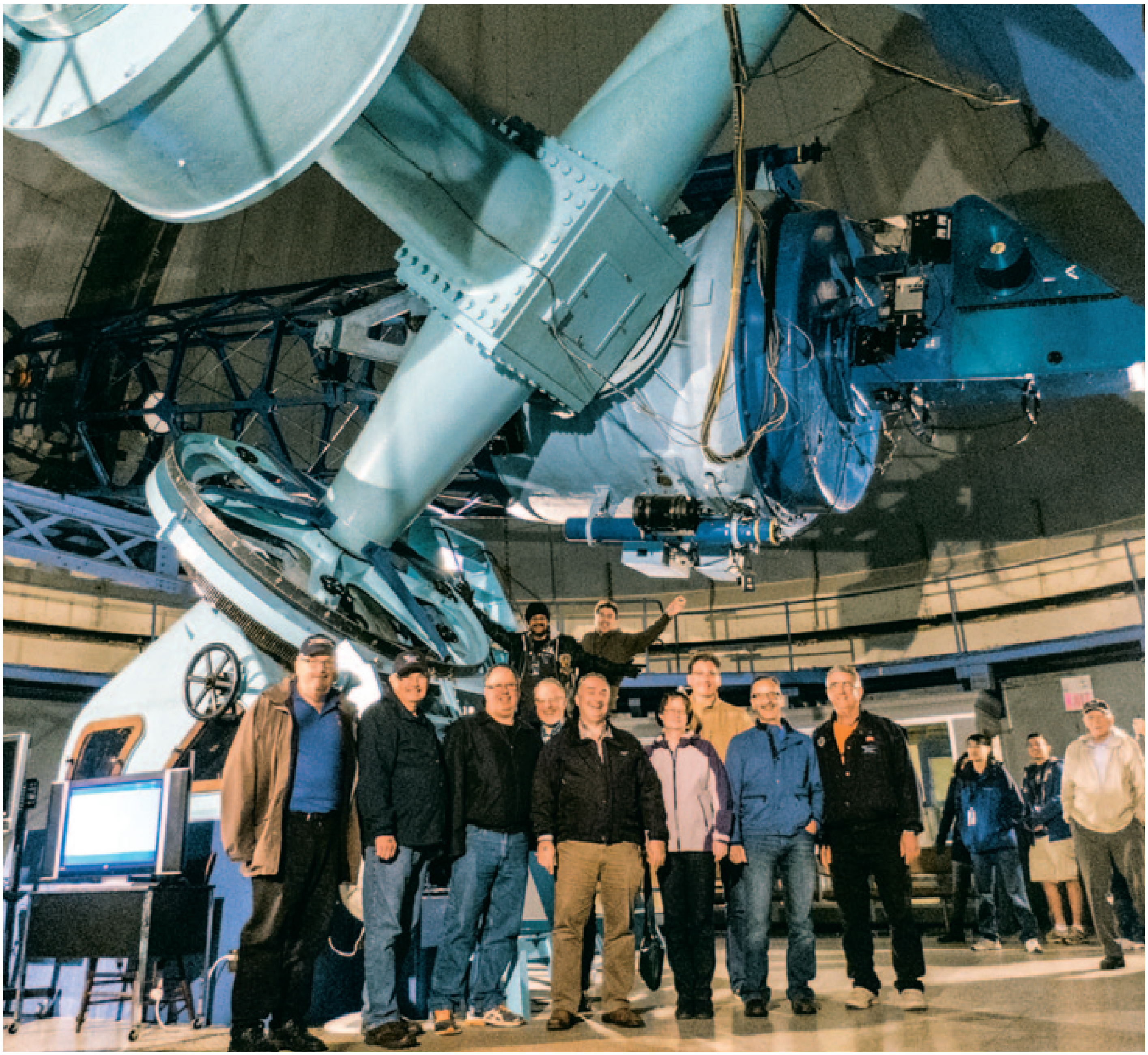

Figure 1 — The RASC Board of Directors met in Toronto in early October, visiting the David Dunlap Observatory on the 5th (missing, Denis Grey, but including the two "photo bombers," Rajesh Shukla and new Toronto Centre President, Paul Mortfield). Photo courtesy Sharmin Chowdhury.

News Notes / En manchettes

Maunakea Spectroscopic Explorer (MSE) Science Team begins development activities

An August 11, the MSE International Science Team met to begin the first steps leading to the development of a science case and the key science requirements in support of the construction of the Maunakea Spectroscopic Explorer. The MSE is envisaged as a 10-m class telescope devoted entirely to spectroscopic observations. It would replace the Canada-France-Hawaii Telescope (CFHT), using much of the CFHT's infrastructure and its site on the peak of Mauna Kea. That site is regarded as one of the best on the mountain.

Figure 1 — The current Canada-France-Hawaii Telescope.

The Science Team is formed of more than 60 astronomers who have volunteered to become a part of the development effort for the new instrument. The members of the team include representatives from across the globe, including Australia, Canada, China, France, Italy, India, Japan, Republic of Korea, Spain, Taiwan, the UK, and the USA. Their first tasks will be to draft a White Paper outlining the key science areas that would be investigated by a new telescope. Once this is done, the key capabilities of a future instrument can be defined.

The MSE would be the only astronomical facility in the world devoted to spectroscopic surveys if the project is completed. According to the MSE Web site (http://mse.cfht.hawaii.edu/project/):

> *Previous engineering studies establish that CFHT's existing summit facility can be modified to support a much larger telescope within the current CFHT footprint. By reusing much of the existing structure and pier, the facility can be upgraded while minimizing the work at the summit and impact on the surrounding summit ridge.*
>
> *When operational, MSE will bridge existing large-sky surveys and the next generation of telescopes. Large surveys, like SDSS, PanSTARRS and CFHT's own Legacy Survey, image millions of faint galaxies and stars. However, there is no other planned or existing facility that can target these faint objects in the numbers required to provide the spectra that are critical to better understand their astrophysical properties and so fully exploit the scientific potential of these datasets. MSE will fill that observational void.*

It has been projected that a fast 10-m telescope could acquire 3000 spectra per hour, or more than 7 million per year. Such a trove of data would allow statistical analysis and characterization of groups of astronomical objects and the identification of rare objects that could be investigated in more detail.

A Project Office was established in March last year with the initial goal of developing a full construction proposal over the next several years. This first phase is tentatively scheduled for review in 2017. Phase 2 will be the decommissioning of the CFHT and the construction of the new facility; phase 3 will begin when the new instrument becomes operational. Rebuilding and re-instrumenting an observatory is a familiar activity to the members of the RASC and now the professionals are following a similar path.

The new project is feasible because the CFHT was built in the 1970s using techniques and design parameters of the time. New telescope designs are much lighter, have much shorter focal ratios, and use a smaller alt-azimuthal mounting; the overbuilt and rugged construction of 45 years ago can be reborn as a new instrument. The current dome volume and support structure is capable of holding the 10-m Keck Telescope, though the slit width is too narrow to accommodate the larger mirror.

Should the project go ahead to completion, Canada's role as a major astronomy centre would be solidified for many more decades.

Now the neighbouring Universe all makes sense

Astronomers from the USA, France, and Israel have mapped the structure of the Universe across the closest half-billion light-years and identified the boundaries of our "home" supercluster, which they have named Laniakea, from the Hawaiian words for "immeasurable heaven." Led by Brent Tulley of the University of Hawaii, and published in the September 3 issue of *Nature*, the team used the Keck Telescope on Mauna Kea to measure the distance and radial velocity of 8000 galaxies in the surrounding part of our Universe. After subtracting the velocity component due to the expansion of the Universe from each of the radial velocities, the team was left with a distance map of peculiar (*i.e.* individual) velocities, which could then be assembled into a diagram showing the streaming of galaxies in the local Universe. Because the peculiar velocities of the galaxies are responding to local gravitational fields, the map developed

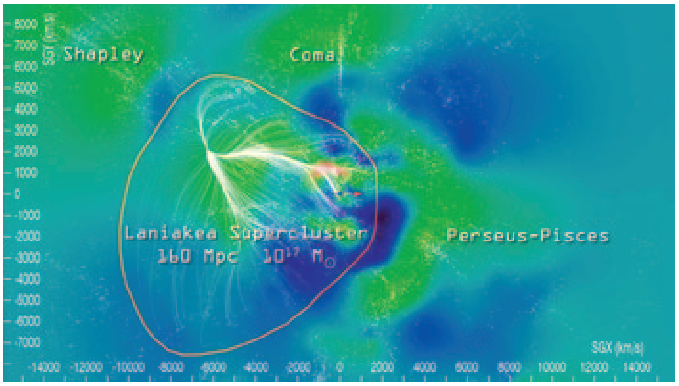

Figure 2 — This image shows a plane cut through the Laniakea supercluster. The Milky Way galaxy is the blue dot; each white dot is another galaxy. The white streamlines represent the flow revealed by the peculiar velocities of the galaxies, converging in the Norma Supercluster and the site of the Great Attractor. The background colours represent matter densities, with blue being less and green more. The orange line represents the boundary of Laniakea. Image: Nature

by Tully and his team reveals the gravitational structure of our and nearby superclusters, and includes the effects of dark matter as well as visible structures.

The technique used by the team has been compared to mapping watersheds on the Earth, in which streams and rivers flow according to the topography and separate from the flows of adjoining watersheds. And, just as a single watershed may contain many streams, rivers, and lakes, so are there counterparts in the galactic flows of Laniakea.

Laniakea spans a distance of 400 million light-years and contains an estimated 100 quadrillion (1017) suns in 100,000 large galaxies. Many well-known clusters are members of our little part of the Universe: the Virgo Cluster and Supercluster, the Local Group, the Pavo-Indus Supercluster, the Fornax-Eridanus Cloud, along with internal structures such as The Arch (part of the galactic wall surrounding the Local Void) and the Antlia Wall. Our next-door neighbours, each with their own characteristic flows, are the Perseus-Pisces group, the Coma group, and the Shapley group.

One consequence of the mapping done by the research team is the identification of The Great Attractor—the point at which galaxies in our local supercluster appear to be moving. The Great Attractor is the gravitational centre of Laniakea, located in the Norma Supercluster; it has been a bit of a mystery for a number of decades.

The other authors of the *Nature* paper are Hélène Courtois (University Claude Bernard Lyon 1, Lyon, France), Yehuda Hoffman (Racah Institute of Physics, Hebrew University, Jerusalem), and Daniel Pomarède (Institute of Research on Fundamental Laws of the Universe, CEA/Saclay, France).

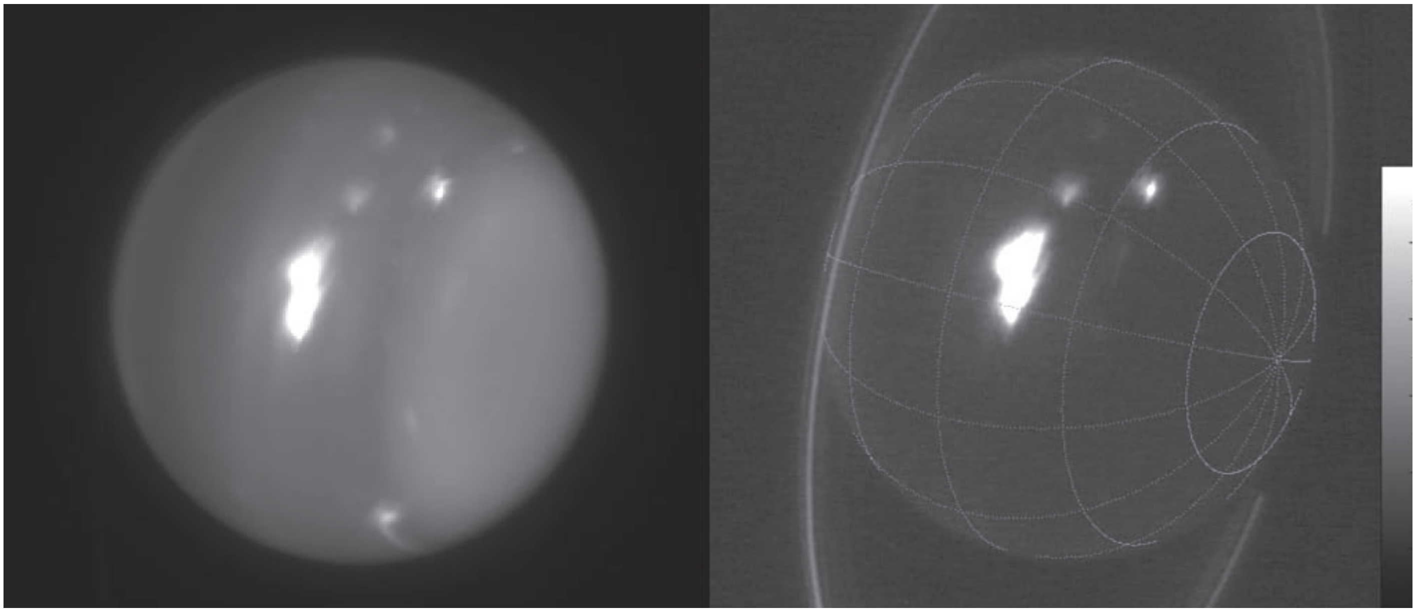

Figure 3 — Infrared images of Uranus (1.6 and 2.2 microns) obtained on 2014 August 6 with adaptive optics on the 10-m Keck II telescope. The white spot is an extremely large storm that was brighter than any feature ever recorded on the planet in the 2.2-micron band. The cloud rotating into view at the lower-right limb grew into the large storm that was seen by amateur astronomers at visible wavelengths. Image: Imke de Pater (UC Berkeley) & W.M. Keck Observatory.

Uranus kicks up a storm

The normally featureless face of Uranus has unexpectedly developed blemishes as the weather on the planet becomes more active. Using the Keck Observatory telescopes on Mauna Kea in Hawaii, a team led by Heidi Hammel of the Association of Universities for Research in Astronomy has detected eight large storm systems circling the planet. One was the brightest ever seen on Uranus.

Astronomers viewed the planet at a wavelength of 2.2 microns, a wavelength that arises from a layer near the planet's tropopause at a pressure of 300 to 500 millibar (equivalent to the 30-40 km layer in the Earth's atmosphere). "The weather on Uranus is incredibly active," said Imke de Pater, professor and chair of astronomy at the University of California, Berkeley, and leader of the team that first noticed the activity when observing the planet with adaptive optics on the W.M. Keck Observatory in Hawaii. "This type of activity would have been expected in 2007, when Uranus's once every 42-year equinox occurred and the Sun shined directly on the equator," noted co-investigator Heidi Hammel. "But we predicted that such activity would have died down by now. Why we see these incredible storms now is beyond anybody's guess."

French and Australian amateur astronomers, observing at visible wavelengths, were able to image one of the storms with their much-smaller telescopes. Their observation was of a storm that had been detected at 1.6 microns by the Keck telescope and that lay much deeper in the atmosphere than those seen at 2.2 microns. The storm was ongoing in October. Observations by the *Hubble Space Telescope* (Figure 3) showed the storms in much more detail. ✶

Featured Articles / Articles de fond

Blowing Bubbles in Space: the Orion-Eridanus Superbubble

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Abstract

The space between stars is filled with a very low-density gas, known as the interstellar medium, and that gas can be shaped on very large scales by massive stars. The Orion star-forming region is the nearest region to the Sun that is actively forming stars significantly more massive than the Sun, and the intense light and fast-moving streams of gas coming off of these young stars in Orion have pushed away most of the interstellar medium within 1000 light-years of the Orion star-forming region. This giant bubble in the interstellar medium is the Orion-Eridanus superbubble. By comparing the known shape of the Orion-Eridanus superbubble to state-of-the-art models of superbubbles, I have been trying to understand the processes that have led to the creation of the Orion-Eridanus superbubble as we see it today. I have found that changes in the density of the interstellar medium can explain the elliptical shape of the superbubble, but only if the Eridanus end of the superbubble is directed away from the Sun, and if there is some as-of-yet-unknown secondary processes that help to tilt the superbubble slightly towards the galactic plane. I have also identified a prominent ribbon of emission on the Eridanus side of the superbubble that was likely formed when the expanding superbubble collided with and compressed a pre-existing gas cloud.

1. Foreward

This article is based upon the research that I conducted to earn my Ph.D. with my collaborators, Doug Johnstone, John Bally, and Carl Heiles, among others. While I use "I" in this article, this work is based upon the labours of the entire collaboration. The in-depth papers describing this research are Pon *et al.* (2014a) and Pon *et al.* (2014b).

2. Introduction

The night sky is dominated by an inky black void, punctuated by the occasional pinprick of light from a star. While the space between stars is devoid of most matter, it is not completely empty. The space within our galaxy is filled with an extremely low-density gas, referred to as the interstellar medium (ISM) that typically has only one particle every few cubic centimetres (Tielens 2005). That density is over a trillion, trillion times less dense than the Earth's atmosphere and still over a thousand times less dense than the best vacuum ever created in a laboratory on Earth (Benvenuti & Chiggiato 1993). The ISM is so diffuse that individual atoms can last decades before encountering any other atom. The gas in the ISM exists in many forms, with some parts being very cold (10 K or -263 °C) and containing complex molecules, such as ethanol and simple sugars, and other parts having temperatures greater than 10^6K and consisting primarily of bare protons and electrons (Tielens 2005).

The ISM plays a significant role in the life cycles of stars and, in turn, is dramatically influenced by stars in the galaxy. Stars form in the densest regions of the ISM, in gigantic assemblages of gas known as giant molecular clouds (GMCs). These GMCs can contain enough mass to form millions of stars and can be hundreds of light-years in diameter (McKee & Ostriker 2007). The masses of the stars that form within a GMC, and the relative number of lower-mass *versus* higher-mass stars, are believed to be dependent upon the gas properties of the GMC (*e.g.* Padoan & Nordlund 2002).

Once stars form within a molecular cloud, the stars begin to release energy into the ISM and start to influence their surroundings. While the life spans of the most massive stars in the galaxy are only a thousandth of that of our own Sun, each of these stars will manage to inject significantly more energy into the ISM over its short lifetime than a star like our Sun will in its entire life (Carroll & Ostlie 2007). As such, it is the most massive stars in the galaxy that have the largest impacts on the ISM, despite only accounting for a small fraction of the mass of the stars in the galaxy.

To fully understand the lifecycle of stars and the processes involved in forming a star system, it is crucial that this interplay between the ISM and stars is understood. The nearest region actively forming stars significantly more massive than the Sun is located approximately 1500 light-years away in the constellation of Orion (Menten *et al.* 2007) and is aptly named the Orion star-forming region. The Orion star-forming region has created a large cavity in the ISM that is unusually elongated (it is over twice as long in one direction as another) and contains an oddly bright hook of emission (the Eridanus filaments) far from the young stars in Orion. This cavity is the Orion-Eridanus superbubble.

In this article, I will describe my efforts to understand why the Orion-Eridanus superbubble is elongated, and why it is oriented in the direction that it is, as well as to reveal the nature of the bright Eridanus filaments. I will describe in general what a superbubble is and how it is formed in Section 2.1 and I will describe the Orion-Eridanus superbubble in more detail in Section 2.2. In Section 2.3, I will describe the current state-of-the-art superbubble model, the Kompaneets model. I will then show whether the shape of the Orion-Eridanus superbubble can be explained by such a Kompaneets model in Section 3. Section 4 will deal with the nature of the Eridanus filaments. Finally, I will summarize my main conclusions in Section 5.

2.1. Superbubbles

There are three ways in which young, massive stars generally influence their surrounding ISM. First, massive stars tend to be the hottest stars and thus emit copious quantities of high-energy light, including large amounts of UV and even X-ray emission. This high-energy light gets absorbed by the surrounding ISM and heats the ISM to very high temperatures. This light also has enough energy to strip electrons out of atoms and molecules, thereby ionizing the gas. Secondly, massive stars are continually emitting streams of very fast particles that act as a wind coming off the stars. This wind pushes on the surrounding material and can blow the surrounding ISM away from the young stars. Finally, stars with masses of roughly eight or more times greater than our Sun will explode as supernovae at the ends of their lives, thereby releasing prodigious amounts of energy into their surroundings via powerful blast waves. One supernova explosion can release as much energy as our Sun will emit over its entire lifetime (Carroll & Ostlie 2007).

The combined impact of the high-energy light, stellar winds, and supernovae explosions from clusters of young stars can easily push away most of the ISM in their vicinities, thereby creating large cavities in the ISM that can be thousands of light-years in size (*e.g.* Heiles 1979). Most of the material pushed away by the young stars piles up in thick walls along the edge of the cavity, while the small amount of material remaining inside the cavity gets superheated to millions of degrees (*e.g.* Mac Low, McCray, & Norman 1989). These large cavities created by clusters of young stars are referred to as superbubbles.

2.2. Orion-Eridanus Superbubble

The Orion star-forming region is the nearest region actively forming stars significantly more massive than the Sun and has formed multiple groups of young stars over the last ten million years, with the Trapezium stars being members of the youngest group (Brown, de Geus, & de Zeeuw 1994). The Orion star-forming region contains stars with masses up to 40 times the mass of our Sun (O'Dell *et al.* 2011) and these stars have created a large superbubble that stretches into the constellation of Eridanus in the night sky. As such, the superbubble formed by the Orion star-forming region is referred to as the Orion-Eridanus superbubble.

