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Journal

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PROMOTING ASTRONOMY IN CANADA

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Volume/volume 107
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The Emu Rises

Astrophotographers take note!

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

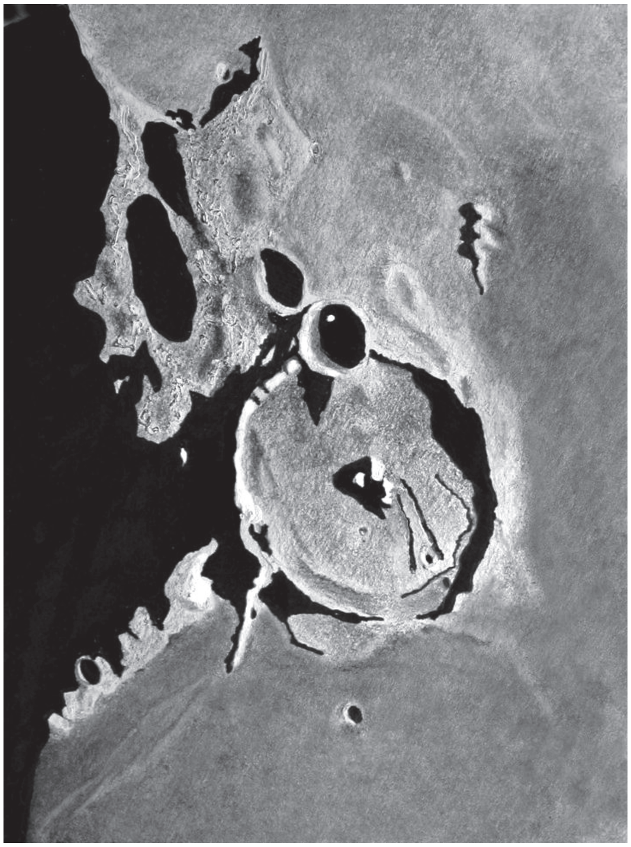

Figure 1

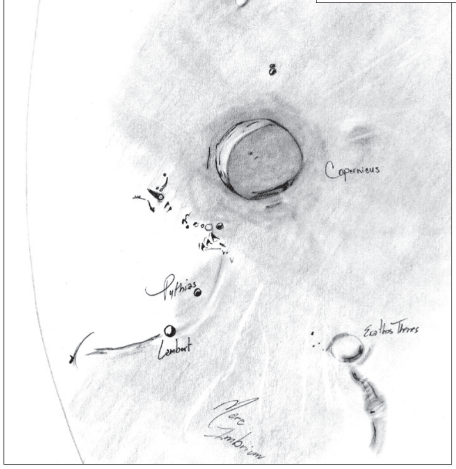

Figure 2

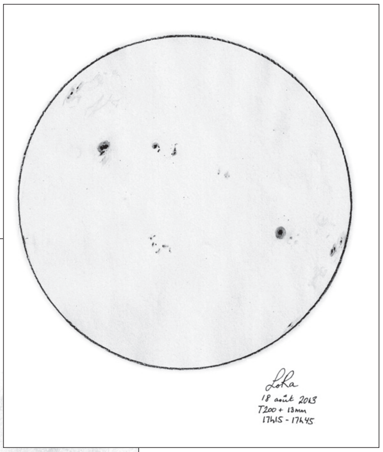

Figure 3

Some of the RASC Astrosketchers have found time and enough darkness to make it out into the night sky and provide us with these examples of what the human eye and hand can do. Gerry Smerchanski, from the Winnipeg Centre, won the "Summer Solstice to Autumn Equinox Contest" with this fine image of Gassendi (Figure 1). In Gerry's words:

> *Here is my sketch of the Crater Gassendi. Gassendi is found on the "north shores" of Mare Humorum and is a very complex structure. South rim seems inundated by the Mare, while the crater itself exhibits rilles, central peaks, craterlets, wall breaches... Sketch was done on 2013 Sept 15 from 21:00 to 23:00 CDT from Teulon, Manitoba, Canada. Viewed through an old Celestron Ultima 8 with binoviewer at ~150× to 300× (exact power hard to determine as Barlows are separated from eyepieces). Seeing was quite good (Antoniadi 2).*
>
> *Sketch done using graphite pencils, ink and "whiteout" on smooth white paper. "Whiteout" is used not only to get those brilliant peaks and white patches, but to create roughness so as to simulate rougher terrain, which is then sketched over with pencils. I rather like the effect (seen in my sketch up to the left of the main crater) as it is quick and effective when using smooth paper, but it is done to simulate rough terrain rather than actually plot exact features. I think of this as being similar to just making a lot of dots to simulate a globular rather than plotting each star. These lunar scenes contain far more data than I can plot so some compromises are taken. The sketch was photographed and flipped to proper view with north up and west to the right. The usual contrast and brightness were applied to compensate for the imaging process and to make it appear more like the visual experience.*
>
> *This sketch was done some 37 years after my first sketch of Gassendi. It's an old friend that still holds much interest.*

Silvia Graca turned her talents to the Moon as well (Figure 2) on September 14, with an overview of Copernicus and its surroundings. The view was composed through a Meade LightSwitch telescope with a 2-inch 8-mm eyepiece using graphite pencil and an eraser.

Louise Racine (Figure 3) opted for the Sun, catching the disk in one of its more active moments on August 18. She used graphite pencils, a yellow pencil, and black pen on standard white paper. Her telescope was a 8-inch Newtonian Dobsonian with a Baader Astrosolar filter and a 13-mm eyepiece.

Journal

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Société Royale d'Astronomie du Canada

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***Front cover** — "The Emu Rises." A crescent Moon illuminates The Pinnacles in southwest Australia while the southern Milky Way rises in the background. The dark lanes in the Milky Way form the "Emu" with its beaked head, long neck, and slender body. The Southern Cross is just above the head, which is made up of the Coal Sack Nebula. Winnipeg Centre's Jay Anderson captured this scene with a Canon 60Da and 10-mm lens using an exposure of 2 minutes at f/3.5 and ISO 1600.*

Journal

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

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News Notes / En manchettes

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Infrared space telescope continues to produce cutting-edge scientific results

The *Spitzer Space Telescope*, the fourth of NASA's four Great Observatories, celebrates its 10th anniversary in 2013 as a working space-based, astronomy-focused, scientific instrument. The other three space telescopes that were part of the Great Observatories program were the *Hubble Space Telescope*, the *Chandra X-ray Observatory*, and the now-defunct *Compton Gamma Ray Observatory*. Each of the four telescopes was designed to cover a distinct range of electromagnetic wavelengths. *Spitzer*'s ability to observe in the infrared allows it to see the dark, cold, and dusty side of the Universe that is hidden in traditional white-light observations.

During its first 10 years of service, *Spitzer* has studied comets and asteroids, counted stars, and examined planets and galaxies. It also discovered soccer-ball-shaped carbon spheres in space called buckyballs (or Buckminsterfullerenes)—a spherical fullerene molecule with the formula C_{60}, named in homage to Buckminster Fuller, an American inventor and futurist whose trademark geodesic domes resemble the C_{60} molecule.

The Royal Astronomical Society of Canada

Vision

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

Mission

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

Values

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

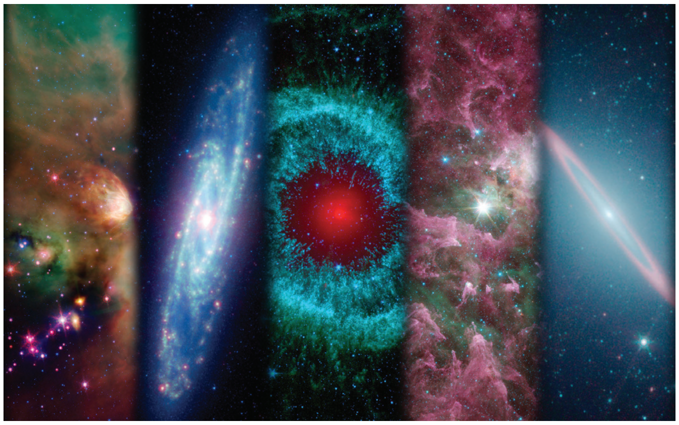

Figure 1 — A montage of images taken by the Spitzer Space Telescope. *Image: NASA/JPL-Caltech.*

Spitzer continues to explore the Universe as it enters its second decade of scientific investigation from an Earth-trailing orbit. Recently it added one further task to its list—to help NASA observe potential candidates for a developing mission to capture, redirect, and then explore a near-Earth asteroid. The United States has set a goal of visiting such an asteroid by 2025.