The size and shape of the Orion-Eridanus superbubble can be determined from different types of observations. The

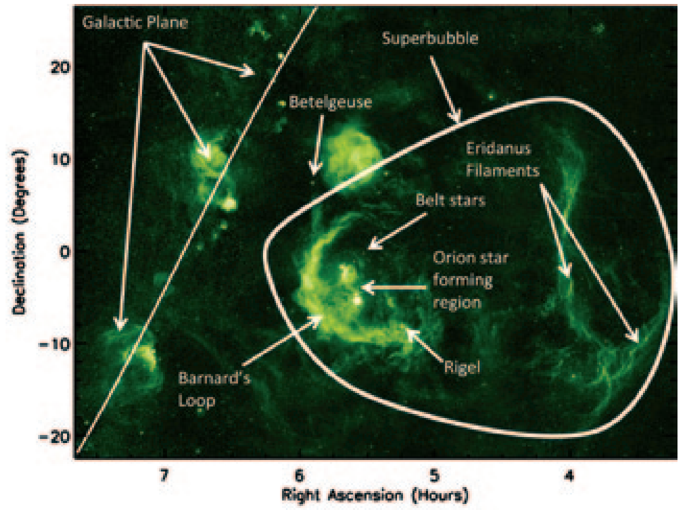

Figure 1 — Orion-Eridanus superbubble as seen in Hα. Labels for the various major components of the bubble have been added to the image from di Cicco & Walker (2009).

high-energy light emitted from the Orion star-forming region traverses the low-density interior of the superbubble before being absorbed by the higher-density, swept-up walls along the edge of the superbubble. As this light is absorbed, it ionizes the atomic hydrogen in the bubble, resulting in the inner wall being composed of bare protons and free electrons. Occasionally, however, a bare proton will encounter one of these free electrons and recombine to form atomic hydrogen. When this recombination occurs, specific colours of light are emitted, including light with a wavelength of 656.28 nm that is known as Hα emission. The rate at which bare protons recombine with electrons quickly becomes equal to the rate at which light from the Orion star-forming region ionizes gas in the wall and a steady emission of Hα light gets emitted from the interior of the bubble wall. This Hα emission can be used to locate the superbubble's edge (*e.g.* Basu, Johnstone, & Martin 1999) and Figure 1 shows an image of the Orion-Eridanus superbubble taken by astrophotographers (di Cicco & Walker 2009) using this Hα emission.

The ghostly outline of the superbubble can be seen stretching from the bright crescent of emission on the left of Figure 1 to the fainter hook of emission on the right side of the figure. The brighter crescent of emission on the left was first identified before the turn of the 20th century by Pickering (1890) and Barnard (1894), and is now referred to as Barnard's Loop. The fainter emission on the right-hand, Eridanus side of the superbubble was discovered over 60 years after Barnard's Loop (Meaburn 1965, 1967) and will be referred to as the Eridanus filaments. To give a sense of the size of the superbubble, the locations of Betelgeuse and Rigel (the right shoulder and left knee of Orion), as well as the three belt stars, are labelled on Figure 1.

As shown in Figure 1, there are numerous faint Hα features in the vicinity of the Orion-Eridanus superbubble, and it is not necessarily obvious which of these features belong to the superbubble and which of these features correspond to small, slightly denser regions in the ISM that the superbubble is expanding into. To confirm the shape of the superbubble, wavelengths of light other than Hα light can also be observed and the combination of the different observations can be used to piece together a cohesive picture of the superbubble's shape.

If a superbubble wall has enough material in it, the wall can absorb all of the high-energy light coming toward it from the young stars in the bubble, such that only the inner portion of the superbubble wall gets ionized. This scenario leaves a shell of atomic hydrogen along the outside of the bubble wall that is essentially shaded from the high-energy light by the inner regions of the wall. This atomic hydrogen tends to emit a particular colour of light with a wavelength of 21 cm and this 21-cm emission can also be used to locate the edge of a superbubble (Basu *et al*. 1999). Because significant 21-cm emission also comes from neutral hydrogen gas in the ISM outside of a superbubble, superbubbles tend to appear as holes in maps of 21-cm emission due to the lack of neutral gas in the interior of the bubble (Walter *et al.* 2008). Figure 2 shows the hole in atomic hydrogen emission created by the Orion-Eridanus superbubble, although the edges of the 21-cm hole lie slightly farther from the Orion star-forming region than the Hα walls, because some of the high-energy light likely makes it through the walls of the superbubble farther away from the Orion star-forming region, where the walls are thinner, and ionizes some of the gas outside of the superbubble. This 21-cm emission was detected by the Leiden/Argentine/Bonn galactic HI Survey (Hartmann & Burton 1997; Arnal *et al.* 2000; Bajaja *et al.* 2005; Kalberla *et al.* 2005).

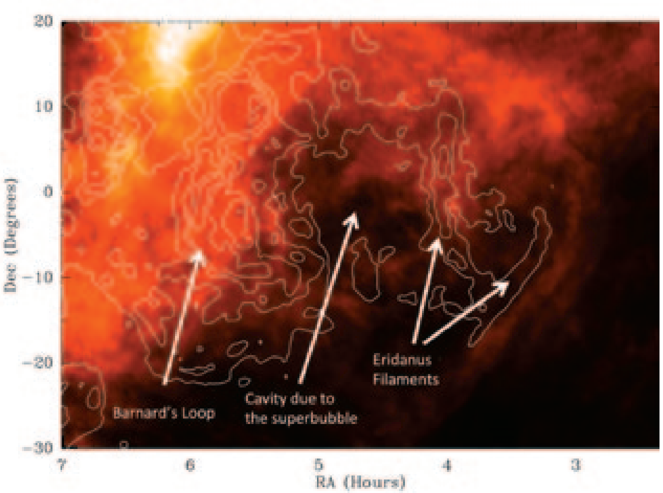

Figure 2 — 21-cm emission as detected by the Leiden/Argentine/Bonn galactic HI Survey is shown in the colour image. The contours show the locations of bright Hα emission as detected by the Wisconsin H-Alpha Mapper survey (Haffner et al. *2003). The locations of the Eridanus filaments and Barnard's Loop are labelled. Note the lack of 21-cm emission coming from the interior of the bubble.*

While the ISM is primarily composed of gas, about one percent of its mass is in the form of solid dust grains (Tielens 2005). These dust grains are extremely small, with typical diameters of 0.1 micron (which is over ten times smaller than the size of a red blood cell) and are primarily made up of either silicates (*i.e.* sand) or graphite (*i.e.* pencil lead; Tielens 2005). This dust gives off light with a variety of wavelengths, including at 100 microns. As gas is pushed out of the central cavity of an expanding superbubble, the dust will also be pushed out of the centre, such that superbubbles will appear as holes in maps of 100-micron emission, similar to how they appear in 21-cm maps. The 100-micron emission from the vicinity of the Orion-Eridanus superbubble was detected by the *Infrared Astronomical Satellite* (*IRAS*) and is shown in Figure 3 (Neugebauer *et al*. 1984; Miville-Deschênes & Lagache 2005). This figure shows a distinct lack of emission from the centre of the superbubble, as expected.

The final indicator of the boundary of the Orion-Eridanus superbubble, and perhaps the most convincing, is the presence of X-ray emission coming from the million-degree gas within the superbubble. Figure 4 shows the 0.75 keV X-ray emission detected by the *ROSAT* satellite (Snowden *et al*. 1997), with the edges of the X-ray emission aligning quite tightly with the locations of the Hα-emitting features.

Between the Hα, 21-cm, 100-micron, and X-ray data, a cohesive picture of the shape and size of the Orion-Eridanus superbubble emerges, with the Hα emission doing an excellent job of identifying the inner boundary of the superbubble wall, separating the million-degree gas in the centre of the bubble

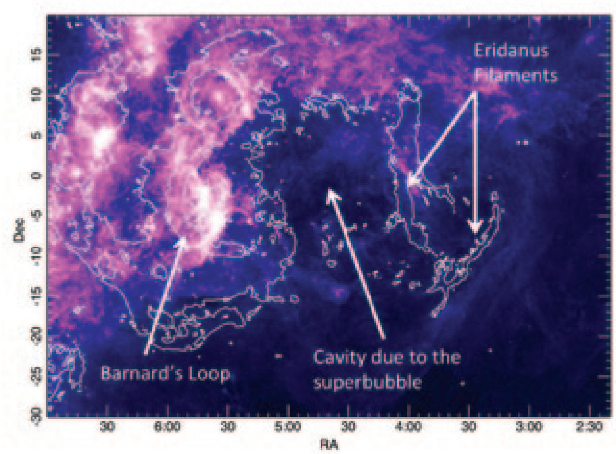

Figure 3 — 100-micron dust emission as detected by the Infrared Astronomical Satellite *mission and reprocessed by the Improved Reprocessing of the IRAS Survey (IRIS) group (Miville-Deschênes & Lagache 2005) is shown in the colour scale. The contours show the locations of bright Hα emission as detected by the Virginia Tech Spectral Line Survey (VTSS), the Southern H-Alpha Sky Survey Atlas (SHASSA), and the WHAM survey (Dennison* et al. *1998; Gaustad* et al. *2001; Haffner* et al. *2003; Finkbeiner 2003). The Orion star-forming region appears prominently in dust emission inside of Barnard's Loop, but there is a distinct lack of dust emission from within the interior of the bubble.*

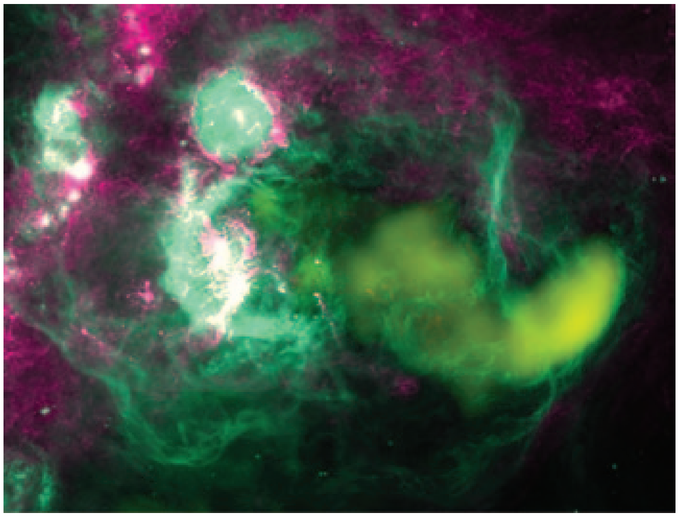

Figure 4 — False-colour composite image of the Orion-Eridanus superbubble. The green shows the Hα emission from the WHAM survey, the purple is the 100-micron dust-continuum emission from the IRIS group, and the yellow shows the 0.75 keV X-ray emission detected by the Röntgensatellit *(ROSAT) mission (Snowden* et al. *1997). Note how the X-ray emission comes from the interior of the bubble*

from the neutral atomic gas of the ISM. These observations reveal that the Orion-Eridanus covers a remarkable 45° by 20° area of the night sky, meaning that the superbubble stretches over 1000 light-years in length. Furthermore, these observations show that the Orion-Eridanus superbubble is highly elongated, with its extent in right ascension being over twice its extent in declination.

2.3. Kompaneets Models

The best theoretical model that exists today for describing the growth of a superbubble is the Kompaneets model. The Kompaneets model is named after Aleksandr Solomonovich Kompaneets, who first determined how the shock wave from an explosion travels through an atmosphere of gas that decreases in density with height (Kompaneets 1960). Dr. Kompaneets, however, originally was not trying to calculate the structure of a superbubble, but rather, was trying to calculate how the explosion from a large nuclear bomb would spread through the Earth's atmosphere. His calculations showed that the blast wave from a strong explosion is preferentially directed up, away from the surface of the Earth, as the blast wave can expand more easily into the lower-density air higher up in the atmosphere. As such, Dr. Kompaneets found that large explosions create structures that look like chimneys, with the superheated gas travelling up between denser walls of gas.

The astronomical community realized that Dr. Kompaneets's model could also be applied to a supernova exploding in the ISM, as the density of the ISM is expected to decrease with increasing distance from the galactic plane, just as the density of the Earth's atmosphere decreases with increasing height from the Earth's surface (Schiano 1985; Basu *et al*. 1999; Kalberla & Kerp 2009; Baumgartner & Breitschwerdt 2013). The Kompaneets model has since been refined to account for energy being emitted by young stars over a longer period of time, due to their continuous winds and high-energy light emission, rather than just accommodating for one supernova explosion at a particular time (Schiano 1985; Basu *et al*. 1999).

One of the key predictions of a Kompaneets-type model is that a superbubble can become significantly elongated. Just as it is easier to lift a feather than a brick, an expanding superbubble shell can more easily push aside lower-density gas, such that a superbubble will preferentially expand towards directions with lower densities. For a superbubble to become significantly elongated, however, there must be a significant density contrast between two ends of the bubble. Thus, a Kompaneets model predicts that, where elongated bubbles are seen, the density of the ISM must change significantly between the top and the bottom of the bubble. The size and elongation of a superbubble, therefore, can provide information on how quickly the density drops going away from the central plane of our galaxy.

A second key prediction of a Kompaneets model is that a superbubble becomes elongated in the direction that the density of the ISM changes. Since gas in the ISM is expected to become less dense moving away from the galactic plane, Kompaneets models predict that superbubbles should be elongated perpendicular to the galactic disk. Highly evolved superbubbles—those that have become highly elongated—will effectively become chimneys venting hot gas into the galactic halo.

3. Model Fitting

To understand the formation of the Orion-Eridanus superbubble, I attempted to find Kompaneets models, with reasonable physical parameters, that reproduce the shape of the superbubble. The idea here being that if I could find a model that produces a feature that looks similar, then it is likely that the physical processes and conditions that went into the model are those that shaped the Orion-Eridanus superbubble in the past.

While the distance to the Orion star-forming region is fairly well established, there is disagreement in the scientific literature over the distance between the Sun and the Eridanus end of the superbubble (Guo *et al*. 1995; Burrows & Zhiyu 1996; Boumis *et al*. 2001; Welsh, Sallmen, & Jelinsky 2005; Ryu *et al*. 2006). To account for the different possible distances to the Eridanus end, I examined two general classes of models: one in which the Eridanus end is closer to the Sun than the Orion star-forming region, such that the Eridanus end is coming out of the page, and one where the Eridanus end is farther away, such that the Eridanus end is going into the page. I will refer to the best-fitting models for each geometry as Models T and A, respectively, for towards and away from us.

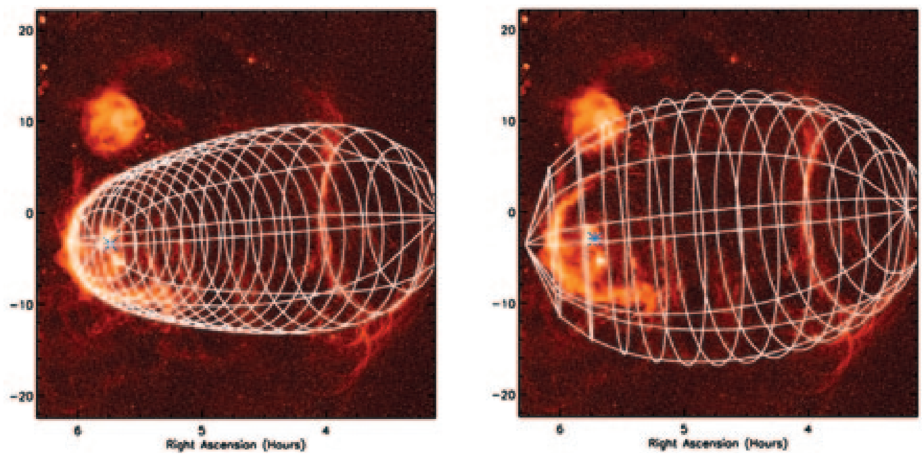

Figure 5 — Best-fitting Kompaneets models of the Orion-Eridanus superbubble, shown as white lines overplotted on the Hα image of di Cicco & Walker (2009). The left panel shows the best-fitting model for a bubble oriented toward the Sun (model T), while the right panel shows the best-fitting model for a bubble oriented away from the Sun (model A). The asterisks denote the locations of the driving sources in the Kompaneets models.

3.1. Model T

The best-fitting model for a bubble with the Eridanus side closer to us than the Orion star-forming region is shown in the left panel of Figure 5. In the panel, as predicted by the Kompaneets model, the position of the young stars forming the superbubble is denoted with an asterisk and is roughly coincident with the position of the Orion star-forming region. A schematic diagram of this model is shown in the top panel of Figure 6. Model T does an excellent job of reproducing the shape of the Orion–Eridanus superbubble. In this model, all parts of the Eridanus filaments lie at the same distance from the Orion star-forming region, hinting that their formation mechanism may be related to their proximity to the young stars in Orion.

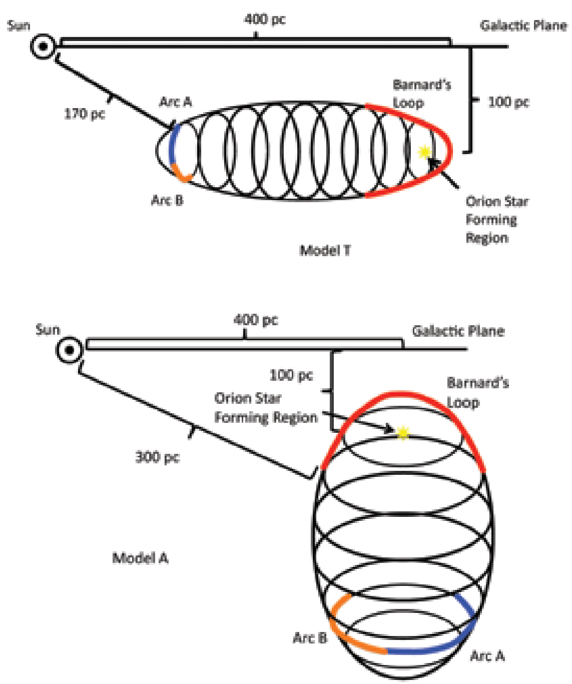

Figure 6 — Schematic diagram of models T and A. Model T is shown in the top panel and model A is shown in the bottom panel. In each of these schematic diagrams, the superbubble major axis is inclined roughly 30° into the page in order to match the offset between the superbubble axis and the normal to the galactic plane apparent in Figure 1. Thus, the major axis of the bubble in model A is still 35° inclined from the normal to the galactic plane. The distances in this figure are labelled in parsecs, with one parsec being roughly equivalent to three light-years. The features labelled as Arcs A and B are the two halves of the Eridanus Filaments.

Unfortunately, this model has two significant flaws. First, to match the observed elongation of the superbubble, model T requires that the surrounding ISM decrease in density by a factor of 10 every 100 light-years, whereas the ISM density is believed to only change by a factor of 10 every 1000 light-years (Kalberla & Kerp 2009). That is, to explain the highly elongated shape of the superbubble in model T, the ISM around the bubble would have to change in density a factor of 10 times faster than what is typically found in the galaxy. Such a large discrepancy in how quickly the density changes is very tough to explain.

The second major flaw with model T is that the superbubble's major axis would have to be inclined 85° away from being perpendicular to the galactic plane, such that the superbubble would be elongated almost parallel to the galactic plane. The apparent extension of the superbubble away from the galactic plane on the plane of the sky, as seen in Figure 1, would just be due to projection effects, based upon the Orion star-forming region's location 300 light-years below the galactic plane (Bally 2008). Such a situation is illustrated in the top panel of Figure 6. This elongation parallel to the galactic plane would mean that the ISM density would have to change in a direction parallel to the galactic plane.

Because model T requires the density in the ISM to change in a direction parallel to the galactic plane and to change 10 times faster than expected, model T was rejected as being an adequate fit to the Orion-Eridanus superbubble. The required parameters for the model are just too far off from the expected behaviour of the ISM in the galaxy.

3.2. Model A

The best-fitting model for a bubble with the Eridanus side farther from us than the Orion star-forming region is shown in the right panel of Figure 5. A schematic diagram of this model is also shown in the bottom panel of Figure 6.

It is clear that model A does not do nearly as good a job of fitting the Hα shape of the Orion-Eridanus superbubble as model T did. In particular, model A overpredicts the size of the bubble in the vicinity of Barnard's Loop, although model A does a reasonable job of matching the Hα features on the Eridanus side of the bubble.

The failure of model A to reproduce the size of Barnard's Loop is not completely unexpected. The Kompaneets model does not take into account the presence of all of the extra gas in the giant molecular cloud out of which the Orion star-forming region has formed. The presence of extra material in the molecular cloud would hinder the expansion of the superbubble, as the superbubble would have to push more material out into the bubble wall. If Barnard's Loop is related to this extra material, then it makes sense that the loop would be smaller than predicted by model A.

Model A requires the surrounding ISM to decrease in density by a factor of 10 every 300 light-years, which is still a factor of three smaller than expected for the galactic ISM, but much more reasonable than the factor of 10 discrepancy for model T. Other superbubbles fitted with Kompaneets models, such as the W4 superbubble, also require the ISM density to change about as quickly as required by model A (Basu *et al*. 1999; Baumgartner & Breitschwerdt 2013).

The superbubble in model A is 35° away from being perpendicular to the galactic plane. While such an inclination is by no means in perfect agreement with the expectation that the bubble will be exactly perpendicular to the galactic plane, this tilt is about as close to perpendicular as the Orion-Eridanus superbubble can be, given the angle to the galactic plane that the bubble makes in the plane of the sky (as seen in Figure 1).

I thus believe that model A provides a decent framework for understanding the Orion-Eridanus superbubble. It provides a general explanation for the elongation of the superbubble, but it does require some secondary physical effect that is not included in the Kompaneets model to fully explain the full elongation of the superbubble and the slight tilt of the bubble away from being perpendicular to the galactic plane.

3.3. Possible Secondary Processes

The ISM is threaded by magnetic fields that can influence the formation of large-scale structures (*e.g.* McKee & Ostriker 2007). Magnetic fields act similarly to bundles of pipes, with gas flowing easily along the magnetic field directions but being hindered in moving perpendicular to the field. As such, magnetic fields can channel superbubbles in particular directions, making them appear more elongated than they otherwise would be (Stil *et al*. 2009). Based upon measurements of the magnetic-field direction near the Sun (Rand & Lyne 1994; Heiles 1996), the part of the magnetic field parallel to the galactic plane in the Orion-Eridanus superbubble should be roughly oriented in the same direction as the elongation of model A along the galactic plane. While the magnetic field in our galaxy typically lies along the plane of the galaxy, the presence of a molecular cloud can alter the direction of the field such that it points slightly away from the galactic disc (this process is referred to by astronomers as a Parker instability; Parker 1966). Such an orientation of the magnetic field toward the Orion-Eridanus superbubble would naturally guide the superbubble's expansion towards the direction of elongation seen in model A.