As was expected, the telescope ran out of coolant to chill its longer-wavelength instruments in 2009 and since then has been operating in its "warm" mission phase. During its lifetime, the infrared telescope has returned spectacular space images while advancing our understanding of the hidden parts of the Universe. Astronomers agree that *Spitzer* has gone far beyond anything that was first imagined when the planning and design for the telescope started some 30 years ago.

Some of *Spitzer*'s accomplishments and discoveries have included:

- Studying comet Tempel 1, which was hit by NASA's *Deep Impact* mission in 2005, showing that its composition resembled that of planetary systems beyond Earth's neighbourhood;
- Discovering the largest of Saturn's many rings—a wispy band of ice and dust particles that is very faint in visible light, but easily spotted with *Spitzer*'s infrared detectors by the glow from the ring's heat;
- Being first to detect light coming from a planet outside our Solar System, an achievement not in the mission's original design;
- Conducting ongoing studies of the composition and dynamics of exoplanets and revolutionizing the study of their atmospheres;
- Obtaining a complete census of forming stars in nearby clouds;
- Making a new and improved map of the Milky Way's spiral-arm structure; and
- Discovering, in collaboration with the *Hubble Space Telescope*, that the most distant known galaxies are more massive and mature than expected.

Originally called the *Space Infrared Telescope Facility*, the space observatory was renamed after its launch in honour of the late astronomer Lyman Spitzer Jr. (1914-1997), considered the father of space telescopes.

In 2006, George H. Rieke, Deputy Director of Steward Observatory and Regents' Professor of Astronomy at the University of Arizona in Tucson, published a highly regarded insider's account of the 30-year quest to get *Spitzer* built and launched. A key member of the scientific team, Rieke, in his book titled *The Last of the Great Observatories: Spitzer and the Era of Faster, Better, Cheaper at NASA*, relates the teamwork that was needed to have the historic infrared telescope designed, manufactured, tested, and launched into space, and the response once *Spitzer* achieved "first light."

Titan's polar collar captured in ultraviolet-light image

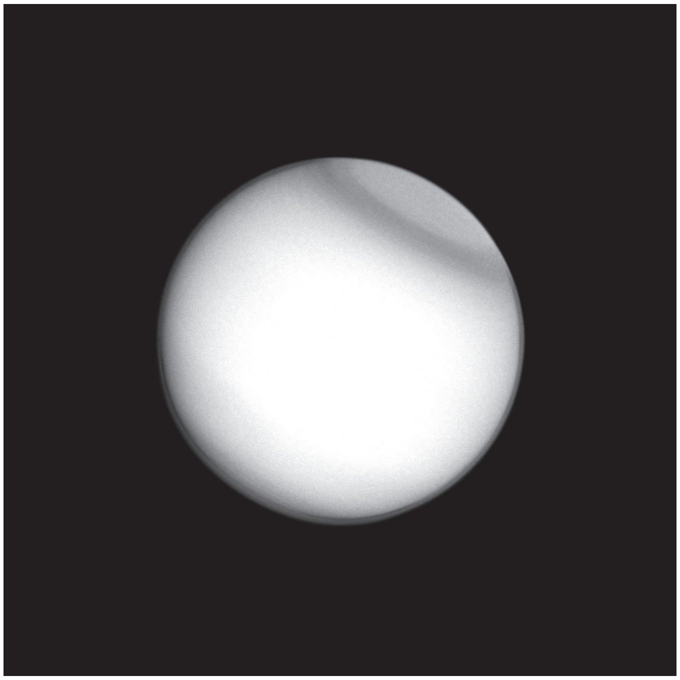

Figure 2 — Titan's polar collar seen in ultraviolet light by the Cassini *spacecraft. Image: NASA/JPL-Caltech/Space Science Institute.*

The *Cassini* spacecraft, which continues to explore the Saturnian system and to make new discoveries, has observed Titan's polar collar in ultraviolet light. Titan is a moon of Saturn. Believed to be seasonal in nature, the polar collar was previously been seen by *Voyager 2* and the *Hubble Space Telescope*.