Computer simulations of superbubbles expanding into gas with magnetic fields (Stil *et al.* 2009) show that the rate at which the density of the gas surrounding a bubble changes can be easily overestimated by fitting Kompaneets models, because the magnetic field can enhance the apparent elongation of a superbubble. This effect, however, is dependent upon the orientation of the observer with respect to the magnetic-field direction. The apparent rapid change of the ISM density required by model A may thus be just an artifact created by the presence of a magnetic field in the vicinity of the Orion-Eridanus superbubble.

Alternatively, if, in the recent past, there were a small star-forming region toward the constellation of Eridanus, such a star-forming region could have created a lower-density region in the ISM toward Eridanus. When the expanding superbubble formed by the Orion star-forming region intersected with this low-density feature, the Orion-Eridanus superbubble would have then preferentially expanded into the constellation of Eridanus, potentially explaining the large elongation of the superbubble and its direction of elongation.

One potential source of such a low-density region is the IC 2118 gas cloud. IC 2118 is located 2° to the northwest of Rigel and is roughly 750 light-years from the Sun, placing the cloud approximately 750 light-years in front of the Orion star-forming region (Kun *et al*. 2001). IC 2118 harbours tens of young stars with masses equal to or less than the Sun (Kun *et al*. 2001, 2004). Betelgeuse, a supergiant star with a mass 17 solar masses, is known to move in the sky relative to other stars and the direction of its motion has led to speculation that it was originally formed in IC 2118 (Bally 2008; Harper, Brown & Guinan 2008). Rigel, another massive supergiant star, is also nearby the IC 2118 cloud and is not moving significantly either away from or towards IC 2118, suggesting that it may have formed near its present location (Kharchenko *et al*. 2007; Bally 2008). The motions of Betelgeuse and Rigel, as well as the lower-mass stars in IC 2118, hint that more-massive stars may have been present in IC 2118 in the past, and these massive stars could have created a lower-density region in the ISM that has caused the Orion-Eridanus superbubble to become more elongated.

4. The Mystery of the Eridanus Filaments

The Eridanus filaments deserve a bit of extra attention, as they are very prominent features and relatively smooth models of superbubbles, such as the Kompaneets model, do not predict the formation of such features. The Eridanus filaments are 1.5°-thick, tube-shaped features that are 600 light-years from the Orion star-forming region, yet are much brighter than any other Hα features in their vicinity (Haffner *et al*. 2003).

Since the emission that comes from the edges of the superbubble wall is powered by the absorption of high-energy light from the Orion star-forming region, it would naïvely be expected that the strength of the Hα emission should decrease with increasing distance from the Orion star-forming region, because the amount of this light reaching the bubble wall would be decreasing. Such a decrease, however, assumes that all portions of the superbubble wall absorb the same fraction of the incident light. If the walls surrounding the Eridanus filaments only absorb a small fraction of the incident light, then the filaments could plausibly be much brighter if they absorb almost all of the light that reaches them, as would be expected if the filaments have more material within them than the typical section of the superbubble wall. The distribution of 21-cm emission and the apparent interaction of light from the Orion star-forming region with gas clouds outside of the Hα limits of the superbubble (Moriarty-Schieven *et al.* 2006; Lee & Chen 2009) both support the idea that some of this high-energy light leaks through the walls of the superbubble around the Eridanus filaments.

While this variation of the fraction of the light absorbed by the filaments can explain why the filaments are brighter than the surrounding portions of the superbubble wall, there still remains the question of whether there is enough energy in the light reaching the filaments to explain how bright the filaments actually are. That is, there is the question of whether the light from the Orion star-forming region provides enough energy to the filaments to power the level of emission that is observed from the filaments.

The amount of light coming from the Orion star-forming region is relatively well known (Reynolds & Ogden 1979; O'Dell *et al*. 2011) and more-detailed calculations show that this light from the Orion star-forming region can only power the Eridanus filaments if the filaments are four to six times larger along the line of sight than in the plane of the sky. In other words, the filaments would have to be more like sheets seen along their thin edge, rather than being cylindrical tubes. Such a situation, unfortunately, is very improbable, although not completely impossible.

The above situation assumes that the Eridanus filaments give off as much energy as they take in, such that the light from the Orion star-forming region ionizes gas in the filaments just as quickly as protons and electrons recombine in the filaments to form neutral atoms. An alternative possibility is that the filaments are giving off more energy than they receive, with the filaments slowly using up some internal store of energy. The filaments may have been completely ionized in the past by some event and recombinations are now occurring faster than the Orion star-forming region can re-ionize the gas such that the fraction of neutral gas in the filaments is slowly increasing over time.

One interesting quirk about ionized gas is that the same amount of high-energy light can ionize a greater quantity of gas if the gas is at lower density. If the mass within the Eridanus filaments were a little further spread out in the past, such that the average density in the filaments was a factor of four lower than it is today, then the light from the Orion star-forming region would have been sufficient to completely ionize the filaments, whereas today this high-energy light is only sufficient to ionize part of the filaments. It is thus possible that the Eridanus filaments started off as a gas cloud lying outside of the Orion-Eridanus superbubble that was slowly ionized by light from the Orion star-forming region. At some point after the cloud was ionized, the edge of the expanding superbubble would have impacted and compressed the cloud. A factor of four compression of the cloud would be well within the plausible range of compressions for such an impact (Shu 1992). After being compressed, the cloud would then emit at the higher, observed Hα intensity for the next million years or so, as the cloud slowly returns to an ionization equilibrium state.

5. Conclusions

The Orion-Eridanus superbubble is a large, 1000-light-year-long cavity in the interstellar medium that has been formed by the Orion star-forming region, the closest region actively forming stars with masses significantly greater than that of the Sun. I have fit Kompaneets models to the Orion-Eridanus superbubble and shown that the shape of the Orion-Eridanus superbubble can be reasonably reproduced by a model where the Eridanus side of the superbubble is oriented away from the Sun. This model fit indicates that the most important influence on how the Orion-Eridanus superbubble has formed is the decrease in the ISM density going away from the galactic plane. Such a model (model A) provides a framework for understanding the Orion-Eridanus superbubble, although a secondary physical process not included in the Kompaneets model, such as magnetic fields or a second, smaller star-forming region, is also required to fully explain the large elongation and direction of elongation of the superbubble.

I have also found that the prominent filamentary features on the Eridanus side of the superbubble, the Eridanus filaments, must either be sheets seen along their thin edge or that the filaments must be losing more energy than they are gaining from the Orion star-forming region. As an alternative, I have suggested that these filaments might have formed from the compression of a pre-existing, fully ionized gas cloud by the expanding wall of the superbubble less than one million years in the past. Thus, these filaments might be the remnant debris from a cosmic collision between a gas cloud and the superbubble in the recent past of our galaxy.

6. Acknowledgements

I would like to heartily thank Dr. Basu for providing some of his code to calculate the surface densities of Kompaneets bubbles, as well as for general advice on dealing with superbubbles. I would also like to thank Dr. Vaidya, Dr. Caselli, and the anonymous referees on my science papers for useful discussions and comments. I also would like to thank my co-authors on the scientific papers, Dr. Johnstone, Dr. Bally, and Dr. Heiles for all of their contributions to this work. I was partially supported by the Natural Sciences and Engineering Research Council of Canada graduate scholarship program. This research has made use of the Smithsonian Astrophysical Observatory (SAO) / National Aeronautics and Space Administration's (NASA's) Astrophysics Data System (ADS). The Wisconsin H-Alpha Mapper (WHAM) is funded by the National Science Foundation. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France. Some of the displayed Hα contours have utilized data from the Virginia Tech Spectral-Line Survey (VTSS) and the Southern H-Alpha Sky Survey Atlas (SHASSA), both of which are supported by the National Science Foundation. Finally, I would like to give a big thank you to the Canadian Astronomical Society and The Royal Astronomical Society of Canada for honouring me with the 2014 J.S. Plaskett medal and for giving me the opportunity to write this article for the *Journal of The Royal Astronomical Society of Canada*. ✶

This manuscript was derived from Dr. Pon's Northcott Lecture, delivered remotely from Scotland at the 2014 GA in Victoria, B.C. [Ed.]

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The Historical Madoc, Ontario, Iron Meteorite

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Abstract

October marked the 160th anniversary of the recovery of the Madoc meteorite, the first meteorite known to Canadian science. The 168-kg iron was recovered from the eastern Ontario village of Madoc by William Logan of the fledgling Geological Survey of Canada. Promptly placed in the Survey's Ottawa Museum, the meteorite laid the foundations for Canada's National Meteorite Collection. Madoc was exhibited at the Exposition Universelle of 1855 in Paris, where it won awards, and at the Centennial International Exhibition in Philadelphia in 1876. Although early analyses by scientists classified the meteorite as a fine octahedrite [the most common class of iron meteorite, composed primarily of nickel-iron alloys], modern analyses reveal it to be a medium octahedrite of Group IIIAB. The large suite of IIIAB irons enables scientists to explore and model the crystallization of metal phases at all depths in the core of an asteroidal parent body.

Figure 1 — The Madoc meteorite, on the base and pedestal of grey and white marble from Renfrew, Ontario, upon which it sat for many years in the museum of the Geological Survey of Canada, Ottawa. Photo from Hailstone (2012, p. 7).

The Finding of Madoc

October marked the 160th anniversary of the recovery of the Madoc iron meteorite (Figure 1). Although the First Nations on the Alberta plains knew of the existence of—and venerated—the large Iron Creek iron meteorite long before this time (Plotkin 2014), Madoc was the first meteorite recovered for science in Canada, and the largest and heaviest single individual meteorite mass yet found in the country. No extensive account of its finding in the eastern Ontario village of Madoc in Hastings County in 1854, thirteen years prior to Confederation, exists.

The earliest account was written a year after its recovery by Thomas Sterry Hunt (1826-1892), a chemist and mineralogist working at the fledgling Geological Survey of Canada under William Logan (1798-1875), its founder and first director. Hunt's short note was published in the *American Journal of Science and Arts* (Hunt 1855, p. 417):

> *A large mass of native iron was found last autumn upon the surface of the earth in the township of Madoc, C[anada] W[est]; it has since been procured by Mr. Logan, the director of the Geological Survey, in the collection of which it has been placed. The mass is rudely rectangular and flattened, but very irregular in shape; its surface is deeply marked by rounded depressions which are lined with a film of oxyd…The iron is very soft and malleable, and from a trial with a small fragment exhibits a coarsely crystalline structure; the weight of the mass is 370 pounds [circa 168 kg].*

A subsequent description that Hunt published in 1863 in Logan's *Geological Survey of Canada. Report of Progress from its Commencement to 1863* (Hunt 1863, p. 508) does not provide any additional information:

> *The native nickeliferous iron from Madoc is also to be mentioned here; although there is little doubt that, like similar masses in other parts of the world, it is of extra-terrestrial origin, and an aerolite. The specimen here noticed was found in 1854, upon the surface of a field, and weighed 370 pounds…*

Although the farmer who found the meteorite on his grounds has never been identified and the precise location of the find has never been confirmed, valuable information as to how Logan acquired it for the Geological Survey of Canada is provided by Thomas Chesmer Weston in his 1899 book *Reminiscences Among the Rocks, in Connection With the Geological Survey of Canada* (Weston 2013, p. 319):

> *It is probable that this specimen was first found on the surface of a field; but Sir William Logan told me that he found it propping up the corner of a barn, and at once sought the owner of the barn and offered to put a good square stone in its place; the offer was accepted and Sir William immediately had this valuable specimen removed and placed in the [Geological Survey of Canada's Ottawa] museum.*

A later etched slice of the meteorite displaying its name and year of discovery also gives the coordinates of the place where it was supposedly found (Figure 2). The coordinates, 44°28′N, 77°30′W, place the find location near the southwest edge of Moira Lake, some 4.5 km SSW of the centre of the small town of Madoc and 1 km upstream from the lake. This seems to be the most precise published location, which, provided it is accurate, has an inherent uncertainty of 1-2 km. The Madoc area has a long history of mining, quarrying, and mineral collecting, including such commodities as gold, fluorite, and marble.

A note from Logan to Paul Maria Partsch (1791-1856) in Vienna, presenting a 200-gram slice of Madoc to the Naturhistorisches Museum there, dates the finding of Madoc to October 1854 (Burke 1986, p.177).

Early Analyses

In Hunt's 1855 note, he reported that a single analysis gave 6.35 percent nickel, that no cobalt was present, and that he proposed to have the meteorite cut in order to make a more complete analysis. By the time of his 1863 note, he had cut the meteorite, observed its Widmanstätten structure, and noted that "small portions of the phosphuret of nickel and iron [schreibersite $(FeNi)_3P$] are disseminated throughout the iron, and, in making a section of it, rounded masses of magnetic iron pyrites [troilite FeS] were met with." A few kilograms of the meteorite were distributed to some of the leading scientists of the day around this time, including Karl Ludwig von Reichenbach (1788-1869) in Vienna, Aristides Brezina (1848-1909) at the Naturhistorisches Museum in Vienna, and Emil Wilhelm Cohen (1842-1905) at the University of Greifswald. According to Vagn Buchwald's *Handbook of Iron Meteorites. Their History, Distribution, Composition and Structure*

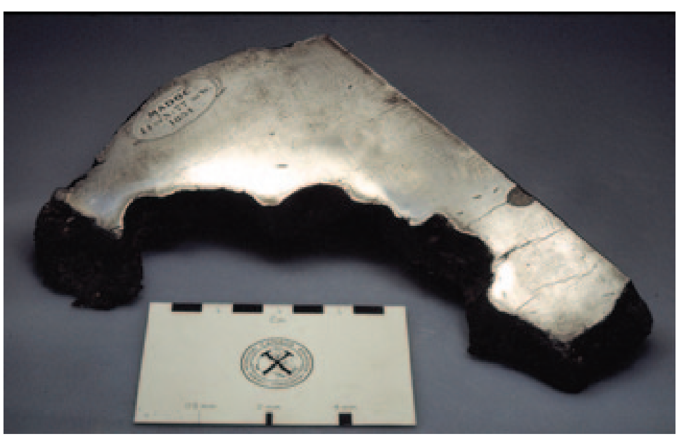

*Figure 2 — An etched slice of the meteorite showing its name, date of discovery, and the supposed coordinates of its find. The meteorite's Widmanstätten structure is clearly visible. Curiously, the minute values of the find coordinates are reversed in Grady (2000) and the derived **Meteoritical Bulletin** on-line database, where they appear as 44°30′N, 77°28′W, a point near the junction of highways 7 and 62, on the north side of the town centre. Natural Resources Canada, Earth Sciences Sector photo No. 2006-096.*

(Buchwald 1975, p. 791), all three scientists were evidently puzzled by the meteorite's fine structure, and classified it as a fine octahedrite. Buchwald, however, classified it as a medium octahedrite, a classification accepted today by the meteoritical community (Grady 2000, p. 314).

Stanislaus Meunier (1843-1925) at the Musée National d'Histoire Naturelle in Paris thought the meteorite so unique that he established a separate classification group for it, with Madoc as its sole member; this, of course, did not hold up for long (Buchwald 1975, p. 791).

Modern Research on Madoc

A latter-day analysis by three iron meteorite specialists (Scott, Wasson, and Buchwald 1973, p. 1961) produced the following results for nickel, gallium, germanium, and iridium, which have become key elements in the chemical classification of irons. Additional results are added for platinum and gold from R.R. Brooks *et al.* (1992) and for thallium from X. Guo *et al.* (1994):

Nickel	7.52 percent
Gallium	19.4 ppm
Germanium	36.4 ppm
Iridium	6.8 ppm
Platinum	17.9 ppm
Gold	0.6 ppm
Thallium	7.3 ppb

Buchwald (1975) noted that Madoc is composed of kamacite, taenite, and plessite (Ni-Fe alloys and intergrowths), schreibersite, troilite, and traces of carlsbergite (CrN), a rare nitride first described in the large Agpalilik fragment of the Cape York iron. He also noted that the fusion crust on Madoc consists of layers of dendritic, rapidly solidified metal, 0.05-0.15 mm thick.

In metallographic terms, the Madoc meteorite is a shock-hardened medium octahedrite, kamacite bandwidth 0.95 mm, a normal member of Group IIIAB. This is the most populous group of iron meteorites. According to the on-line *Meteoritical Bulletin* database, 2014 October 05, IIIAB irons total 299 or 30.0 percent of 997 approved irons, ahead of the populous IAB group with 271 members.

The geochemistry of IIIAB irons shows very wide fluctuations, such as a three-order-of-magnitude range in iridium contents, indicative of formation by fractional crystallization of a metallic magma. The large suite of IIIAB samples makes this group a fine suite in which to explore and model the crystallization of metal phases at all depths in the core of an asteroidal parent body (Wasson 1999).

The topic goes well beyond the scope of the current note, but the origins of the various classes of iron and stony-iron meteorites (the pallasites and mesosiderites) appear to involve a combination of 1) internal "magma chamber" processes and core-mantle relations and 2) external phenomena, such as the role of impact events in fragmenting, re-melting, and mixing metal and silicate magmas at and below the surficial regolith. This discussion is ongoing (see, *e.g.* Wasson and Choi 2003; Yang *et al.* 2010).

Analysis of Madoc and Manitouwabing, another Ontario iron, including nickel, gallium, and germanium, and all six platinum-group elements plus gold, served to dismiss a suggestion that the two irons might be paired (Brooks *et al.* 1992); additional metallographic and chemical work also support this conclusion (Kissin 1994). In the case of another possible pairing, a mysterious 600-gram etched slice from the Royal Ontario Museum (catalogue number M21786) was shown to have chemistry similar to Madoc, a more likely identity than the previous suspect (Welland, Kissin and Lacombe 2000).

Exhibitions

Less than a year after its recovery, Madoc was exhibited at the Exposition Universelle of 1855 in Paris. Following London's Great Exhibition of 1851, the Paris Exposition was a major event in France; it covered 16 hectares (40 acres), included 24,000 exhibitions from 34 participating countries, and was attended by more than 5 million visitors. The collection of Canadian minerals displayed by Logan, which included the meteorite, was awarded the Grand Medal of Honour, and Louis Napoleon presented him with the Cross of the Legion of Honour (Winder, no date).

Some two decades later, Madoc was displayed at the Centennial International Exhibition in Philadelphia in 1876, held to celebrate the 100th anniversary of the signing of the Declaration of Independence. This was the first official World's Fair in the United States, and was attended by more than 10 million visitors, equivalent to about 20 percent of the population of the country at that time. The Exhibition covered 450 acres (182 hectares), with exhibits in more than 200 buildings. Eleven nations beside the US had their own exhibition buildings. One of the showcases of the exhibition was the right arm and torch of the Statue of Liberty. For a fee of 50 cents, visitors could climb a ladder to the top; the money raised this way was used to fund the statue's pedestal (Wikipedia, no date).The meteorite was prominently placed in the Canadian Mineral Department (Honeyman 1888, pp. 120-121).

More recently, the Madoc meteorite has been displayed at the Canadian Museum of Nature in Ottawa, the Planétarium de Montréal, and the Musée des Beaux Arts in Montréal. In the summer of 2004, a fine plaster reproduction of the Madoc mass was placed on display in the Madoc Library and Cultural Centre (Jackson 2004). The local population has a lively interest in fireballs and meteorites, though at the time of writing, the region has yet to produce a second meteorite, either a new find or fall, or an additional individual of the 1854 find. The original mass is currently in its permanent home at the Geological Survey of Canada, Ottawa.

Conclusion

Madoc's acquisition by Logan for the Geological Survey of Canada laid the foundations for the National Meteorite Collection (Herd 2002; Spratt 1988, p. 24). The National Collection has the largest and widest collection of meteorites in the country, with more than 2700 samples of some 2000 different meteorites, and plays an important international role in meteorite collection, research, and education (Herd 2002). As of this date, 61 Canadian meteorites have received official international recognition from the Nomenclature Committee of the Meteoritical Society, while at least 12 more are "in process" for submission (Wilson and McCausland 2013, p. 4, list 60: the Lone Island Lake iron is the latest addition). Recovered 160 years ago, Madoc holds the distinct honour of not only being the first meteorite recovered for science in Canada, but also of being Canada's largest and heaviest individual meteorite ever to have been found. ✶

Acknowledgments

We thank Richard K. Herd, Curator Emeritus of National Collections, Geological Survey of Canada, for providing documents and photographs from the Geological Survey of Canada's Madoc file, and for his comments on an early draft of this paper. We also thank Stephen A. Kissin, Lakehead University, for his thoughtful comments on a later draft. We also appreciate discussions with Jim Laidlaw concerning the stated location of the historic find.

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The Solar Analemma Over Edmonton

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If observed at the same time each day, in the course of a year, the Sun's position in the sky traces a figure-8-shaped curve called the "analemma." The analemma is produced by the combined effects of the Earth's tilted axis of rotation and its variation in speed along its elliptical orbit around the Sun. Over the year, the Earth's axial tilt shifts the Sun's position north/south and the Earth's elliptical orbit shifts it east/west. Solstices correspond to the top and bottom of the figure-8,

Figure 1 — The lookout at St. George's Crescent with the sturdy park bench that served as a base for the camera.

indicating the northern and southernmost limits of the Sun in the sky. The cross-over point on the curve is around both April 12 and August 30 as the Sun's apparent position ascends and descends respectively. The analemma curve is also a graphical representation of the equation of time, which describes the difference between *sundial time* (apparent solar time) and *clock time* (mean solar time).

Phil Plait has an article describing the causes of the analemma in detail with nice animations. It can be found at www.analemma.com.

In 1979, *Sky & Telescope* editor Dennis di Cicco produced the first photograph of the analemma, recorded on a single piece of film. di Cicco's photograph started the "sport" of capturing the solar analemma as a single image that continues to this day. For many years, the quest was to capture the analemma on a single frame of film—a very difficult photographic challenge, as many things can go wrong over the course of a year. Digital photography has made things a bit easier, since it is more forgiving of mistakes, but capturing the analemma digitally is still difficult. *Astronomy Picture of the Day* has featured images of the solar analemma several times and a Web search finds many targets.

On 2009 December 20, *Astronomy Picture of the Day* published an unusual analemma image by Cenk E. Tezel and Tunç Tezel. In the description of how they accomplished it, Tunç Tezel said "I have to express my respect to single-film, multi-exposure achievers of the image, starting with Dennis di Cicco and ending with Anthony Ayiomamitis. Or should it be apologies?" I had been thinking about taking on the analemma challenge when I read Tezel's remark and I thought "ending with? Not so fast, Tunç. I have a film camera that is now just sitting in a closet. Let me see if I can't add another film-based analemma to the pantheon."

And so began my saga to capture the analemma. Why a saga? Because photographing the analemma is difficult, whether you do it on film or with a sensor.

- It takes about a year to do it, which requires commitment to a shooting schedule for a long time. Unless you have a location that can safely remain unattended and a fully automated set-up, a flexible personal schedule is needed to take advantage of days when the Sun is visible, since it may be cloudy on a scheduled shooting date. An assistant may be required if absences prevent you from taking an image.
- Dedicating a camera and mount to a fixed position or repeating a fixed position with a portable mount is fraught with dangers. For example, in Edmonton, where I live, winters present special challenges, since snow and ice tend to accumulate on horizontal surfaces.
- You need a clear sky near the Sun every week to two weeks or so throughout the year. The window in which to capture a solar image is very narrow—a specific time of day and only that time of day will do.
- With film, a single error means you have to restart the whole thing. Even worse, you may not realize that an error has occurred until the film is developed. With digital cameras, an error can be overcome by imaging again on the next available opportunity, but the opportunity may not present itself soon enough due to weather.
- Murphy is always hanging around and there are ample opportunities to make a mistake.

I mulled and pondered about where and when to shoot the analemma, and by June 2010, I was ready. Since this was going to be an "old school" analemma photo, I decided to use my old but trusty Canon A-1 film camera and my equally old and classic 28-mm, wide-angle lens. I figured my chance of success was 50-50 in one year, but I ought to get it in two years. I figured wrong.

Choosing a location from which to photograph the analemma took some time. I couldn't do it from my yard (the most convenient location), because there are too many trees. Edmonton's exquisite river valley was my next choice, and finding a location proved to be easy. The lookout at St. George's Crescent immediately came to mind, as it has a very fine view of the river, valley, and some skyline. I had photographed several moonrises from that location over the years (Figure 1).

Figure 2 — The camera mounted on a tripod head affixed to a custom wooden mount that could be accurately placed on the park bench.

The location's best feature was an extremely sturdy park bench that would serve as a stable base for a custom camera mount, thanks to the City of Edmonton parks department. Snow clearing would be required in winter, but because the bench was bolted onto a concrete pad, I figured it would not move. I constructed a mount that would sit on the back of the park bench using one of amateur astronomy's time-honoured materials—wood, in this case, scraps of pressure-treated 2×6 lumber. I bolted a simple but very versatile Manfrotto tripod head to the wooden mount and secured the camera to the head. I made a solar filter using Baader filter material and more classic materials—cardboard and tape (Figure 2).

Selecting the time of day for the solar images was another important factor to consider. Since I don't have an extremely wide-angle lens, a morning or afternoon time was needed to slant the analemma so it fit, along with some foreground, within a frame of 35-mm film when using a 28-mm lens. In Edmonton, mornings are typically better than afternoons for chances of clear skies. I chose a morning time that kept the Sun above the horizon all year, including the depths of winter when the Sun sits low above the horizon. Too early would increase the chances of clouds or steam plumes covering the low winter Sun. I selected 9:30 a.m. as the compromise between a low, winter Sun and a slanted analemma curve.

The First Attempt (2010-2011)

I started the analemma on 2010 June 20 at 9:30 MST. The camera was loaded with Kodak Gold 200 film and I shot the solar images at 1/60 sec at f/22. Things went well until late December, when I noticed that my choice of 9:30 a.m. put the Sun at 3.5 degrees altitude around the winter solstice. At this low altitude, the Sun was occasionally obscured by steam plumes from a power plant at the University of Alberta, which was in the foreground. On December 21, a planned shooting date, I discovered that the bolt holding the tripod head on the wooden mount had loosened.

Even though I had used masking tape to draw alignment marks on connections and movement axes, I had missed marking a connection between rotating sections of the tripod head. The first hard choice had to be made: start all over or attempt to realign the mount. I found photos I had taken of the original set-up and used scratch marks (!) on the head and mount to realign the camera. Thinking it would be close enough, I rebolted the head to the mount, added the missing alignment tape, and forged ahead.

On 2011 June 5, after taking 43 solar images and 1 foreground image, the first attempt was complete (Figure 3, left). It had failed. The loose bolt on the mount had shifted 2–3 Sun exposures *before* I discovered it was loose. Also, a slight wiggle in the way the mount sat on the bench distorted the shape a bit. To top it off, something happened, completely unknown to me, on the 3rd or 4th solar exposure to shift the Sun's apparent position. As an aside, I recorded the temperature on all shooting dates—it ranged from a brisk -26 ˚C to a comfortable +20 ˚C.

I must take a moment now to acknowledge my astrophotographer friend Alister Ling, who did not roll on the floor laughing when I first told him about my quest, acted as a sounding board for my ideas about how to do it, and who kindly stepped in when an absence prevented me from taking two solar exposures. As in many things, having a buddy can be paramount to success.

The Second Attempt (2011-2012)

I started the second attempt on 2011 June 22 at 9:45 MST. The camera was again loaded with Kodak Gold 200 film and I shot the solar images at 1/60 sec at *f*/22. I moved the time to 9:45 a.m. to put the lowest Sun altitude at 5.2 degrees, comfortably above the steam plumes of winter. I also reduced the number of solar exposures a bit to reduce the effort of the project. All tape marks were double checked, and by now I had developed a consistent technique for seating the mount on the bench.

On 2012 June 3, after taking 34 solar images and 1 foreground image, and with no obvious problems occurring, the second attempt was complete (Figure 3, middle). It had failed. Somehow, the *very first* solar image was shifted relative to all of the others, even though I had not detected any tape marks moving. Also, at another time during the year, the camera had moved on its base plate, so I realigned it using the tape marks—there were no position anomalies because of it. But there was that one position shift that occurred right after the first exposure! A pretty nice result, but not good enough. Thanks again to Alister Ling for stepping in for two solar exposures in my absence. The temperature range for this attempt: -17 ˚C to +23 ˚C.

The Third Attempt (2012-13)

The third attempt began on 2012 June 20 at 9:45 MST. By this time, Kodak had filed for bankruptcy, and I could not find Kodak film, so I switched to Fuji Superia 200 film (while wondering how long film was going to last). I shortened the solar exposures to 1/125 sec at f/22, to avoid halos around the Sun caused by thin cirrus clouds. Everything was good to go and the procedure had become quite routine.

On 2013 June 4, after taking 34 solar images and 1 foreground image, the third attempt was complete, but with an obvious problem that had occurred (Figure 3, right). The attempt had failed because on February 10, the camera had somehow again shifted on its base plate and the tripod head had twisted a bit on the wooden mount. I had used the tape marks to realign the mount, but I didn't do it well enough, since 12 solar images had shifted up. Even though this would be fairly easy to digitally correct with a scan of the negative, it was still not good enough for the classic "single-frame-of-film" analemma. Sigh. Once again, thanks to Alister for taking one solar exposure in my absence.

This film business was starting to get me down, so I started thinking about a digital analemma sequence. I had an older DSLR camera that I could dedicate to the cause, but that would leave the film quest incomplete. One day, I happened to see again Tom Matheson's excellent *Analemma Over New Jersey* (http://apod.nasa.gov/apod/ap071204.html) time-lapse movie. Matheson's movie inspired me to attempt a fourth analemma sequence, but this time there would be two cameras employed. Going digital would almost guarantee that I could successfully complete it in one year, but digital also meant that I could create a time-lapse video of the Sun's position on the analemma curve that also showed the changes of the four seasons. And while I was at it I thought, why not try the film-based analemma again? Doing both in parallel would not add much effort. Hah!

The First (and Final) Digital Analemma Attempt (2013-2014)

Since the digital sequence would also showcase the changes of the four seasons in Edmonton, I wanted a better view of the river valley foreground. Just in front of the sturdy park bench I had been using for three years was a sturdy fence, so I built another wooden mount that could sit on the top rail of the fence. Another Manfrotto tripod head, another Baader solar filter, more tape marks—well, you get the idea.

On 2013 June 21 at 9:45 MST, I started the project to image the solar analemma with a digital camera. The project had two objectives: (1) capture the figure-8 curve of the Sun's position over a year above an Edmonton foreground in a single composite image, and (2) capture the changes of the four seasons in Edmonton in a time-lapse movie with the figure-8 of the analemma evolving as the seasons progressed. I used a Canon XTi camera with a 18-mm focal-length lens, ISO 200, solar images 1/100 sec at *f*/11, and foreground images at

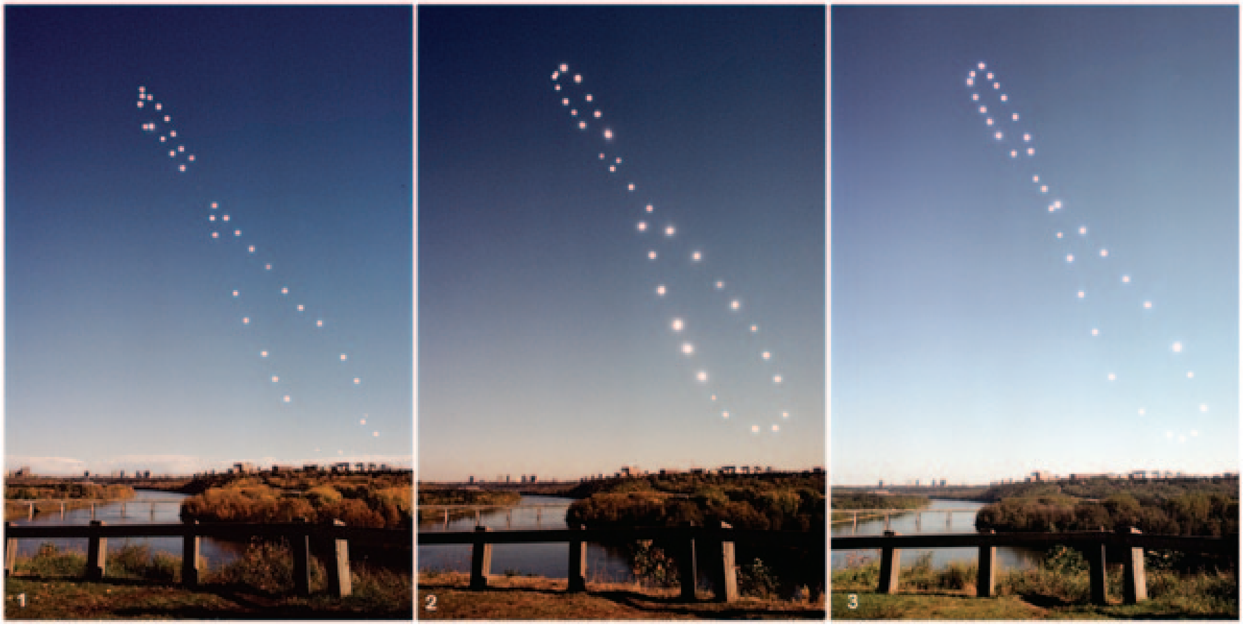

Figure 3 — The results of the first three attempts.

various exposures. Things generally went well with the digital camera. The ability to review each day for problems meant that images with errors could be discarded without compromising the attempt. Repeating the exact placement of the mount on the fence proved a bit more problematic than placement on the bench, so some tiny position adjustments were needed in post-processing.

The digital sequence ended on 2014 June 2 after capturing 38 solar images and several foreground images per month (Figure 4, left) for the seasonal changes. It had succeeded!

The time-lapse movie illustrating the Sun's motion on the analemma curve, from 2013 June 21 to 2014 June 2 is on YouTube at http://youtu.be/jQT5XRdrqvw and is best viewed in full-screen HD with sound. The foreground images showing the changes of the four seasons were taken at the St. George's Crescent location, some at 9:45 a.m. and others in the afternoon.

The Fourth Film Attempt (2013-2014)

I conducted the fourth film attempt in parallel with the digital sequence, starting on 2013 June 21. Since the digital camera images were going to be showing more of the river valley foreground, and therefore less sky, I decided to delay the shooting time of the film camera time by five minutes to 9:50 MST. I figured I needed five minutes to shoot the digital images, stow the digital camera, and set up the film camera. Five minutes would lift the film analemma a bit but there was enough room in the film frame to accommodate.

Fuji film was still available, so once again I used Superia 200 film. I modified the solar exposures a bit, using 1/125 sec at *f*/22 in the upper loop of the analemma and 1/125 sec at *f*/19 in the lower loop (to make the lower solar images brighter against the lower sky, which was always a bit whiter due to the color gradient in clear, blue skies. To ensure that the camera would not move against the base plate of the tripod head (it had moved on two prior attempts), I hot glued the bottom of the camera to the base plate.

On 2013 September 19, after three years of no issues with the park bench, I found that the City, as part of routine maintenance, had replaced the bench's seat and back! Although the frame in the viewfinder appeared very similar to before, the wooden mount moved around more on the back of bench. I had to assume that there would be a position anomaly. At least this problem had occurred only three months into the sequence and I knew about it. The parallel, digital analemma sequence still had nine months to go, so sadly, I advanced the film to the next frame.

The Fifth Film Attempt (2013-2014)

I reassembled the mount for a tighter fit on the park bench and the skies cooperated, so I was able to start the fifth film attempt the next day, on 2013 September 20. Things went smoothly except for one exposure.

2014 January 4 was a clear winter day, the first clear day since December 22. With the temperature hovering at a cool -22 °C, as I stood in the deep snow, the appointed time arrived and I fired the shutter. Nothing. Thinking I had forgotten to reset the shutter on the previous shot, I quickly reset it. Fire. Nothing. Press the battery test button. Nothing. The camera battery had died! It had been so long since I had needed to replace the camera battery (several years in fact), that I had forgotten to

Figure 4 — (left) The Solar Analemma over Edmonton. This is the composite digital image, consisting of 38 separate solar exposures from 2013 June 21 to 2014 June 2. Each solar image was taken at 9:45 AM at St. George's Crescent in Edmonton. The solar images were digitally combined with a single foreground image taken at the same location on 2013 July 3. All images were taken using a Canon XTi camera with a 18-mm focal-length lens. The solar images were typically at 1/100 sec at f/11, ISO 200 (sometimes a different exposure was used due to clouds). The camera was mounted on a tripod head affixed to a custom wooden mount that was placed on a fence.

Figure 4 — (right) The Solar Analemma over Edmonton on a single frame of film. This is the composite film image, consisting of 38 separate solar exposures from 2013 September 20 to 2014 September 13 and a foreground exposure on 2014 August 11, all on a single frame of film. Each solar image was taken at 9:50 a.m. at St. George's Crescent in Edmonton. All images were taken using a Canon A-1 film camera with a 28-mm focal-length lens. The solar images were typically at 1/125 sec at f/22, ISO 200.

periodically check it. Luckily, the next day was also clear, so I was able to get the solar image at the bottom of the analemma, in what some of us call "Edmonton Cold," that is, clear with a temperature of -29 °C and a windchill of -39 °C (maybe not so lucky). There were major steam plumes from University of Alberta power plant, but the Sun was just above them.

On 2014 September 13, after taking 38 solar images and 1 foreground image, my fifth attempt at a film-based analemma was complete. It succeeded. Well, mostly. For reasons I have not been able to determine, one of the solar images ended up slightly out of place. No obvious errors had occurred and none of the tape marks had ever moved. Perhaps I had seated the mount on the bench incorrectly without noticing. Unlike the other four attempts, in which position anomalies had explanations, this one was a mystery. But after fours years and three months of trying, and with a successful digital analemma in the bag, I had had enough. A simple edit of the scanned negative, equivalent to the dodge and burn darkroom techniques, fixed the small error (Figure 4, right).

As far as I know, this is only the second time the solar analemma has been photographed from a location in Canada. In 2000-2001, Steve Irvine, of Keppel Henge fame, produced on film what I believe is the first analemma from Canada.

JRASC Production Manager, James Edgar, was so taken by my analemma image in the December *Journal* that he decided to make an oak carving out of it, using a CNC carver (Figure 5). The carver software interprets the prepared greyscale image as lighter = more wood removed, and darker = less removed. Thus, the Sun is small dimples in the sky and the river valley protrudes like in a diorama. A very interesting transformation from film to digital to wood—thank you, James! ✶

Figure 5 — The oak carving of the analemma image, made by James Edgar.

The Miracle at Camp Kawartha

by John Crossen
(johnstargazer@xplornet.com)

Normally I wouldn't write about myself in this column. But recently, I had such a remarkable and rewarding experience that I though it worthy of sharing. Perhaps it will inspire some of you. First, allow me to do a little stage setting.

Those of us who live in Southern Ontario know what November means—clean eyepieces and sparkling optics thanks to a seemingly endless procession of cloudy nights. It's as though some heartless fiend had placed a giant grey Tupperware bowl over the lower half of the province. Good Lord, even being home to the Toronto Maple Leafs shouldn't warrant such cruel and unusual punishment.

Until the night of November 28, the month had been running its dreary course. On that particular night, I was doing an astronomy presentation to a group of conservationists and outdoor education councillors at nearby Camp Kawartha. The arrangements were made by Kathy Reid, Co-ordinator Communications and Education for the Otonabee Region Conservation Authority. To her I owe many thanks for assisting me with my gear and arranging the meeting. It was a real treat.

My talk focused on how to use one constellation as a guidepost to help find others. It being the late fall, I had chosen Orion as the launch pad for finding Taurus, the Pleiades, Gemini, Auriga, and Canis Major. Being November, it was a perfect night for an indoor presentation—cloudy. Happily, my group was fascinated and filled with questions by the video presentation of the constellations. They were also quick learners, as I was soon to discover.

Toward the end of my talk, I held the usual question-and-answer session. As we prattled on about light speed and light-years, I noticed that a couple of members of the audience had drifted outside to check the sky conditions. Suddenly the doors to the presentation room burst open and something unheard of in November blurted out across the hall—the sky had cleared.

With that, the question period snapped closed. My audience hustled into their winter coats, grabbed their binoculars, and headed outdoors. As quickly as possible I got my gear packed up and joined them beneath "The Miracle at Camp Kawartha"—a sparkling-clear, Moonless, November sky.

Orion was well above the trees in the clear patch where the group had congregated. As I drew near them, I could hear their excited voices, shouting out the names of the other constellations. Looking up, it was as though we were viewing my indoor presentation, only now it was in IMAX with surround sound.

Orion stood front and centre. To the right of his belt lay Taurus and the Seven Sisters. To the left were Canis Major, Sirius, and M41. My audience had translated my indoor images to the night sky almost perfectly. I only had to use my laser pointer to help them find Auriga and Gemini, but for the most part, they had it nailed.

I can't begin to tell you how rewarding that moment was. To see something put into practice by someone you had just taught was incredibly exciting for me. Knowing that these teachers will spread that knowledge to future generations suddenly made all the frozen-toed nights I had spent learning the night sky worthwhile.

I enjoy the serenity of observing by myself; I never feel alone beneath the stars. But, as I sat on the crude camp bench beneath the stars, I couldn't help but reflect on how sharing the experience with others makes a beautiful time even more so. ✶

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.

Pen & Pixel

Figure 1 — Steve McKinney of the Toronto Centre trapped this image of M13, the Hercules globular cluster, from the Carr Astronomical Observatory at Blue Mountain, Ontario. Steve used an AT6 RC telescope and an SBIG ST-8300M camera with an exposure of 6×300 s in each of R, G, and B, and 9×300 s for luminance (L). M13 is a relatively close object, about 22,000 light-years distant, and subtends an angle on the sky of about ½ a lunar diameter, making it an easy object for binoculars and faintly visible to the eye. Its age of about 11.7 billion years gives it a large complement of old stars, seen here in shades of yellowish-red.