The spacecraft, part of the *Cassini-Huygens* mission, took the image of the polar collar while looking toward the Saturn-facing hemisphere of Titan in April 2013. A narrow-angle camera with a spectral filter sensitive to wavelengths of ultraviolet light was employed in the imaging process as *Cassini* travelled approximately 1.8 million kilometres distant from Titan.

On another note, the research spacecraft has detected propylene on Titan. Propylene is a chemical used to make food-storage containers, car bumpers, and other consumer products. Seen in Titan's lower atmosphere, the small amount of propylene was identified using the spacecraft's composite infrared spectrometer (CIRS), which measures infrared light emitted from Saturn and its moons. A paper published in the 2013 September 30 edition of the *Astrophysical Journal Letters* announced the details of the discovery. According to NASA, this represents the first definitive detection of the plastic ingredient on any moon or planet other than Earth.

The detection of the chemical fills in a mysterious gap in Titan observations that dates back to NASA's *Voyager 1* spacecraft. In the first-ever close flyby of Titan in 1980, *Voyager 1* identified many of the gases in Titan's hazy brownish atmosphere as hydrocarbons, the chemicals that primarily make up petroleum and other fossil fuels on Earth. *Voyager 1* found propane, the heaviest member of the three-carbon family, and propyne, one of the lightest members. However, the middle chemicals, one of which is propylene, were missing. Propylene remained elusive until it was finally identified during a detailed analysis of the CIRS data.

Hydrocarbons form on Titan after sunlight breaks apart methane, the second-most plentiful gas in the moon's atmosphere. The now-freed fragments then can link up to form chains with two, three, or more carbon atoms.

X-Ray images bring high-energy sources into focus

The astronomical community now has access to unique X-ray images of the Universe taken by the *Nuclear Spectroscopic Telescope Array* (*NuSTAR*), a NASA space-based telescope capable of focusing high-energy X-ray light. This high-energy focusing ability allows for more detailed images than were possible before. It complements the European Space Agency's *XMM-Newton* X-ray telescope and NASA's *Chandra X-ray Observatory*, which have observed the Universe at lower-energy X-ray light.

The *NuSTAR* images represent the first publicly released batch of data from the black-hole-hunting telescope. Taken between July and August 2012, the images are comprised of an assortment of extreme objects including distant black holes, some of which are considered the most luminous objects in the Universe. Other types of black holes in the new batch of data comprise a blazar (an active, supermassive black hole with a jet pointing toward Earth), pairs of black holes called X-ray binaries (where one partner feeds off the other), and remnants of stellar supernova blasts.

Figure 3 — This new view of the historical supernova remnant Cassiopeia A, located 11,000 light-years away, was taken by NASA's Nuclear Spectroscopic Telescope Array, *or* NuSTAR. *Blue indicates the highest energy X-ray light; red and green show the lower end of* NuSTAR*'s energy range, which overlaps with NASA's high-resolution* Chandra X-ray Observatory. *The outer blue ring is where the shock wave from the supernova blast is slamming into surrounding material, whipping particles up to within a fraction of a percent of the speed of light. X-ray light, with energies between 10 and 20 kiloelectron volts, is blue; X-rays of 8 to 10 kiloelectron volts are green; and X-rays of 4.5 to 5.5 kiloelectron volts are red. Image: NASA/JPL-Caltech/DSS.*

NuSTAR data are held in NASA's High Energy Astrophysics Science Archive Research Center (HEASARC). Use of the data allows astronomers to better understand the capabilities of the *NuSTAR* platform and, thereby, design future observing proposals for the telescope. It also permits scientists to compare data sets from different missions housed at the HEASARC archives—data from such missions as *Chandra*, *Fermi*, *Swift*, the *Cosmic Background Explorer* (COBE), *Wilkinson Microwave Anisotropy Probe* (WMAP), and others. HEASARC also offers high-energy observation holdings in the extreme-ultraviolet, X-ray, and gamma-ray bands, as well as data from space missions, balloons, and ground-based facilities that have studied the relic cosmic microwave background. ✶

Andrew I. Oakes, a long-time unattached member of RASC, lives in Courtice, Ontario.

The North Polar Cap of Mars from 2007 to 2012

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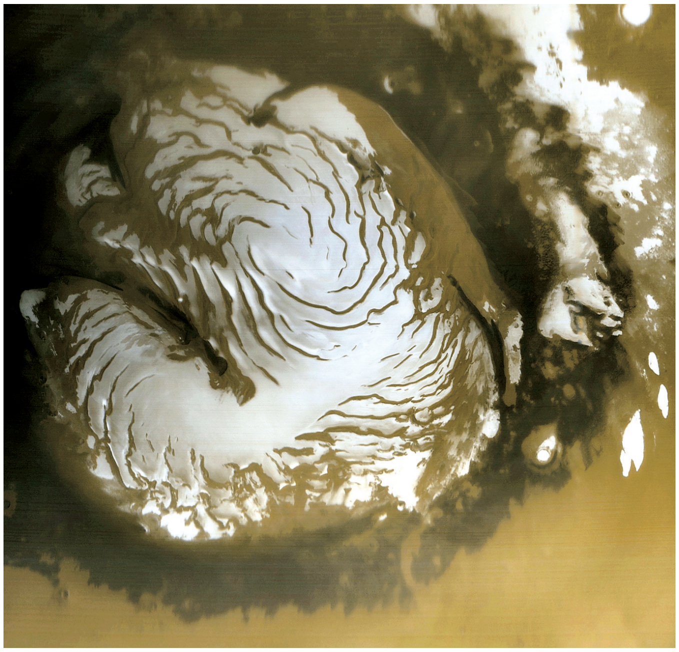

Figure 1 — The north polar ice cap from the Mars Global Surveyor, acquired 1999 March 13. The dark band surrounding the ice cap is the North Polar Dune Field. The light sandy tones contain residual water ice. Image: NASA/JPL/Malin Space Science Systems.

Abstract

Mean latitudes of the North Polar Cap (NPC) of Mars are reported for 2007-2008, 2009-2010, and 2012. These were determined from the procedure used by James & Cantor (2001). Wilcoxon Signed Rank Tests were carried out on data from 1990 to 2012. Most of the tests are consistent with the NPC extending farther south in 2009-2012 than in 1990-1997 and in 2000. It is concluded that the mean NPC latitude changed at a nearly linear rate with respect to the areocentric longitude of the Sun as seen from Mars (L_s) in 2009-2012.

Keywords: Mars, North Polar Cap, Year-to-Year changes

Introduction

One objective of carrying out measurements of Mars's NPC is to look for year-to-year changes in size and shape. A second is to determine what impact the shrinking NPC has on the seasonal water cycle of the planet. One problem with many previous studies of the NPC is the large data scatter. Much of the scatter may be the result of researchers assuming a circular NPC and assuming that it is centred on the North Pole. This paper focuses on a technique that reduces data scatter thus enabling a better comparison with previous NPC measurements. New results for 2007-2012 are presented.