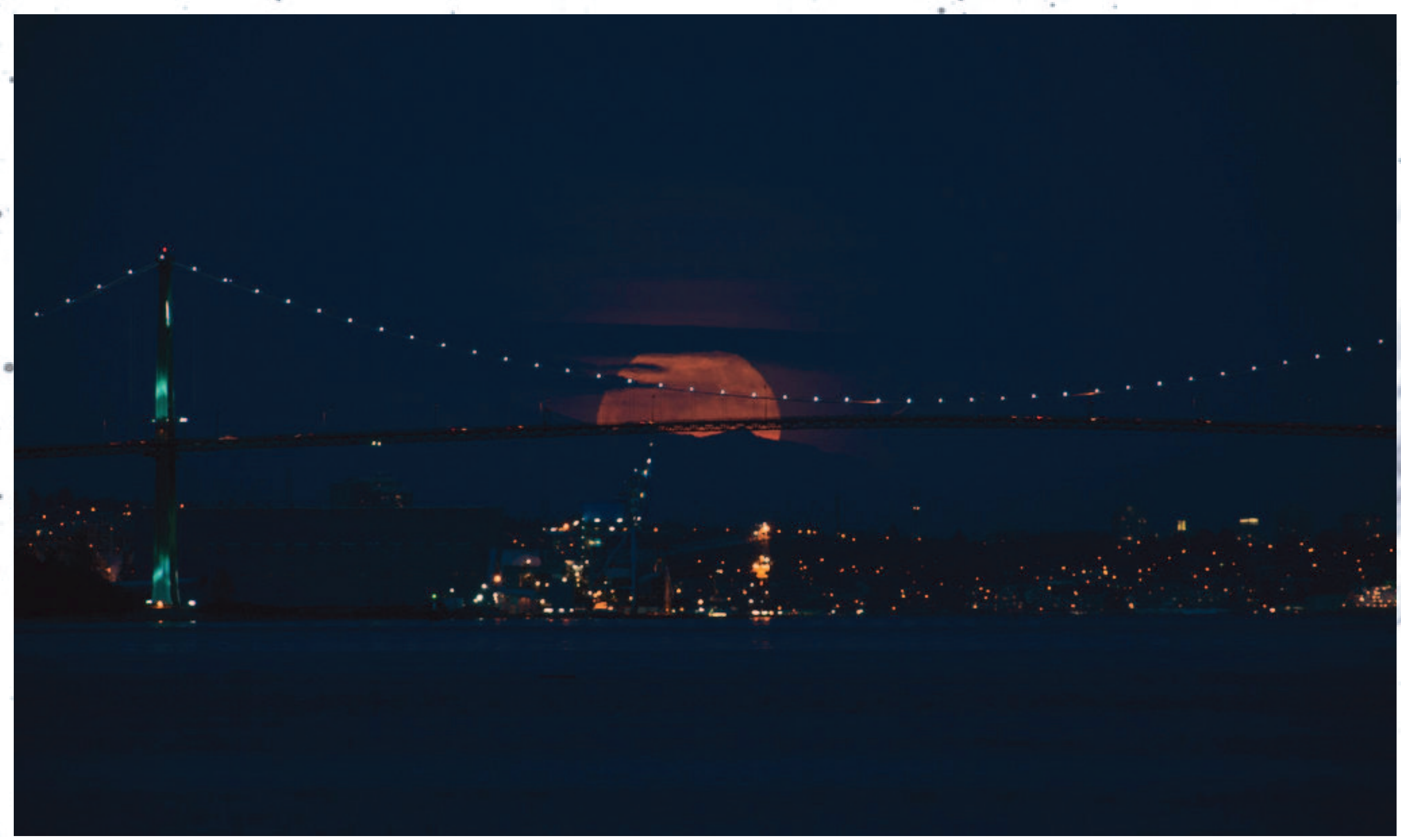

Figure 2 — Sometimes an ordinary object—the full Moon—takes on an extraordinary guise when presented in the right setting. Terry Halverson captured the Moon behind Lions Gate Bridge in Vancouver, B.C., using a Nikon D800E, a 300-mm ƒ/2.8 lens with a 1.7 x teleconverter. Exposure was 1/13th second at ƒ/4.8 and ISO 400.

Figure 3 — François Theriault brings us this image of one of summer's favourite targets—the Dumbbell Nebula or M27 in Delphinius—from his Genesis Observatory at Moncton, New Brunswick. François used an Antares 200-mm ƒ/5 Newtonian telescope with an SBIG ST8300M camera for this 4.5-hour exposure (54×300 s) in LRGB.

Figure 4 — IC 410, otherwise known as the Tadpole Nebula, is an often-overlooked emission nebula surrounding the open cluster NGC 1893. That is unfortunate, as the "tadpoles" in the lower left of the central nebula are one of the more attractive gas structures in the galaxy's nebular offerings. The Calgary Centre's Dan Meek collected the photons for this image of the Tadpole with a 345-minute exposure last December on a TeleVue NP127 is using a QSI583wsg camera.

World To Come To An End: Stars Falling, 1833—A Canadian Painting of the 1833 Leonid Shower

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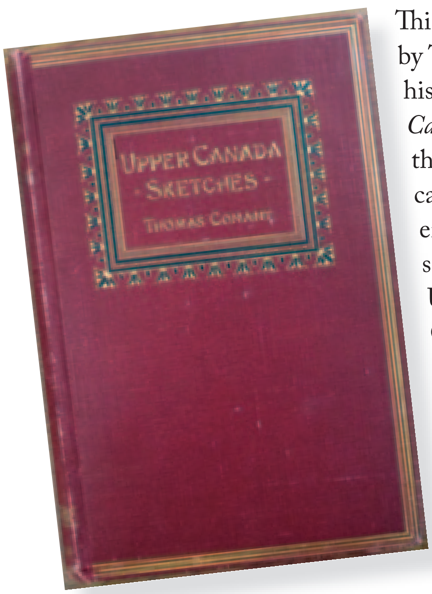
The eastern half of North America was witness to an astonishing meteor display in 1833 November 12/13 with estimates of the rate of fall ranging upward from 30,000 meteors/hour. Some of the specifics were described in a previous article in the JRASC April 2014, where I noted that other Canadian-based reports would likely surface. Such an example has recently been brought to my attention.



This instance was recalled by Thomas Conant in his1898 book *Upper Canada Sketches*. In the book, Conant catalogued the experiences of his family's settlement and life in Upper Canada (now Ontario). Within the book are many scenes, painted by Edward Scrope Shrapnel, that illustrated the narratives.

Figure 1 — Cover of Thomas Conant's book, Upper Canada Sketches *(Toronto: W. Briggs, 1898). Image: Clark Muir*

Thomas Conant wrote about the 1833 Leonids as it was witnessed by his father Daniel Conant from and near his home in Oshawa, Ontario. The report was passed on to him by his mother in the form of a memorandum. As with most other eyewitness accounts of the event, the details included in the book are dramatic. Daniel Conant's description starts in the evening of 1833 November 12, when fireballs fell from the sky around his fishing boat, possibly in Lake Ontario. He eventually headed for home with his catch of the night, partly in fear of the scene emerging around him. The meteors continued into the predawn hours, Conant noted.

What makes this account exceptional is that it is supplemented with a painting, one of 26 lithographs included in Conant's book. Aided with a photograph of the Conant family home, Shrapnel composed the scene as it was described by Daniel Conant some 60 years earlier. Below the lithograph is the caption "WORLD TO COME TO AN END. STARS FALLING, 1833."

The artist, Edward Scrope Shrapnel (1854–1920), was born in England and moved to Canada with his father during his childhood, settling in Orillia, Ontario. His early artistic work included landscapes in the Muskokas that featured native peoples and animal scenes. Shrapnel later moved to Whitby, Ontario, to teach at the Ontario Ladies' College, a job lasting for about five years. In 1889, he moved to Victoria, B.C., where he resided until his death in 1920.

The Shrapnel painting is the first Canadian artwork that I have encountered depicting the 1833 Leonid meteor storm. While there are many sketches, woodcuts, and paintings that recount the notable event, virtually all of them are from the United States.

The Painting

The 10-cm x 15-cm image shows the Conant home framed from near ground level and dominated by four chimneys, one of which is producing smoke. A person near the house on the yard in the foreground wearing boots, a jacket, and a hat, has his arms in the air probably looking up in bewilderment. Another person at the door is praying (This was a detail provided by the witness). Throughout the scene, meteors are falling from the sky with many shown reaching the ground; some are apparently smoldering. The artist's name appears at the bottom-left corner, and the lithographer's (Barclay, Clark & Co. Litho. Toronto) at the bottom-right corner. The house strongly resembles photographs taken later in the century (Figure 3), cementing the claim that a photograph aided the artist.

On first viewing the lithograph of the Shrapnel painting, two peculiarities are apparent. First, the painting does not show a radiant; instead, the meteors are seemingly falling like snowflakes. The second oddity is the embers on the ground.

It should be noted that the witness did not describe the meteors as coming from a radiant, though the intensity of the shower was such that a credible eyewitness should have recognized this element. So, it is puzzling why a radiant was not perceived or included in the report. Conant also mentioned that at day break he "…hunted closely upon the ground, but not a trace was left of anything." It seems clear that Daniel Conant believed that the meteors were a localized event, and that he was convinced that burning embers could be the result of the meteors falling from the sky, though he wrote that "…the fire-balls did not burn or hurt."

The author of the book, Thomas Conant, notes that his father rarely spoke of the meteor shower, and believes that he was

Figure 2 — The lithograph of the Leonid shower of 1833 November 12/13 included in the book Upper Canada Sketches *by Thomas Conant 1898. Painting by Edward Scrope Shrapnel. Scanned original lithograph: Clark Muir*

genuinely frightened by the ordeal. Thomas Conant editorializes that "…back in 1833 astronomers had not taught 'Upper Canadians' in regards to meteor showers as we know today [today being 1898] and we do not marvel at their consternation and fright."

Conant Home and Family

The Conant family home has a fascinating history that should not be neglected here. The home was built in 1811 near the corner of what are now Harbour Rd. and Farewell St. in the Port of Oshawa, close to the shores of Lake Ontario. During the war of 1812, it was used to temporarily house American POWs. A battle at Detroit, Michigan, had led to American prisoners being transported along the Lake Ontario shoreline to Québec. The long journey required that a temporary camp be set up to feed and house the prisoners while *en route*.

Figure 3 — Photograph of Conant family home in the Port of Oshawa. The photograph has a considerable resemblance to the home painted by E.S. Shrapnel. Date unknown

In 1963, the house was still in the ownership of the Conant family. The owner at the time, Verna Conant, permitted the house to be set on fire on December 6 of that year in an exercise to train new recruits for the fire department. The home had been abandoned three years earlier, was derelict, and had become a safety hazard.

The Conant family was very prominent throughout the history of Oshawa. A public park, street, and school are among the landmarks that are named in honour of the family in the city. Gordon Daniel Conant, son of the author of the book, became the 12th premier of the province of Ontario in 1942.

Conclusion

There is little doubt that Thomas Conant was well aware that his father was mistaken in his interpretation of the meteor shower. Nonetheless, the artist depicted his painting by the description the witness had provided rather than the way it actually transpired. When compared with most other interpretations of the 1833 Leonids, the Shrapnel painting can be considered even whimsical.

Original copies of the book can be found in some library collections throughout the country, but it is not known whether the original painting survives. ✶

Acknowledgements

Thanks to the Oshawa Historical Society for their assistance.

A large portion of the text of the account is published in *Stars Fall Over Canada* (Millman, Peter M. & McKinley, D.W.R.; JRASC Vol. 61 p.277)

A Photograph of the Ontario Ladies' College Observatory

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The Trafalgar Castle School, Whitby, was founded in 1874 as the Ontario Ladies' College and is today an independent day and residential school for girls. Shortly after opening, the school was supplied with scientific apparatus that included a 6-inch refracting telescope from Fitz of New York (Broughton). It was housed south of the main school building in a frame shed with a roof that opened to the sky (Winters).

In 1882, the observatory was part of a chain that stretched from Woodstock to Fredericton to record the December transit of Venus. While equipped with suitable equipment, including a chronometer, to record the event, no useful observations are known to have been made, although skies were clear for at least part of the transit (Broughton). Several years later, the telescope was replaced with a 6-inch Wray refractor manufactured in London, England (Anon. a).

The accompanying photograph, showing the observatory and its open roof, was made in 1893 (Whitby Public Library), and, therefore, presumably depicts the Wray instrument. The observatory survived into the early 1900s (Anon. b). ✶

Acknowledgements

Thanks to Laura Hallman, Assistant Archivist, United Church of Canada Archives. Thanks also to David Edwards, Trafalgar Castle School, for supplying a copy of the photograph and who, when asked if he knew of the observatory replied, "Oh, yes! It stood right over there!"

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Anon. b, *Ontario Ladies' College Calendar*, 1894

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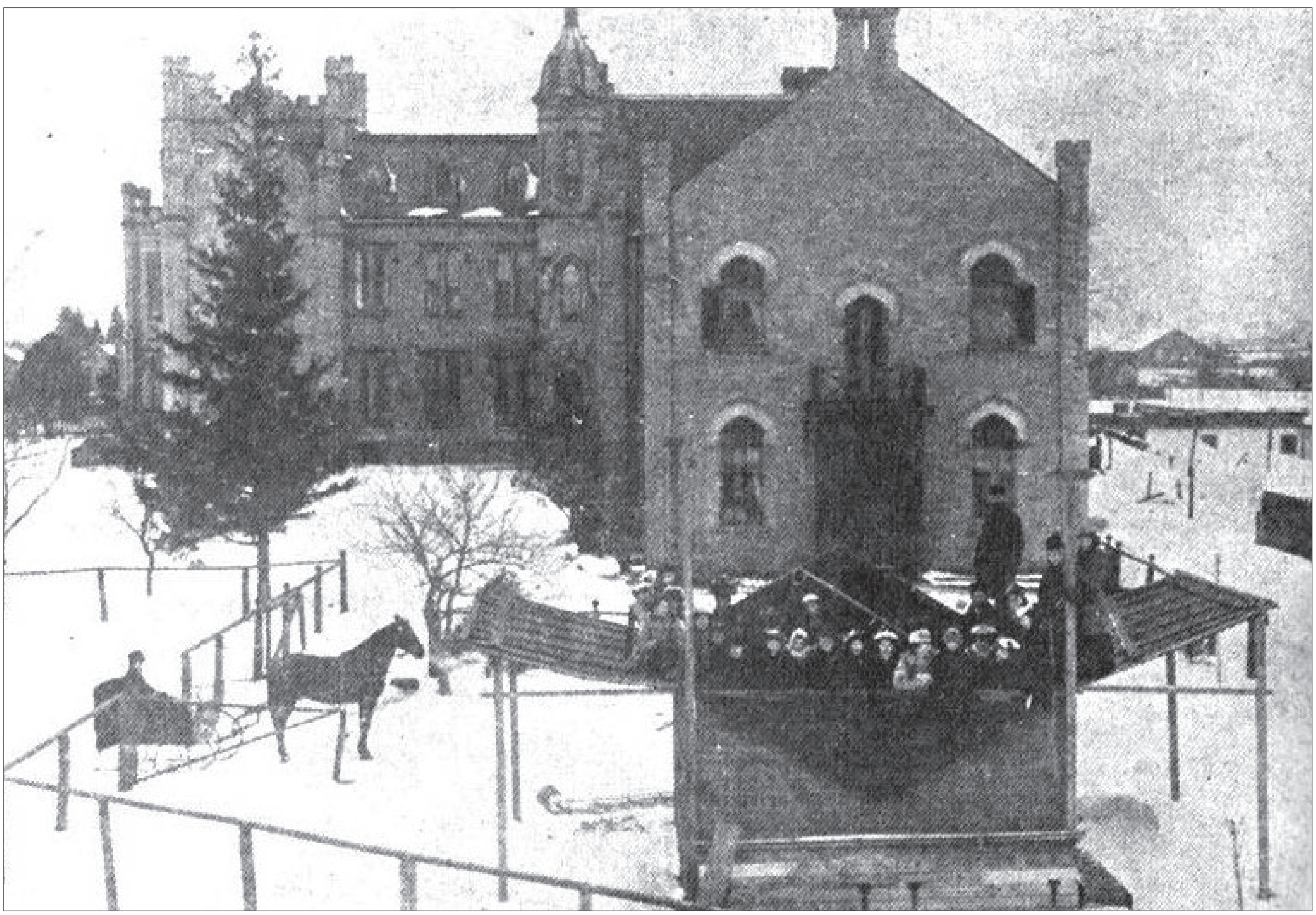

Figure 1 — South view of the college with observatory in the foreground.

Binary Universe

Stellarium

by Blake Nancarrow, Toronto Centre
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When we meet people new to astronomy, we want to get them started on a good foot. One of the first things we recommend is one of the good, primer books, like *NightWatch*. We encourage the beginner to visit a local astronomy club. And, when people say they are looking for some helpful software, I often suggest *Stellarium*.

I first started using *Stellarium* around 2007. At that time, I was drawn to the planetarium application for a few reasons: the price was right; it looked good; and, it helped me to go deeper into astronomy and the night sky. *Stellarium* is distributed under a General Public Licence; the full application, for Windows, Macintosh, or Linux, is freeware. A limited smartphone-capable version is available for a small fee.

Stellarium produces pleasing eye candy. This is due, in part, because it is designed to simulate a very realistic sky with a digital, spherical, or fisheye projector beneath a planetarium dome.

On a personal computer, it also produces surprisingly realistic views. Natural sky colours, rendered Milky Way, colourful sunrises and sunsets, twinkling stars, random meteors—all of these can be turned on to better simulate a nighttime environment. Zooming in causes the numerical simulation to be replaced by actual photographs of deep-sky objects and planets. *Stellarium* even shows the Moon with crater shadows. In full-screen mode, without the chrome or interface showing, it is eerie.

All that said, I find the automatic contrast adjustment, when looking toward the bright Moon, heavy-handed. I have turned off that setting (Dynamic Eye Adaptation) in the Sky and Viewing Options tab. I also lowered the Absolute and Relative settings for the stars from the default for a more natural-looking night sky. A light-pollution value can be adjusted to brighten or darken the sky.

A decent number of preference settings can be adjusted via the graphical user interface, but not all. For advanced users, some options require diving into the INI configuration text files. However, each new release of the software generally offers more accessible controls.

The 0.13.1 version of *Stellarium* displays a number of the standard items in the sky, some automatically, some after adjustments: stars and the Moon (of course); man-made satellites and orbiting spacecraft; planets (major and minor); comets; exoplanets; the Messier objects; a good number of targets from the NGC catalogue; and supernovae. If that isn't enough for you, additional objects, such as current comets, can be added manually into *Stellarium*.

Figure 1 — A classic night-sky scene from Stellarium.

Figure 2 — A detail-rich view with a description of Antares upper left.

Click on an item, and the upper corner blossoms (Figure 2) with a list of details about the object including equatorial and azimuthal position, magnitude, spectral type, and several other additional details that seem to be a standard part of planetarium software these days. Interestingly, the distance to stars is shown, but not planets. Planetary phase is noted.

The number of stars that the software displays is determined by the number of additional catalogues the user downloads. Loading the "deepest" catalogue brings the total available stars to approximately 210 million, down to a magnitude of around 14. This proved to be useful to me for a time, when I found myself seeing beyond the faintest stars in my *Pocket Sky Atlas* and *Sky Atlas 2000*.

The star data comes from multiple sources, with most provided by the NOMAD catalogue (Naval Observatory Merged Astrometric Dataset), version 1. Unfortunately, faint stars in *Stellarium* do not show identifiers and in some cases are not in the correct locations. As my observing skills improved, and as my needs grew more demanding, this became an increasing problem. Now, when I'm splitting faint double stars, chasing an occultation, or trying to identify backgrounds in an astrophotograph, I use other tools. If your needs are basic, certainly for small instruments, *Stellarium* will yield a good starfield.

In general, *Stellarium* is good at rendering a view similar to what you'll see, regardless of instrument. The wide-field, naked-eye view is very realistic and offers a selection of landscapes. The software even compensates for refraction near the horizon. The default scene presented to the user is the natural one, reproducing the orientation of a naked-eye view or a binocular field. Up is up and left is left. However, *Stellarium* also lets us flip the view both horizontally and vertically to reproduce the views through various kinds of telescopes. It includes an ocular mode that masks the screen outside the eyepiece field of view and allows the user to outline camera fields. As a regular user of SCTs however, I find *Stellarium* lacking in one important way: it does not allow the user to rotate the field a random amount.

Of course, if we want the computer at the eyepiece, it will need to be dim. *Stellarium* has a pleasing red-light mode. A recently added, new feature is one that tells you when an object is best viewed—a helpful feature when planning a night's observing.

While the application does not support printing, the user can take screen snapshots and create png files. These can be dropped into a document or image-editor program for printing.

Some might argue this is not necessarily a good thing, but I like that *Stellarium* can be controlled by accelerator keys, much like *Photoshop*. For those who don't like memorizing keys, a bottom toolbar and a sidebar menu are available. The keyboard shortcuts, many of which are mnemonic, enhance control of the application without cluttering the display—something very handy when doing demos or sky tours.

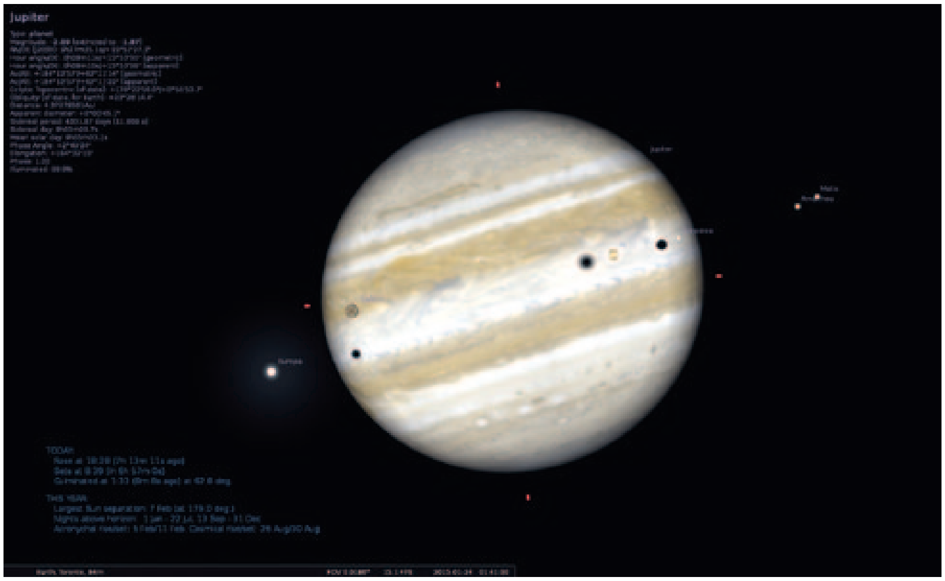


Figure 3 — Jupiter with Moons.

For example, planet labels can be toggled on or off with the P key. The equatorial grid can be toggled with E. The C key shows or hides the constellations. There are many keys and learning them all can be a challenge. I made a quick reference guide listing them all for the Windows and Mac environments. It can be found in my blog resource area (http://computer-ease.com/darkskies/), in the software support section.

For a long time now, *Stellarium* has existed in beta release. As such, one must use *Stellarium* knowing that it may fail at times or not work correctly in some respects. The most common issues involve graphics and display. Ensure you have the latest *OpenGL* drivers for your computer's video circuitry. The small team of developers and volunteers work on the project when they can, resolving bugs and adding features. User manuals, forums, and other materials can be found on the main Web site (http://stellarium.org/).

I continue to use *Stellarium* to this day, particularly during presentations when I'm demonstrating "what's up." I also find it quite useful, with custom landscapes for my small backyard or the Centre's observatory, for assessing conjunctions, gauging visibility, and checking sightlines.

Stellarium is a good application that renders the sky in a realistic way. It is easy to use and the price can't be beat. If you're getting started and looking for an attractive program for your desktop or laptop computer, try it out. ✶

Blake's interest in astronomy waxed and waned for a number of years, but joining the RASC in 2007 changed all that. He volunteers in EPO, co-manages the Carr Astronomical Observatory, and is a councillor for the Toronto Centre. In daylight, Blake works in the IT industry.

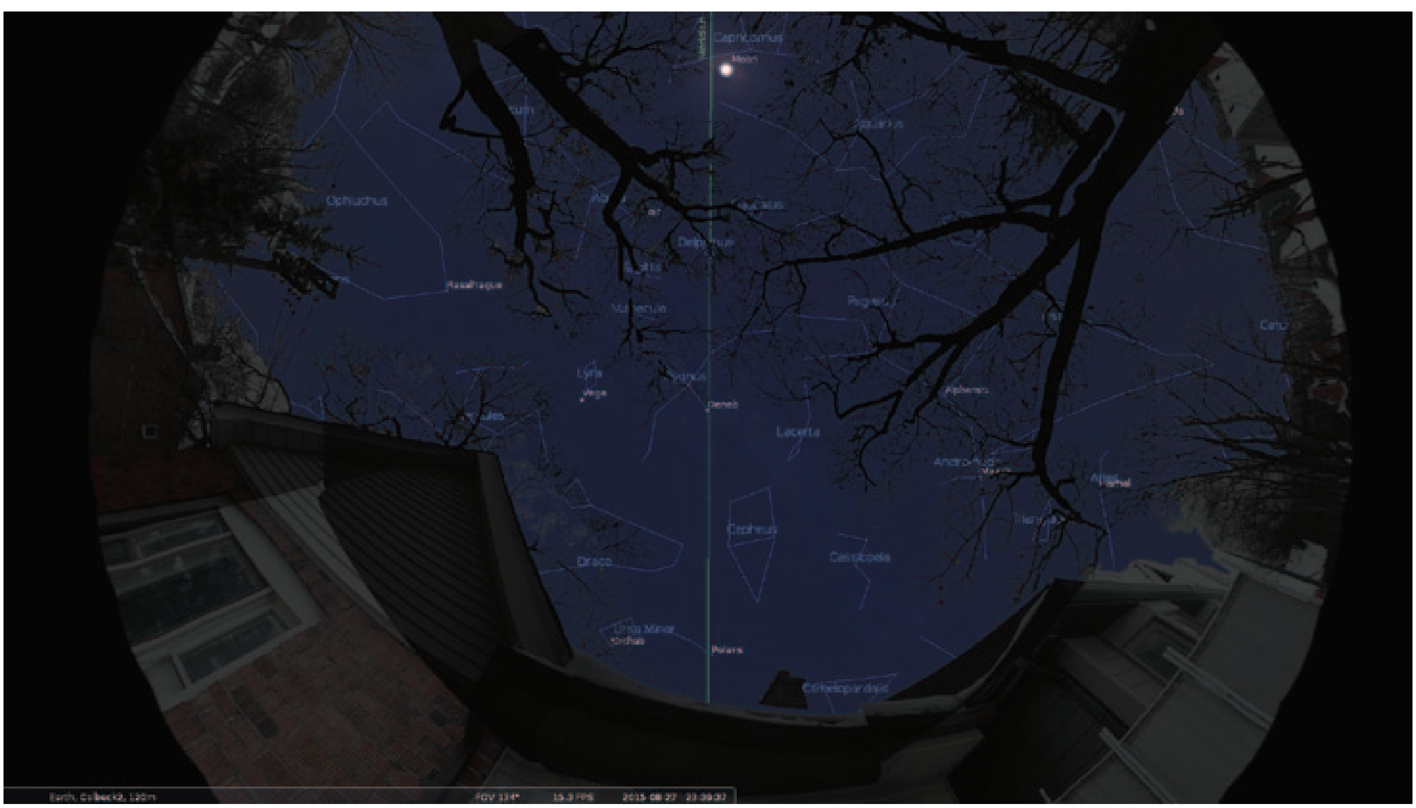
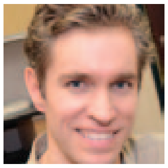


Figure 4 — An overhead view that mimics a suburban back yard.

Dish on the Cosmos

What's in a Name?



by Erik Rosolowsky, University of Alberta
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Canada's newest national telescope is the Atacama Large Millimetre/submillimetre Array (ALMA), which is being commissioned now in Chile. As part of an international consortium, many Canadian astronomers are using this telescope in limited capacity while some final capabilities of ALMA are being brought on line. Once fully operational, ALMA will be uniquely poised to answer a suite of outstanding questions about the Universe. In this article, I aim to explain why ALMA has scientists like me so excited and also present an outline of the phenomena for which the new telescope has a privileged view. While much of the science of ALMA will be explored in other articles, this article will focus on the telescope itself. One guide to understanding ALMA's novelty is to look at each of the letters in the acronym, which reveals why ALMA really is a next-generation telescope.

Since astronomers categorize telescopes by the wavelength of light they observe, the best place to begin describing ALMA is with the M for *millimetre/submillimetre*. This letter refers to the wavelength of radiation that the telescope can detect and is intimately linked to the types of objects that can be studied with ALMA. Visible light—or more generally, electromagnetic radiation—has wavelengths between 400 and 700 nanometres (1 nanometre is 1 billionth of a metre). Not surprisingly, hot objects like our Sun give off copious amounts of visible light. Our brains perceive the different wavelengths of visible light as colour: blue light has a shorter wavelength than red light. In contrast with our eyes, ALMA is sensitive to light with wavelengths from 300 micrometres (1 micrometre is one-millionth of a metre) to 3 millimetres (mm), significantly longer in wavelength than visible light. Still other telescopes observe much shorter wavelengths of light, for example, the *Chandra X-ray Observatory* detects light with a wavelength 100 times shorter than visible radiation. Astronomers need so many different types of telescopes, because the varieties of objects in the Universe are bright at different wavelengths.

Light with wavelengths near 1 millimetre—what ALMA observes—arises from two specific phenomena: *thermal emission*, which is given off by all warm objects, and *spectral line emission*, which comes from molecules. These two types of emission also occur in the visible wavelength range and can be seen in light from the Sun. If the visible light from the Sun is sorted into different wavelengths (colours), forming a spectrum, we find that the Sun gives off some light at all wavelengths. This "rainbow" of thermal emission is similar to that which arises from all opaque objects. There are also certain narrow lines of colour where the Sun gives off significantly less light than in other nearby wavelengths, forming a dark line in the spectrum. The specific spectral lines represent light that is absorbed in the Sun's atmosphere by certain types of atoms. One of the strongest lines is associated with hydrogen, but there are also strong spectral lines from sodium and calcium.

The formation of spectral lines is one of the primary observed features of quantum mechanics. The differing lines for different atoms are directly linked to the structure of the electron orbits, which is unique for every type of atom. This relationship between spectral lines and atoms is the key tool that allows us to know the chemical makeup of distant celestial objects.

ALMA also detects these two classes of emission, although with some differences that stem from operating at longer wavelengths of light. Indeed, these differences are exactly what make ALMA such a novel observatory. Cold objects with temperatures of -260 ˚C emit almost no visible-light thermal emission, but they can emit significant radiation at millimetre wavelengths. Detection of emission from these ultra-cold objects is very rewarding, since the earliest stages of star formation occur in cold, dark clouds with such low temperatures. ALMA's capabilities are throwing open a new window into the cold, dark, and molecular Universe.

At these frigid temperatures, the hydrogen gas that dominates the ordinary contents of the Universe is found in its (diatomic) molecular form: H_2. This molecular state is not unique to hydrogen. Many of the rarer atoms, including carbon, oxygen, nitrogen, and sulphur are also bound up into simple molecules such as carbon monoxide (CO) or hydrogen cyanide (HCN). Just like the hydrogen, calcium, and sodium in the Sun's atmosphere, these molecules have spectral-line signatures, though in the case of lines seen by ALMA, the rules of quantum mechanics dictate spectral lines linked to the rotations and vibrations of the molecules instead of their electrons.

The first A in ALMA is short for *Atacama*, which is a high desert plateau in Chile, reaching an altitude of 5000 metres above sea level at the site of the telescope. The desert conditions at high altitude mean that ALMA is located above most of the Earth's atmosphere. In particular, it is above most of the water vapour in the air. Because ALMA aims to see the emission from very cold objects in space given off by molecular emission from species like water, similar molecules in the atmosphere will contribute interference to the observations. Atmospheric air is warm (-10 ˚C to 10 ˚C rather than -260 ˚C) and it is filled with emitting molecules that could drown out the signals from space. On the Atacama plateau, interfering effects are also minimized because of the added bonus of a smooth laminar flow in the thin atmosphere that blows from the Pacific Ocean. There is little atmospheric turbulence in such a flow, which improves

Figure 1 — This beautiful image of the Atacama Large Millimetre/submillimetre Array (ALMA), shows the telescope's antennae under a breathtaking, starry, night sky. Image: ALMA/ESO/ Christoph Malin.

the seeing conditions. And yes, seeing can still be a limitation at millimetre wavelengths.

The L in ALMA simply means *Large*, continuing in the creative astronomical vein that brought such poetic descriptions as "Big Bang." Even so, ALMA has ten times the collecting area of previous millimetre telescopes, making it more sensitive by at least this factor. When paired with the superior site and improvements in detector technology, this improvement can exceed factors of 100 for many observations. Even during its construction, ALMA was the best telescope in its class. While operating at only a fraction of its full potential, a team led by Canadian astronomer Rita Mann used ALMA to study developing stars in the Orion star-forming region (around M42), finding previously undetected disks of emission around the protostars in the system. Since these newly forming stars are located near the massive star θ^1 Orionis C, they are bathed in high-energy radiation that destroys the disks that feed the protostar during formation. The traces of disks that were found were tiny, pointing to the importance of the hostile environment at controlling star formation in the area.

Finally, the closing A in ALMA is short for *Array*, which indicates that the telescope is made of several independent antennae (dishes) operating in concert to produce images. The process, called *aperture synthesis*, describes how to link the combined signals from a suite of antennae to form a single, high-resolution image. The technique is sufficiently sophisticated to merit both a Nobel Prize (to Martin Ryle in 1974) and a separate JRASC article in the future. ALMA alone can achieve a resolution of 0.01 arcseconds and could even be linked with other, older telescopes to achieve a resolution 1000 times smaller than this. The results of this remarkable image quality are that ALMA will be providing more amazing pictures in millimetre-wavelength light. Such images are revealing structures in forming planetary systems and may soon measure the event horizon of the black hole at the centre of our galaxy.

The name ALMA is a utilitarian description of all the features that make this telescope revolutionary. But, when translated into Spanish, *alma* means *soul*. The new telescope will indeed be the soul of decades of scientific discovery and this new era is just beginning. ✶

Links to the Mann *et al*. research:

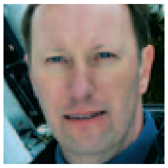
www.almaobservatory.org/en/press-room/press-releases/674-death-stars-in-orion-blast-planets-before-they-even-form

http://arxiv.org/abs/1403.2026

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

Imager's Corner

Contrast Layering



by Blair MacDonald, Halifax Centre
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In this edition, we'll take a look at a layer technique that's one of the older techniques to increase contrast and detail. The basics of the approach have been around since *Photoshop* first introduced layers and blend modes, and I like this one because of its subtle and controllable results.

Contrast layering relies on using multiple copies of the same image combined with different blend modes to accomplish the desired effect. Depending on the blend mode, you can increase saturation or add contrast and detail. Add masks into the mix, and you can tailor the effect to target just what you want in the image.

To demonstrate, let's start with an image of one of my favourite galaxies, M81. See Figure 1 above.

Figure 1 — Lightly stretched M81 image

Now build a stack of three layers, all duplicates of the initial M81 image. Next, make a luminance mask from the image and apply it to the middle layer. Change the blend mode on the middle layer to screen. Duplicate the mask, then invert the duplicate, and add it to the top layer of the stack. Finally, switch the blend mode of the top layer to soft light to produce the final image stack as shown below.

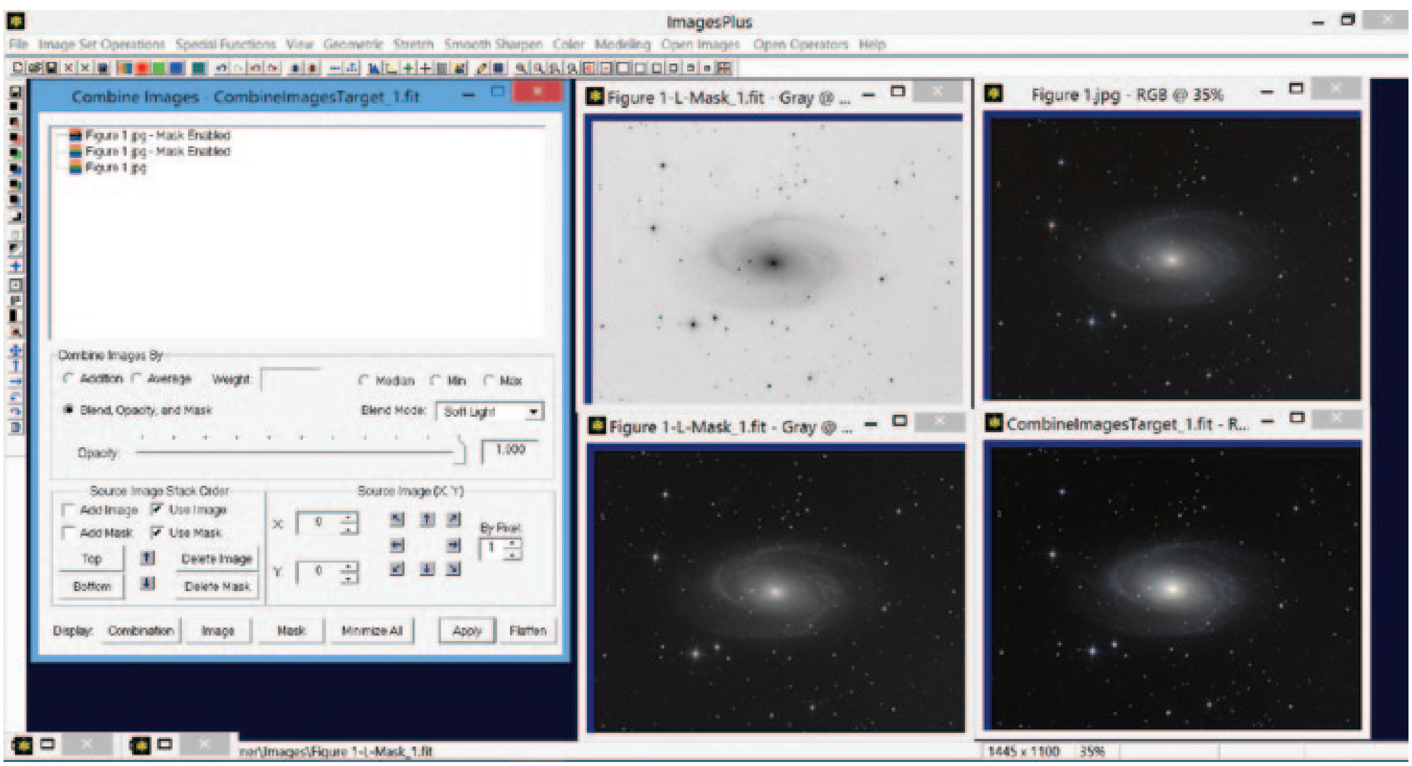


Figure 2 — Final image stack with both masks

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

Figure 3 — Final enhanced image

The way this works is straight forward: the screen layer tends to lighten the image, while the soft light increases contrast by darkening the already-dim areas. The luminance mask on the screen layer limits the brightening to the brighter areas, and the inverted mask on the soft-light layer will limit the darkening to the dimmer areas. This has the effect of gently increasing contrast and detail. The masks can be painted to limit or emphasize the effect in parts of the image. In addition, the process can be applied iteratively to greatly increase the contrast.

Figure 4 — Core of M81 in original image (top) and after enhancement (bottom)

The image produced by this technique shows a very nice gentle contrast boost as shown in Figure 3 on the left.

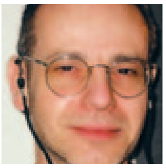
Zooming into the core, you can readily see the effect in the two images in Figure 4.

Remember, this column will be based on your questions so keep them coming. You can send them to the list at hfxrasc@lists.rasc.ca or you can send them directly to me at b.macdonald@ns.sympatico.ca. Please put "IC" as the first two letters in the topic so my email filters will sort the questions. ✶

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

Astronomical Art & Artifact

RASC Catalogue of Meteorites—Third Supplement



by R.A. Rosenfeld, RASC Archivist
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Abstract

This third supplement to the RASC Catalogue of meteorites records the addition of specimens of twelve different meteorites, four different impactites, and one associated object.

Introduction

The RASC Archives have benefitted yet again from the generosity of the anonymous RASC member whose three earlier gifts of meteoritic materials now comprise the majority of the objects in the RASC Archives' meteoritical collection (previous material catalogued in Rosenfeld 2009; 2010; 2011). Among the newly added materials are fragments from the Abee (RASC M23) and Buzzard Coulee falls (RASC 25), and the Lone Island Lake find (RASC 24). The collection now also includes fragments of Weston (RASC M26), Almahata Sitta (RASC 27), and Chelyabinsk (RASC 28). Also newly accessioned are pieces of tempered glass shattered by the Chelyabinsk shock wave (RASC O1), pieces of Sudbury distal ejecta (RASC I9), and several moldavites (RASC I10)

Catalogue

The catalogue fields consist of:

1. inventory number;
2. type and origin;
3. provenance;
4. dimensions;
5. weight;
6. form;
7. appearance;
8. state of preservation; and
9. bibliography (previous publications of a RASC specimen precede general type citations).

Entries for **7** provide the colour in the Munsell system in the *Earthcolors* version (Anon. 1997). No conclusions should be drawn about the original size and shape of the fragments from the use of the Krumbein Phi Scale and Wentworth Classification, as most of the fragments received their current shape and size from post-impact human agency, *e.g.* some are bandsaw fines. Both systems are employed here merely to give some indication of comparative fragment size. Given the limited extent of the collection, a little more detail can be supplied in the fields than is usually the case in such catalogues. This is not to be taken as a sign of the relative importance of the specimens in the RASC collection; rather it attests to the opposite. It should also be noted that characterizations of the material are based on descriptions of the type specimens, or other properly analyzed specimens in the literature, for samples from none of the RASC specimens have been subject to extensive laboratory analysis. This catalogue has been prepared with the needs of the amateur uppermost, rather than the professional.

Meteorites

29. **1**. RASC M23.20141001; **2**. Abee, enstatite chondrite (EH4), Alberta, Canada (54°13′N, 113°W), fall 1952 June 9, 107 kg.; **3**. anonymous gift 2014 October 1; **4**. 3 fragments; range of fragment sizes ϕ scale=-2 to 2 (Wentworth size class=very fine gravel to fine sand), 0.06-0.30 cm; **5**. 0.051gr.; **7**. colour range: 2.5Y 2.5/1 Black to 2.5Y 7/1 Light Gray matrix, with sparse inclusions at 2.5Y 8/3 Pale Yellow (Munsell); **8**. good, but friable as per this type; **9**.not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=6; *MB* 8 (1958), 2; MBDB www.lpi.usra.edu/meteor/metbull.php?code=6; Whyte (2009), 155-189

30. **1**. RASC M24.20141001; **2**. Lone Island Lake, medium octahedrite (IAB-sLL), Manitoba, Canada (50° 0′ 34″N, 95° 23′ 7″W), find 2005, 4.8 kg.; **3**. anonymous gift 2014 October 1; **4**.fragment, ϕ scale=-1 to -2 (Wentworth size class=very fine gravel), 0.36×0.24×0.12 cm; **5**. 0.08 gr.; **7**. colour range: 5Y 2.5/1. This specimen is iron shale; **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=55762; *MB* 101 (*forthcoming*); MBDB www.lpi.usra.edu/meteor/metbull.php?code=55762

31. **1**. RASC M25.20141001; **2**. Buzzard Coulee, ordinary chondrite (H4), Saskatchewan, Canada (52° 59′ 46″N, 109° 50′ 53″W), fall 2008, 41 kg.; **3**. anonymous gift 2014 October 1; **4**. 4 fragments; range of fragment sizes, ϕ scale=1 to -2 (Wentworth size classes=coarse sand to very fine gravel), 0.05-0.35 cm; **5**. 0.051 gr.; **7**. colour range: N 7/ (Light Gray) matrix, with 2.5Y 8/1 White to N3/ Very Dark Gray chondrules; **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=48654; *MB* 95 (2009), 5; MBDB www.lpi.usra.edu/meteor/metbull.php?code=48654; Fry. C., *et al.* (2013)

32. **1**. RASC M26.20141001; **2**. Weston, ordinary chondrite (H4), Connecticut, USA (41° 16′N, 73° 16′W), fall 1807, 150 kg.; **3**. anonymous gift 2014 October 1; **4**.fragment, ϕ scale=1 to 0 (Wentworth size class=coarse sand), 0.1×0.08×0.05 cm; **5**. 0.012 gr.; **7**. colour range: 2.5Y 8/1 White to N3/ Very Dark Gray; **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=24249;

MB 96 (2009), 1359-1369; MBDB www.lpi.usra.edu/meteor/metbull.php?code=24249; Noonan & Nelson (1976); Marvin (2011)

33. **1**. RASC M27.20141001; **2**. Almahata Sitta, Ureilitean, Nubian Desert, Sudan (20° 44′ 45″N, 32° 24′ 46″E), fall 2008, 3.95 kg.; **3**. anonymous gift 2014 October 1; **4**.fragment, ϕ scale=0 to -1 (Wentworth size class=very coarse sand), 0.16×0.12×0.1 cm; **5**. 0.01 gr.; **7**. Colour range: 5YR 7/6 (Reddish Yellow) to N 2.5/ (Black); **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=48915; *MB* 96 (2009), 1355-1356; MBDB www.lpi.usra.edu/meteor/metbull.php?code=48915; Jenniskens *et al.* (2010)