Astronomers have measured NPC dimensions for over a century. Antoniadi (1930, 1975) listed mean NPC diameters for different heliocentric longitudes of Mars based on measurements from drawings. Slipher (1962) reported that the NPC reached a maximum diameter of 53°. Dollfus (1973), mainly using a double-image micrometer and a 0.60-m telescope, measured the NPC between 1946 and 1952. His maps for $L_s = 68°$ and 108° showed the classical bright spots Ierne and Olympia. Miyamoto (1963) reported latitudes of the NPC edge for 1960-1961 and 1962-1963. He adopted a new technique, breaking down latitudes into four graphs, each one for a different range of longitudes. Fischbacher, Martin, and Baum (1969) carried out an analysis of 3000 red- and yellow-light photographs covering the time span from 1905 to 1965. They constructed maps of the mean boundaries of the NPC for several values of L_s between 340° and 80°. Their maps showed that the NPC was not often centred on the North Pole, and that it was not circular. For their analysis, Fischbacher *et al.* also adopted a new approach, measuring the NPC's latitude about eight times on each image for every 10° of longitude.

Iwasaki, Saito, and Akabane (1982) reported NPC latitudes at all longitudes between $35° < L_s < 49°$, obtaining a mean of 67° N. They stated that the NPC latitude "appears to be independent of longitude." However, the standard deviation of their points is 2.2° and therefore data scatter may have masked small cap asymmetries. James (1982) reported NPC latitudes for 1979-1980 based on *Viking Orbiter* images. He reported that the NPC latitude (L_N) follows the relationship $L_N = 57.7° + 0.216° L_s$, where L_s is the areocentric longitude[1] of Mars in degrees. His data fall nearly on a straight line. James, Pierce, and Martin (1987) summarized telescopic observations of the NPC between 1975 and 1980. They reported that the NPC reached a standstill between $23° \le L_s \le 42°$ in 1977-1978 and suggested that dust activity may have been responsible for the pause. Warell (1996) used images taken with the Swedish Vacuum Solar Telescope to study Mars's NPC in February and March of 1995. He reported that the NPC is asymmetric for $61° \le L_s \le 66°$, and that the mean boundary is 72° N at 270° W but is 77° N at 90° W.

The *Hubble Space Telescope* (HST) and the *Mars Global Surveyor* have given astronomers much better pictures of the NPC. Cantor, Wolff, James, and Higgs (1998) reported mean NPC cap latitudes at several longitudes from a study of HST images made with the red (F673N) filter. They made nine latitude measurements for each image: one at the central meridian and the others at 10°, 20°, 30°, and 40° east and west. They tabulated 45 latitudes between 1990 December 13 and 1997 April 17 along with the central-meridian longitude range of all images for each data set. These cover many longitudes and are consistent with a non-circular cap. This group also reported that the NPC shrinks faster at some longitudes than at others, noting that red- and blue-filter images yield similar cap sizes within the uncertainty of measurement. James and Cantor (2001) report mean latitudes of the NPC based on red-filter images recorded by the Mars Orbiter Camera onboard the *Mars Global Surveyor*. Each of their values is based on about 100 points measured along the NPC boundary. A total of 46 mean latitude values are reported for 343° < L_s < 70°. The latitude values are plotted against L_s, and they also fall on nearly a straight line.

Parker, Beish, Troiani, Joyce, and Hernandez (1999) showed that the NPC in 1995 was smaller than in the early 1980s. They also showed that the NPC in the 1960s was larger than in either 1980-1984 or 1995-1997. They suggested that the high water-vapour abundance on Mars in 1969 may have been related to the unusually large NPC that year, pointing out some correlation between NPC size and cloud frequency.

This paper has two goals. The first is to report mean NPC latitudes between 2007 and 2012 and to compare these with previous results. The second is to carry out statistical tests with the aim of determining whether year-to-year changes in NPC latitudes can be measured from Earth-based images and whether NPC asymmetries are the result of random error. In all cases, the mean NPC latitude will be calculated using measurements from all available longitudes. In this way, data scatter should be reduced, allowing for better comparison with previous work.

Method and Materials

The software package *WinJUPOS* was used in analyzing images. Only those made with either a red filter or some combination of visible light and luminance filters were analyzed. Once an image was selected, an electronic grid was positioned to yield nearly the same NPC latitudes 30° east and west of the central meridian. In a few cases, surface features, the illuminated limb, or the east and west edges of the NPC were used as reference points. Once the grid was positioned, about nine measurements were made (Figure 2). The procedure was repeated for the other images with different central-meridian longitudes. Over about nine days (a 4° interval of L_s), cap latitudes were measured across all longitudes. The mean latitude of the polar-cap edge was then computed for each 15° longitude interval. Finally, the overall mean cap latitude was computed from the 24 15° longitude intervals (Table 1). Figure 3 illustrates all of the measurements in Table 1 along with the selected NPC boundary. This procedure was carried out in each 4° interval of L_s. Mean latitudes for three 4° intervals of L_s are reported for 2007-2008, along with 12 for 2009-2010 and 12 for 2012.