34. **1**. RASC M28.20141001; **2**. Chelyabinsk, ordinary chondrite (LL5), Chelyabinskaya oblast', Russia (54° 49′N, 61° 7′E), fall 2013, 1 t.; **3**. anonymous gift 2014 October 1; **4**. 3 fragments, ϕ scale=1 to -3 (Wentworth size class=coarse sand to fine gravel), 0.09-0.53 cm.; **5**. 0.017 gr.; **7**. colour range: N 7/ (Light Gray) matrix, with N 4/ (Dark Gray) chondrules. Fusion crust on the two largest fragments, colour N 2.5/ (Black); **8**. Excellent; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=57165; *MB* 102 (*forthcoming*); *MB* 103 (*forthcoming*); MBDB www.lpi.usra.edu/meteor/metbull.php?code=57165; Galimov *et al*. (2013); Marov *et al.* (2013)

35. **1**. RASC M29.20141001; **2**. Lahoma, ordinary chondrite (L5), Oklahoma, USA (36° 23′N, 98° 5′W), find 1963, 21.8 kg.; **3**. anonymous gift 2014 October 1; **4**. *ca*. 15 fragments, ϕ scale=1 to -2 (Wentworth size class=coarse sand to very fine gravel), 0.06-0.26 cm.; **5**. 0.028 gr.; **7**. colour range: N 2.5/ (Black) matrix; **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=12432; *MB* 83 (1999), A172; MBDB www.lpi.usra.edu/meteor/metbull.php?code=12432

36. **1**. RASC M30.20141001; **2**. Northbranch, ordinary chondrite (H5), Kansas, USA (39° 59′ 30″N, 98° 20′ 30″W), find 1972, 76 kg.; **3**. anonymous gift 2014 October 1; **4**. *ca*. 30 fragments, ϕ scale=3 to -3 (Wentworth size class=fine sand to fine gravel), 0.019-0.54 cm.; **5**. 0.04 gr.; **7**. colour range: N 3/ (Very Dark Gray) matrix; **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=17010; *MB* 81 (1997), A162; MBDB www.lpi.usra.edu/meteor/metbull.php?code=17010

37. **1**. RASC M31.20141001; **2**. Koltsovo, ordinary chondrite (H4), Kaluga District, Russia (54° 45′ 2″N, 36° 58′ 41″E), find 2004, 20.02 kg.; **3**. anonymous gift 2014 October 1; **4**. fragment, ϕ scale=-3 (Wentworth size class=fine gravel), 6.1×5.9×3.0 cm.; **5**. 0.161 gr.; **7**. colour range: N 4/ (Dark Gray) matrix, with N 5/ (Gray) to N 3/ (Very Dark Gray) chondrules; **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=30742; *MB* 89 (2005), A209; MBDB www.lpi.usra.edu/meteor/metbull.php?code=30742

38. **1**. RASC M32.20141001; **2**. Jbilet Winselwan, carbonaceous chondrite (CM2), Western Sahara, Morocco (26° 40′ 3″N, 11° 40′ 38″W), find 2013, 6 kg.; **3**. anonymous gift 2014 October 1; **4**. complete granule, ϕ scale=-1 to -2 (Wentworth size class=very fine gravel), 0.38×0.28×0.24 cm.; **5**. 0.089 gr.; **7**. colour range: N 4/ (Dark Gray) to N 2.5/ (Black) exterior, N 2.5/ (Black) interior visible at broken surface; **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=57788; MB 102 (*forthcoming*); MBDB www.lpi.usra.edu/meteor/metbull.php?code=57788

39. **1**. RASC M33.20141001; **2**. NWA 2999, achondrite (angrite), Morocco or Algeria, find 2004, 0.392 kg.; **3**. anonymous gift 2014 October 1; **4**. fragment, ϕ scale=-1 to -2 (Wentworth size class=very fine gravel), 0.37×0.29×0.18 cm.; **5**. 0.08 gr.; **7**. Colour range: N 2.5/ (Black); **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=33449; *MB* 90 (2006), 1396; MBDB www.lpi.usra.edu/meteor/metbull.php?code=33449

40. **1**. RASC M34.20141001; **2**. NWA 4473, achondrite (diogenite), find 2006, 7.02 kg.; **3**. anonymous gift 2014 October 1; **4**. *ca*. 30 fragments, ϕ scale=4 to -2 (Wentworth size classes=very fine sand to very fine gravel), 0.01-0.36 cm.; **5**. 0.081 gr.; **7**. colour range: N 3/ (Very Dark Gray) matrix, 5R 8/1 (White), 5Y 8/3-5Y 8/4 (Pale Yellow), and 2.5YR 7/6 (Light Red)-2.5YR 5/6 (Red) clasts; **8**. good; **9**. not previously published; IMCA EoM www.encyclopedia-of-meteorites.com/meteorite.aspx?id=44946; *MB* 92 (2007), 1657; MBDB www.lpi.usra.edu/meteor/metbull.php?code=44946

Impactites

41. **1**. RASC I9. 20141001; **2**. Sudbury distal ejecta, Hillcrest Park (Thunder Bay), Ontario, Canada (48° 26′ 4″N, 89° 14′ 4″W); **3**. anonymous gift 2014 October 1; **4**. 2 fragments, 5.2×3.5×1.6 cm., 5.1×3.3×1 cm.; **5**. 15.1 gr., 13.8 gr.; **8**. friable; **9**. not previously published; Addison (2005); Addison (2010); Glass & Simonson (2012)

42. **1**. RASC I10. 20141001; **2**. Moldavite, Czech Republic; **3**. anonymous gift 2014 October 1; **4**. 2 fragments, 1.3×1.2×0.6 cm., 1×0.70×0.68 cm.; **5**. 0.84 gr., 0.5 gr.; **8**. good; **9**. not previously published; Trnka & Houzar (2002); Baier (2007)

43. **1**. RASC I11. 20141001; **2**. Tektite, Australasian Strewn Field; **3**. anonymous gift 2014 October 1; **4**. 5.17×2.3×1.8 cm.; **6**. pear-shaped splashform; orientated; **8**. excellent state of preservation; **9**. not previously published; McCall (2001), 51-54

Other

44. **1**. RASC O1. 20141001; **2**. tempered-glass fragments created by meteor shock wave, Chelyabinskaya oblast′, Russia (54° 49′N, 61° 7′E); **3**. anonymous gift 2014 October 1; **4**. 5.17×2.3×1.8 cm.; **4**. 2 fragments, ϕ scale=-2 to -3 (Wentworth size class=fine gravel), 0.65×0.6×0.4 cm., 0.59×0.52×0.4 cm.; **5**. 0.3 gr.; **8**. good ✶

Acknowledgements

The author wishes to thank the donor of the anonymous gift of meteorites for reading over this paper and catalogue, and the *Specula astronomica minima* for the generous loan of lab equipment. This research has made use of NASA's Astrophysics Data System.

Abbreviations

IMCA EoM=	International Meteorite Collectors Association. Encyclopedia of Meteorites
M&PS=	*Meteoritics & Planetary Science*
MB=	*Meteoritical Bulletin*
MBDB=	Meteoritical Bulletin Database
NWA=	Northwest Africa

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MBDB=Meteoritical Society. Meteorite Bulletin Database. www.lpi.usra.edu/meteor/metbull.php (accessed 2011 February 1)

John Percy's Universe

What My Students and I Have Learned about Pulsating Red Giants

by John R. Percy
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Red giants are *cool*—literally. They are huge; you could put a million Suns into one. They are common: there are several hundred red (type M[1]) giants among the naked-eye stars, and several thousand orange (type G and K) giants. They are variable in brightness—which is why I am interested in them. My students and I have observed and/or analyzed a large fraction of the naked-eye M giants. They are *interesting*, and astrophysically *important*.

The Sun will become one, in its old age. Its outer layers are presently shimmering in a complex mixture of thousands of pulsation (vibration) modes or patterns whose amplitudes are so small that they can only be detected with special equipment. As the Sun exhausts its hydrogen fuel, it will slowly expand and cool. It will briefly stabilize when its core becomes hot and dense enough to fuse helium to carbon. Then, as the helium fuel is exhausted, it will expand and cool again and begin to pulsate radially—in and out—with increasing period and amplitude. At its most extreme, it will pulsate with a period of about a year, so vigorously that its outer layers will be driven off into space, forming a planetary nebula, and exposing the Sun's white dwarf core, a million times denser than water.

My research career began in 1962 with modelling stellar structure and evolution and stellar pulsation, especially small-amplitude variables such as Beta Cephei stars, which would be of limited interest to amateurs. In 1977, I joined the American Association of Variable Star Observers (AAVSO) and soon became aware of the gold-mine of AAVSO visual observations that were available for analysis. The data would be especially useful for students, since they could use them to develop and integrate their science and math skills, motivated by the excitement of doing real science with real data. The projects described below were done by students—either undergraduates, or outstanding senior high-school students in the University of Toronto Mentorship Program (Percy 1990).

In the 1980s, with grant support from Toronto's J.P. Bickell Foundation, Petrusia Kowalsky and I worked with AAVSO staff to process 75 years of visual observations of 391 Mira stars—large-amplitude pulsating red giants (PRGs)—and determine times and magnitudes of maximum and minimum brightness (Kowalsky *et al.* (1986)[2]. With this database, Barry Sloan identified Mira variables with unusual changes in amplitude or mean brightness. Ted Colivas showed that all the Miras underwent random cycle-to-cycle period fluctuations of a few percent. These made it impossible to detect small evolutionary period changes in individual stars[3] but, in a *tour de force* project, Winnie Au averaged the behaviour of all 391 stars, and was able to detect the slow evolutionary period change in the *ensemble*, at a moderate level of significance (Percy and Au 1999). Swedish amateur astronomer Thomas Karlsson has since confirmed this result at a higher level of significance, using an additional 38 years of data (see Karlsson 2013).

In the 1980s, amateur photoelectric photometry (PEP) blossomed. Off-the-shelf photometers such as Optec's SSP-3 became available. Organizations, how-to books, and conferences sprang up. AAVSO Director Janet Mattei and I developed an AAVSO PEP program, consisting mostly of PRGs whose amplitudes were too small for convenient visual observation. Within a few years, new results were obtained on individual stars and on the PEP program stars as a group (Percy *et al.* 1996). We also carried out surveys, both through the AAVSO PEP network and with a 0.4-m telescope on the University of Toronto campus, of dozens of suspected PRGs.

Also in the 1980s, small robotic "automatic photometric telescopes" (APTs), controlled by first-generation microcomputers, were installed at remote sites by various groups. Tennessee State University astronomer Greg Henry accumulated many years of observations of 34 PRGs with an APT in Arizona, and invited me and my student Joe Wilson to analyze the data (Percy *et al.* 2001). For stars on both the AAVSO and the APT programs, we could merge the data and, for instance, fill in the gaps in the APT data resulting from the Arizona monsoon season.

These studies and surveys provided an excellent overview of how PRGs behave. As the star expands and cools, radial pulsation begins when the spectral type is mid-K (4000 K surface temperature). Thereafter, the star's period and amplitude increase, on average. At first, the pulsation is usually in higher overtones, the 1st, 2nd, and 3rd. Later, the 1st overtone, and finally the fundamental mode tend to be excited. Many PRGs pulsate in *two or more modes* at the same time (Percy *et al.* 2003). About a third of all PRGs also have a "long secondary period," about ten times the fundamental radial period. Its nature and cause are still unknown, despite much research on the topic. The variability of PRGs is not simple and straightforward, and that's not surprising, considering that the most extreme PRGs are pulsating, have huge convective cells on their surface, are losing mass, are rotating, probably have a magnetic field, and may well have an interacting binary companion!

But, there was much good science to be extracted from the AAVSO *visual* database so, about five years ago, we began to use it to study PRGs that had not been well studied before. What about "irregular" (L-type[4]) PRGs, for instance? There are 900 of them in the AAVSO database, mostly with only a handful of observations. We analyzed about 125 that had at least 250 observations, and found that most of them were non-variable—or microvariable at best! No more than about 35 had *possible* periods, with low amplitudes (Percy and Terziev 2011 and references therein). "L-type" seems to be the "scrap heap" of the classification system.

And, what about the "semi-regulars" (SR type)? We studied 55 of these; their behaviour ranged from non-variable to irregular to highly periodic, including 11 stars that had *two* periods interacting together—usually the fundamental and 1st overtone radial periods (Percy and Tan 2013). Knowing two periods is potentially more useful than knowing only one, and Joanna Huang is presently looking into what can be learned, astrophysically, from two periods.

Most recently, we have been using *VSTAR*[5], a powerful new software package for time-series analysis of variable-star data. It was developed by the AAVSO for *Citizen Sky*, an International Year of Astronomy 2009 project that highlighted the bright, enigmatic, eclipsing binary Epsilon Aur, and that encouraged amateurs and students to observe and analyze this and other variable stars. *VSTAR*, among other things, has a Fourier routine to determine average periods and amplitudes of variable stars and a wavelet routine to study the time variability of these periods and amplitudes. *VSTAR* is user-friendly, comes with excellent manuals and tutorials, and is freely available for download.

Romina Abachi used the *VSTAR* wavelet routine to study the amplitudes of nearly 100 PRGs, and found that the amplitudes varied by factors of 2 to over 10 on time scales of about 40 pulsation periods (Percy and Abachi 2013). This was an unexpected and therefore very useful and exciting result. Viraja Khatu then studied 44 pulsating red supergiant stars and also found variations in amplitude of up to a factor of 8, on time scales of about 20 periods! Rufina Kim studied 29 pulsating yellow giants and supergiants—RV Tauri[6], SRd[7], long-period-

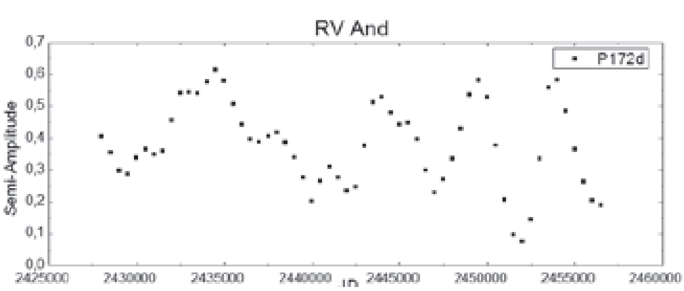

Figure 1 — The semi-amplitude of the pulsating red giant RV And, as a function of Julian Date, as determined by wavelet analysis of AAVSO visual observations. The pulsation period of the star is about 172 days. The semi-amplitude varies from 0.1 to 0.6 magnitudes, on a time scale of about 40 pulsation periods—a quite unexpected result. (The semi-amplitude is measured from the mean magnitude, and is half the peak-to-peak amplitude).

Cepheid, and even hypergiants like Rho Cas—and found that they too vary in amplitude by factors of up to 10 on time scales of 33±4 pulsation periods (Percy and Kim 2014). These results require us to modify our understanding of what excites pulsation in a PRG. It cannot simply be a constant excitation process, like the standard opacity mechanism. Something must semi-regularly give a "kick" to the pulsation amplitude, after which it decays. That "something" may be large convective motions, which are known to be especially significant in cool stars.

A variable-pulsation amplitude makes possible another project that, in a way, dates back to Galileo, who showed that the period of the swing of a pendulum does not depend on the amplitude of the swing. The period of a vibrating object does not depend on amplitude—unless the amplitude becomes large, in which case non-linear processes may cause the period to increase slightly. Does this cause the period of a pulsating star to increase, if its amplitude increases? Jeong-Yeon (JY) Yook set out to find out. In a sample of about 50 such stars, 80-90 percent of those with sufficient data showed a positive correlation between amplitude and period. But it is only the carbon-rich PRGs that show this effect (Percy and Yook 2014). We don't know why (yet). As usual, this leads to the next project…

This 30-year undertaking has been a win-win-win situation. Good science got done. Dozens of students honed their science and math skills by doing real science with real data. It resulted in over 60 research publications, with the students as co-authors. Most of the results were presented and/or published at AAVSO meetings, or in the *Journal of the AAVSO*. In this way, AAVSO observers learned how their work contributed so significantly to both science and education.

Acknowledgements

We thank the hundreds of AAVSO observers who made the measurements on which our work was based, and the AAVSO staff for processing them and making them publicly available. My students' work has been supported by several sources and programs, including the Ontario and University of Toronto Work-Study Programs, the University of Toronto Mentorship Program, the Bickell Foundation, and the Natural Sciences and Engineering Research Council of Canada. I want to publicly acknowledge the students who are explicitly named in this article, and the following students who also participated in the PRG research, and are co-authors of other papers which describe the results: Dalia Bagby, Akos Bakos, Gurtina Besla, Tanya Brekelmans, Estelle Campbell, Adrien Desjardins, Heather Dunlop, Samantha Esteves, Elena Favaro, David Fleming, Jou Glasheen, Metin Guler, Bernadette Ho, Joanne Hosick, David Hou, Asif Hussain, Lola Kassim, Ryan Kastrukoff, Tomas Kojar, Alfred Lin, Junjiajia Long, Margarita Marinova, Marina Mashintsova, Christopher Menezes, Anna

Molak, Cristina Nasui, Zoe Nyssa, Rohan Palaniappan, Michael Parkes, Jorge Ralli, Michael Richer, Hiromitsu Sato, Li Sen, Rajiv Seneviratne, Charles Shepherd, Sabine Polano Stanley, Matt Szczesny, Claudia Ursprung, Vince Velocci, Nancy Wong, Sophia Wu, and Lawrence Yu. Dozens of other students have worked on projects on other kinds of variable stars, many of them also using AAVSO data. ✶

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Endnotes

1 Stars are classified spectroscopically according to temperature OBAFGKM where M stars are coolest.

2 Note that this and other JAAVSO papers are freely available on-line: www.aavso.org/journal-aavso

3 Using the (O-C) method; see Percy (2014)

4 PRGs are classified, in the *General Catalogue of Variable Stars*, as M (Mira), SRa or SRb (semi-regular), or L (irregular)

5 www.aavso.org/vstar-overview

6 Low-mass yellow supergiants with alternating deep and shallow minima.

7 Irregular yellow supergiant variables.

John Percy is Professor Emeritus, Astronomy & Astrophysics and Science Education, University of Toronto, and Honorary President of the RASC.

Second Light

Seeing the Expanding Fireball of a Nova

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

Nova Delphinus 2013 was discovered by a Japanese amateur astronomer on 2013 August 14. Just 15 hours later, Gail Schaefer of Georgia State University and a group of collaborators from around the world had the telescopes of the CHARA array observing it. The array is an interferometer working in the optical/near-infrared, and it enables observers to achieve very high resolutions, equal to a telescope ~300 m in diameter. Using it, Schaefer was able to resolve the expanding ejecta, and could watch its structure change over the next 43 days. This is the first time that a nova has been imaged in this way.

Novae are thought to result from the thermonuclear detonation of hydrogen that has been deposited on the surface of a white dwarf by a very close companion. But, as with most things in astronomy, there is a level of uncertainty, because it is so difficult to get observations of sufficient resolution to actually see what is happening. Most of the time, astronomers draw conclusions from indirect measurements based upon a working "model" understanding of what is going on (usually computer simulations).

For novae, the working model is that the white dwarf and a giant companion are so close together that the giant's atmosphere trickles onto the surface of the white dwarf, where it accumulates over time. Once the layer of hydrogen is sufficiently thick (~50–200 m or so—this is very uncertain) the atoms fuse together at the bottom of the layer, just as happens near the centre of the Sun (and in a hydrogen bomb). This thermonuclear detonation ejects the layer of gas at high speed. The explosion and ejecta are unlikely to be symmetric, because the gas layer will not be a uniform depth over the whole white dwarf, and the nearby companion will affect the ejecta in that direction. Moreover, the white dwarf will be rotating, and may have a magnetic field that is sufficiently large to affect the ejection.

Although earlier observations of novae using photometry and spectroscopy have generally supported this picture, to be able to image it as it happens is quite extraordinary. The Center for High Angular Resolution Astronomy (CHARA) began regular operations of its array of six 1-m telescopes in 2004, with a maximum resolution of 0.0005 arcsec in the infrared (where most of the observations are done). The array is located on Mount Wilson, outside of Los Angeles, at an altitude of ~1700 m.

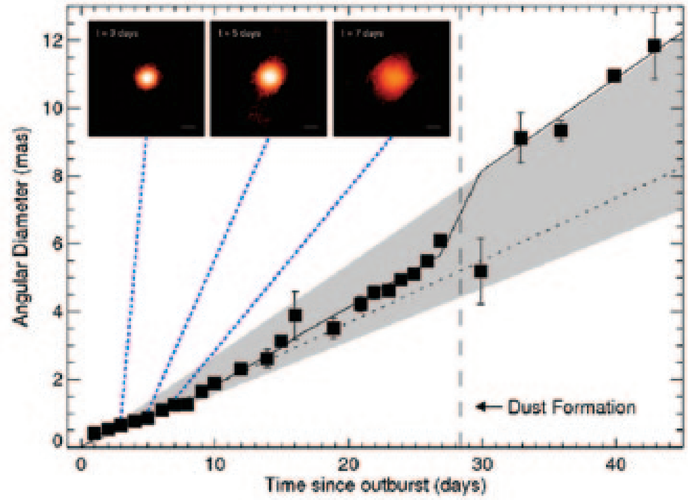


Figure — Expansion curve of Nova Del 2013. The measured angular diameters in milliarcseconds are plotted against the day of observation following the detonation of the nova.Changes in the expansion rate reveal how the structure of the ejected material evolves as the gas expands and cools. The three inserted panels show images of the fireball produced by observations with the CHARA array on days 3, 5, and 7 after the outburst. The colour indicates the relative brightness, not the actual colour; the horizontal bar at the bottom right of each image corresponds to an angular size of 0.5 milliarcseconds or 2.3 astronomical units. Courtesy of Gail Schaefer and Georgia State University.

Schaefer estimates that her first observations were taken less than 24 hours after the light from the initial explosion arrived at Earth (the actual explosion took place almost 15,000 years ago, but light travels with a finite speed). The optical light reached its maximum about three days after the explosion, based upon amateur observations reported to the AAVSO. The peak in the infrared, where the array was observing, happened about three days after that (day 6 after the explosion). On the first night of the observations, the ejecta had a radius about equal to the Earth's orbit around the Sun, and it appeared as a uniformly bright disk. At day 4, the amount of light from the outer layers dropped from 80 percent of the total light down to only 20 percent, which is remarkably rapid evolution. In physical terms, Schaefer interprets this as an expanding, optically thick "fireball" surrounded by a halo. As the expansion continued, the amount of light from the core decreased with time as more of the outer layers turned optically thin. Later, at about day 28, there was a large increase in the amount of light coming from the outer layers as dust began to form in the cooling ejecta.

The boundary between the optically thick and optically thin material is travelling outward at ~600 km/s, while the outer layers are expanding at 1000 km/s, which is fast enough to cause the size of the ejecta to vary over a 6-hour observation! Using the measured (through spectroscopy) speed, and the observed expansion rate, Schaefer calculated a distance of 4.54 kpc, which makes it the best known distance to a nova.

Deviations from circular symmetry were seen on the third day, and became noticeably more complex after that. There were previous suggestions that nova explosions were intrinsically bipolar, and Schaefer's data support that interpretation, though there could be clumpiness too.

There is a general rule of thumb in astronomy that when an event or phenomenon is observed with ten times (or more) better resolution than previously done, new levels of complexity will be seen, and often these complexities are at odds with the theoretical framework that has developed. This is likely to be the case with Nova Del 2013, as further analysis is done on the data.

Investments in technology that were started almost 30 years ago—I saw a presentation about the proposed CHARA array while I was a graduate student at Stony Brook in the mid-80s—are finally coming to fruition. I suspect that I will be writing again about the CHARA array, as it works with various surveys of transients in the sky, such as the Palomar Transient Factory. In the meantime, I encourage observers to keep sending their data about transients to repositories such as the AAVSO, or even strike up collaborations with local professional astronomers. And, do not just look for things that get brighter—look for stars that get dimmer too. Astronomers always want more data, and the more unusual, the better. ✶

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.*

Obituary

Richard Bochonko, a stalwart of the Winnipeg Centre from 1970 to 2003, passed away in Victoria on August 27 after a 20-month battle with ALS.

Richard grew up in Winnipeg's north end, literally—he lived in 15 different homes in 15 years. He was a proud north-ender, graduating from St. John's High School in 1958. Dodging a future as a classical accordionist (but retaining a love of music), Richard earned his B.Sc. honours in Mathematics at the University of Manitoba. He then went on to do a Ph.D. in astronomy at the University of Michigan, where he met Helen Hodgins, the love of his life. They were married in 1965.

Richard Bochonko
1941-2014

Richard and Helen moved back to Winnipeg in the fall of 1970, when Richard became a professor in the Department of Mathematics and Astronomy at the University of Manitoba. They welcomed their daughter, Coca, into the world on the first day of classes. Their son, Thor, followed 19 months later.

Passionate about teaching and learning, Richard spearheaded the acquisition and installation of the 40-cm Evans' telescope and construction of the Glenlea Observatory at the university's agricultural farm south of Winnipeg, thus providing critical hands-on experience for his students. He acted as the Winnipeg Centre's contact with the university, which helped to establish the relationship that led also to the construction of the Centre's observatory at the farm in the late 1970s. Prior to the solar eclipse of 1979 over southern Manitoba, he led the campaign to safely observe the event against the opposition of the school boards and other naysayers.

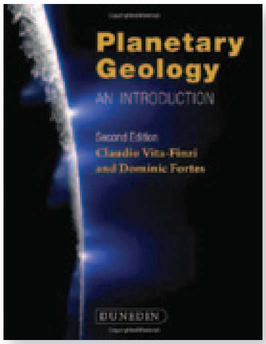
Richard was a Charter Member of the Canadian Astronomical Society, acting as the second secretary of the society from 1977 to 1983, and serving on the education committee. He loved music, chocolate, his family and friends, teaching, and volcanoes (the latter, thanks to a sabbatical at the Canada-France-Hawaii Telescope in 1983/84). Richard loved talking with old friends and finding new friends everywhere he went. His enthusiasm for life, science, and people touched everyone he met.

At the celebration-of-life service in his memory, held in Victoria in November, Dr. Jim Hesser noted that Richard was curious in everything, dedicated to his students, gregarious, and capable of making instant friendships. Dr. David Balam remembered him as the newly minted Ph.D. and "very friendly guy" with whom he shared an office at the Dominion Astrophysical Observatory as a 14-year-old, while exploring his own early interest in astronomy. Richard inspired the teenager-David, to go on to a career in spectroscopic studies and supernovae surveys. During the course of these surveys, Dr. Balam discovered many asteroids, one of which will be formally named Bochonko in February 2015.

Richard Bochonko is a prominent and cherished part of the Winnipeg Centre's history as it expanded from a small group of enthusiasts to the much larger community it now serves. He is, and will be, very fondly remembered. ✶

Reviews / Critiques

Planetary Geology: an Introduction, 2nd edition, by Claudio Vita-Finzi and Andrew Dominic Fortes, pages 192, 20 cm × 26 cm, Dunedin Academic Press Ltd, Edinburgh, 2013. Price ~$45. softcover (ISBN: 978- 1-78046-015-4).



Planetary Geology is an exceptionally well-conceived book that should be compulsory reading for all university-level geoscience students. It is also highly recommended reading for all amateur astronomers with an interest in our planetary neighbourhood. The book is lucidly written by two authors whose grasp of the subject is as impressive as it is comprehensive; their lectures must be very stimulating! In addition, it is exceptionally well illustrated with clear diagrams and high-resolution images integrated into the narrative, many of which are in colour. All of that comes at a cost: publishing constraints in order limit price.

Accordingly, the authors have opted for a very effective strategy in composing the book. First, *Planetary Geology* is presented as a series of thematic chapters, ranging from planetary origins, orbits and cycles, via planetary construction, interiors and exteriors, endogenous and surface processes, to atmospheres, oceans and ice caps, and planetary biology. Each thematic topic is illustrated with tangible examples drawn from throughout the Solar System (and sometimes beyond). Second, the text is intentionally punchy and rapid-fire, with a smattering of wry humour (*e.g.* "… contrary to some opinions, planets do not simply get in the way of real astronomy"). The authors do not have room to explain everything, but their delightful use of prose readily achieves their intent to get readers to grasp the questions at hand, and to arm them to pursue further research either in the university library (*e.g.* students), or via the Internet (*e.g.* most amateur astronomers). Third, and most importantly, the authors judiciously present both argument and counter-argument in interpreting the available evidence, thereby adding an essential element of debate—and even controversy—that successfully brings out the dynamism and excitement of the subject matter. Some RASC members may get lost in places where the more technical aspects of a topic are glossed over rapidly. Such passages are, however, necessarily short—thanks to the rapid-fire writing—and in any event readers will pick up the thread again very quickly as they progress.

I was particularly impressed with how up-to-date the book is. The subject of planetary geology has expanded so rapidly in the past few decades that it is usually difficult for the average amateur astronomer to remain abreast of recent developments. As an amateur astronomer with a long career as a professional geologist, I consider myself reasonably well versed in planetary geology. Yet, as I read the text, I was continually thinking "I knew that, but now I understand it" or "That's news to me!" The former refers to things like comparative cratering statistics as a chronological tool, or the causative factors of the Earth's Chandler wobble. The latter relates to matters as diverse as the potential impact of glaciation and sea-level changes on planetary rotation parameters, recent rationales for plate tectonics in early Martian and Venusian history (though personally I remain dubious), a suggestion that the magnetic field of Uranus may be in the process of flipping, and that Europa's magnetic field flips every 330 minutes(!), current thinking on why mare basalts occur preferentially on "our" side of the Moon , the potential role of surface water in early Venusian history, the influence of atmospheric density on wind-induced erosion and sedimentation, and clear statements and interpretations regarding the most recent observations of both the nature of the surface of Mercury and global models for its crustal shortening (plus other topics too numerous to mention here). Subjects that may induce a similar reaction among RASC members might be as specific as the various factors that appear to determine the origins of major topographic features on Venus, climatic consequences of the dramatic "wobbliness" of Martian precession, or as broad as the chapters on magnetic fields, topography/gravity, and atmospheres in their entirety.

Occasionally, I found myself wondering why the authors did not address some of my favourite topics, such as the evidence of deltas and river channels for locating the shoreline of a possible northern ocean on Mars, but then I remembered their explicit acknowledgement of their publishing constraints, and realized you can't have everything.

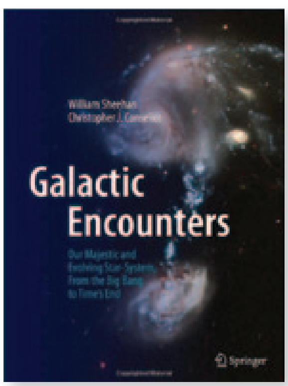
Of course, nothing is perfect, and I did raise my eyebrows in a few places in the tectonics chapter, which is close to my own geological field (structural geology). My picky, specialist sensibilities aside, I would upbraid the authors for presenting uncritically the (highly equivocal) model of the Vallis Marineris as a strike-slip fault, and for even tentatively alluding to double ridges on ice moons (other than southern Enceladus, which they do not mention in the same context) as potential analogues of terrestrial mid-ocean ridges (where then are the requisite high-angle transform faults, not to mention the belts of unequivocal crustal shortening?). That said, I appreciated their use of the conditional tense when presenting the dogmatic interpretation of penetratively lineated terrain on Ganymede as the product of extensional tectonics. Let me emphasize, however, such picky comments on my part in no way detract from the overall quality of the book.

The final chapter on planetary biology is refreshingly informative and conservative. It avoids falling into the all-too-common modern trap of wishful thinking bordering on fantasy. The presentation is nonetheless stimulating and broad, ranging from life's origins and extinctions to its potential influences on planetary processes.

To summarize, *Planetary Geology* is not a book for beginners, nor is it bedside reading. It will, however, make an excellent addition to the library of any amateur astronomer with an active interest in matters planetary and geological. I learned a lot from it, and I think you will too. ✶

Dr. Simon Hanmer is a retired research scientist with 40 years of experience in terrestrial geology, and several decades of amateur interest in astronomy, especially planetary geology. He is an active member of the RASC Ottawa Centre.

Galactic Encounters: Our Majestic and Evolving Star-System, from the Big Bang to Time's End, by William Sheehan and Christopher J. Conselice, pages 385, 21 × 28 cm, Springer, 2015. Price $44 USD, hardcover (ISBN: 978-0-387-85346-5).



In these heady days of spectacular advances in galactic astronomy and cosmology, it's easy to forget just how long and convoluted the road has been to reach this point in human awareness. Barely a century ago, it was still debated whether the various types of spiral "nebulae" observed since the time of Charles Messier and the Herschels, were part of the Milky Way or "island universes" in their own right. Not until the 1920s, with Vesto Slipher's and Edwin Hubble's work, did it become clear that these objects are indeed distant galaxies beyond our own Milky Way and that the Universe as a whole is expanding.

As late as 1902, in his popular book, *Astronomy for Everybody*, Canadian-American astronomer Simon Newcomb summarized our then-state-of-knowledge of cosmology in a chapter titled "A view of the Universe." He took readers on an imaginary voyage to the then-unfathomable distance of 100,000 light-years and states "So far as we know, we should at this point find ourselves in utter darkness, a black and starless sky surrounding us on all sides. But, in one direction, we should see a large patch of feeble light spreading over a considerable part of the heavens like a faint cloud or the first glimmer of a dawn." He goes on to say, "The one we have mentioned, and which we call the universe, is that which we are to inspect." In short, what was known of the Milky Way to that point was perceived as the entire Universe.

Galactic Encounters, by noted historian of astronomy, William Sheehan, and early universe galaxy expert, Christopher J. Conselice, is a beautifully written and illustrated compilation of our progressive understanding of the cosmos since Galileo first pointed his telescope at the Milky Way and saw multitudes of stars. Extensively researched and annotated, the book combines archival information about the personalities, social and political settings of the times, and, of course, advances in astronomical equipment that have led to our current state of knowledge about the Milky Way, galaxies, dark matter and energy, black holes, the origin of the Universe and our perceived place in it. It is an ambitious book, but the authors have managed to do the subject justice.

What this reviewer found particularly enjoyable is the insight provided on how innovative and dedicated the principal actors in this story were. Take William Herschel and his sister Caroline, for example. A more unlikely team of dedicated stargazers is hard to imagine. Both were born in Hanover, Germany, to a musical military family. In his teens, William and his brother joined their father in the Hanoverian regimental band. After his regiment suffered a defeat, William, at age 19, migrated to Great Britain in 1757 and eventually became a respected musician and composer. His interest in music led him to mathematics and optics and eventually astronomy. Caroline, in contrast, was a sickly child with stunted growth and an uncertain future as a woman unlikely to ever marry. She joined William in England in 1772 as a singer, housekeeper, and eventually an accomplished astronomer in her own right. Their combined lifetime contribution to astronomy was nothing short of extraordinary, ranging from telescope making, to the discovery of Uranus, several moons and comets, and the first serious effort to map the Milky Way, its star clusters, and nebulae. This legacy was extended well into the 19th century by William's son John.

The lives, careers, failures, and accomplishments of many other giants of physics and astronomy are similarly outlined, all in the context of their times. In this way, Sheehan and Conselice manage to show how scientific concepts, misconceptions, and progress have brought us to the present golden age of cosmology. *Galactic Encounters* is an informative and enjoyable read for all those interested not only in astronomy and astronomical history, but also the emerging sense that we are on the cusp of answering such profound questions as "Are we alone?", "Does the cosmos have some meaning?", and "Is our consciousness contiguous with it?" ✶

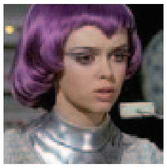
Klaus Brasch is a retired life scientist, and a lifelong amateur astronomer now living in Flagstaff, Arizona, where he volunteers in public outreach at Lowell Observatory and enjoys astro-imaging from his backyard observatory.

Great Images

Solar Shades!

Lily Kezsbom, the 4-year-old granddaughter of Dr. Jay Pasachoff, an Honorary Member of the Society, watches last October's solar eclipse from Pasadena. Image: D. Pasachoff with permission.

Society News



by Karen Finstad, National Secretary
(nationalsecretary@rasc.ca)

My initial plan for this space is to introduce you personally to our Board of Directors as I get to know them. At our fall meeting in Toronto, I announced this intention to the other Directors; well, you should have seen their faces. An appalled silence fell, and I can't say as I blame them. Yet I remain merciless in your service, dear readers.

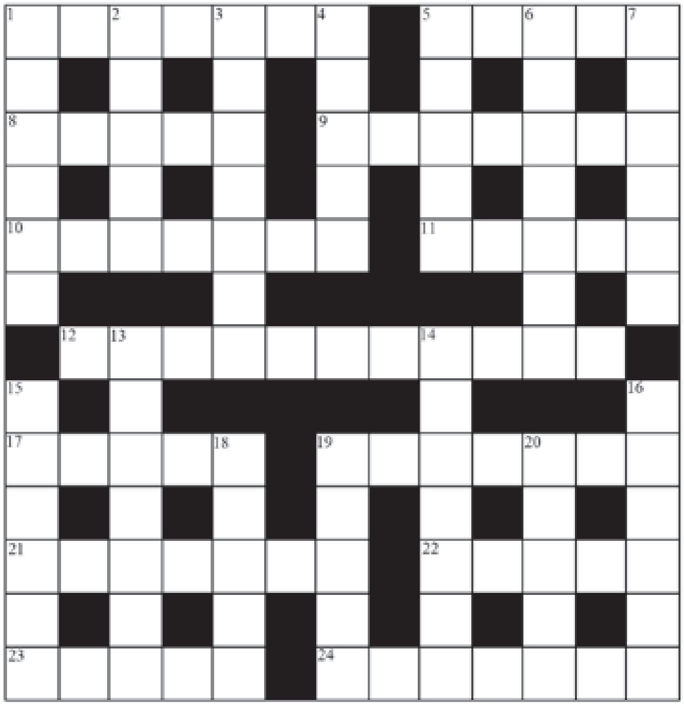
In pursuit of my nefarious plan, I sent them all a set of personal skill-testing questions. The first to respond was President James Edgar, who describes his duties as being "in charge of the Universe." James almost always responds *immediately* to emails, and his Action Items are sometimes accomplished before the end of the meetings at which they are assigned. He is on a one-year term and has things to accomplish, with no time to waste. Now retired, his job was organizing and mobilizing extremely massive objects in complicated trajectories across the country; so mere Directors are hardly a challenge for him. A former barbershop quartet lead, he's also a grandfather, photographer, master woodworker, and a one-man genealogical research institute. He's all about getting things done, occasionally at the expense of policy and procedure—we count on our procedural watchdogs to not let him get away with anything of that nature. Living in Melville, Saskatchewan, James has been a RASC member for over 14 years, because he likes "the sense of belonging, the ability to put my volunteer energies to good use, the camaraderie and relating to fellow like-minded astronomers."

Next (at least in order of response time) is Treasurer Denis Grey, who allows the rest of us to do the cool and exciting bits by slaving away at routine and unexciting stuff that is nevertheless crucial to our operations: preparing budgets and monitoring our financial operations, filing returns, and providing quarterly financial reports. In other words, filling in crazy forms and having to gather lots of little bits of information. Luckily for us, he feels the RASC is worth it, for the "exciting opportunities to learn about astronomy and camaraderie with a group of outstanding enthusiasts." Denis chairs the Finance Committee, is a key member of the IT Committee, and can be counted on to produce thorough spread-sheet analyses of tricky questions that pop up for the Board's attention. A RASC member since 1997, he is an IT professional, active church member, fighter of the good fight against climate change, proud father of a 12-year-old son, and because he lives in the GTA, he's also one of the good-natured fellows who help out when the Supreme Headquarters staff are having a computer problem.

And now for something completely different, and a confession. I enjoy my local Centre meetings, I do—but sometimes I long for a bit more variety, and some new faces behind the podium. Fortunately there is a solution: the **Public Speaker Program**. Funded by donations (not membership dues!) this program *should* be inciting fierce competition between Centres for the $10,000 available each year to help pay the travel costs for speakers from outside their local areas. Applications can be made anytime, for events up to a year in advance, and 50 percent of professional speaker's fees are now eligible to be reimbursed. Centres will need to make sure the event is open to the general public, and advertised widely. So invite somebody exciting, fill out an application form (www.rasc.ca/public-speaker-program) and let's see if we can't use up that entire budget in 2015. ✶

Astrocryptic

by Curt Nason



ACROSS

1. Mak improves interstellar search for argon (7)
5. Produces a dwarf planet, perhaps? (5)
8. Particle often the brightest to Bayer (5)
9. Ain't it a shame about Uranus? (7)
10. Let toes curl around Saturn (7)
11. The French and English born of Eris (5)
12. Rich dive Tim organized to retrieve Maksutov's first (11)
17. Pluto drops to add more extreme eruption (5)
19. Ill man reels after a stellar buckle (7)
21. Mix air and sulphur to make quality eyepieces (7)
22. Early orbiter broke orbit, making BS (5)
23. Buggy stage transcends circumpolar variable star (5)
24. Spenser somehow divided constellation (7)

DOWN

1. Minimum energies achieved through equant angular motion (6)
2. Oust Smolin for backing internal version of *Windows* (5)
3. Orbital phenomenon is intriguing but perhaps isn't art (7)
4. Rocket clothing back in style (5)
5. He is the heaviest that isn't one in a star (5)
6. Energy released from a cattle spasm (7)
7. Grease stains an honorary member (6)
13. Mother is not above being a sunspot charter (7)
14. Cacciatore was put back in Job's Coffin or a vent, perhaps (7)
15. Run laps up around infrared core of a galaxy (6)
16. Astronomical society embraces Urania, for example, and evokes laughter (6)
18. Southern constellation trails the Spanish around Jupiter (5)
19. Periastron, for example, charted in star maps I scanned (5)
20. Early riser of a summer constellation (5)

Answers to December's Astrocryptic

ACROSS

1 TELESCOPIUM (anagram); **9** OCEAN (anag); **10** ROSETTA (anag); **11** OMICRON (hid); **12** INNER (hid); **13** EGG CUP (EC(GG)U + p); **15** WEBCAM (we + bc + a.m.); **18** OKAPI (OK + a + pi); **20 OPPOSED** (op + def); **22** IGNEOUS (anag + o); **23** AVIOR (a + v(Io)r); **24** URANOMETRIA (anag)

DOWN

2 EVENING (2 def); **3** EJNAR (ran + jet-t, rev); **4** CORONA (2 def); **5** PASTIME (past(I'm)e); **6** UPTON (up + not (rev)); **7** MONOCEROTIS (anag); **8** BARRY MADORE (Barrym(ad)ore); **14 UNICORN** (2 def); **16** CASSINI (Cass + in + 1); **17** DORSUM (Rod (rev) + sum); **19** ABNER (anag); **21** PLANT (planet – e)

It's Not All Sirius

by Ted Dunphy

Great Images

Steve Holmes fancies Hα images and brings us this image of NGC 7380 in Cepheus from his collection. Also known as the Wizard Nebula, this contorted cloud of gas surrounds an open star cluster that gives its NGC catalogue number to the formation. The nebula spans 140 × 75 light-years and lies about 7200 light-years distant. It is energized by the hot stars in the cluster. Steve took this 290-minute image from Listowel, Ontario, using a 200-mm aperture 1600-mm, ƒ/8 GSO-RC with a QHY11 camera and a Baader 7-nm Hα filter.

Journal

Great Images

Stuart Heggie returns to the Journal*'s pages with this image of the Cave Nebula (Sh2-155) in Cepheus. The Cave is a complex object, as are most emission nebulae, and shows "reefs" of strong Hα emission surrounding a dark "cave" of opaque, slightly bluish dust that blocks the background nebula. Stuart took this image using a Planewave 12.5" CDK telescope with an Apogee U16M camera. Exposure was 24×30 m in L and 6×30 m in each of RGB.*