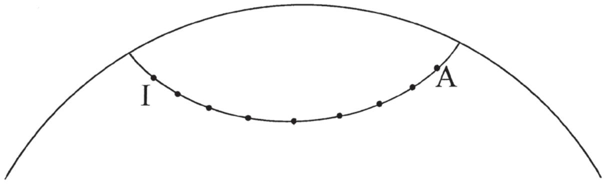

Figure 2 — In this study, several measurements were made for each image. The first measurement was made at point A. Measurements were then made every 15° of longitude up to point I. All measurements were made along the edge of the NPC.

The resulting cap size includes only portions that are attached to the cap, following the convention in McKim (2010). Based on 2012 measurements, Olympia and Ierne became separated near L_s = 70° and were no longer considered part of the NPC. McKim also reports Olympia became separated from the NPC at L_s = 70° in 1995 (McKim 2012) and L_s = 72° in 2007 (McKim 2005). Before L_s = 70°, both regions were connected to the NPC and were considered part of the NPC.

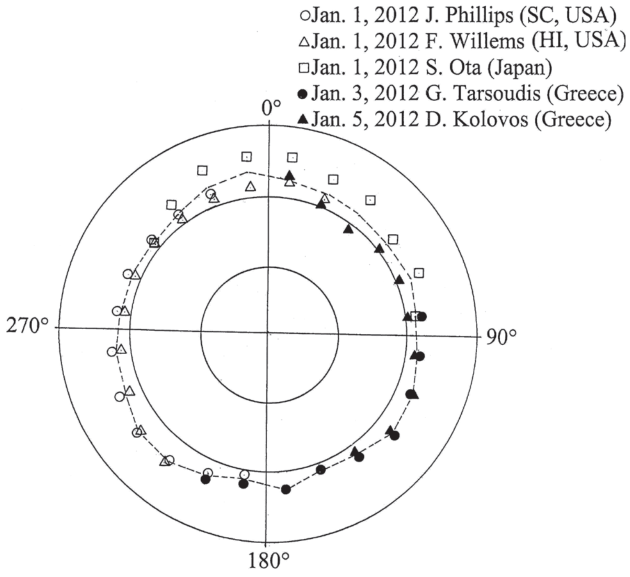

Figure 3 — Latitude measurements were made from five different images taken at four different locations across the planet. The mean North Polar Cap boundary is the dashed curve.

In early 2008, the phase defect covered the northern edge of the NPC (Beish, Parker, and Capen 1986) and only the illuminated limb was used in positioning the grid. This may have led to a greater uncertainty in the 18° ≤ L_s ≤ 22° measurement in early 2008.

Results and Discussion

Figures 4 and 5 show maps of the NPC in 2009-2010 and in 2012. In both years, the NPC deviates from a circular shape, confirming Fischbacher *et al.* (1969) and Warell (1996). The latitudes and general shape of the NPC for $L_s < 70°$ in 2009-2012 are consistent with those in James and Cantor (2001) and Fischbacher *et al*. For example, the NPC extends farther north near 0° W at $L_s = 40°$ in both 2000 (James & Cantor 2001) and in 2009-2010. The cap sizes at $L_s = 20°$-$24°$ and $L_s = 58°$-$60°$ in 2009-2010 and 2012 are consistent with those in Figure 1 of Cantor *et al.* (1998). However, differences in NPC shape do occur. For example, one difference between the 1948 map at $L_s = 68°$ (Dollfus, 1973) and those in Figures 4 and 5 is Olympia. This feature is separated from the NPC in the map in Dollfus (1973) but is connected to the NPC here. The mean latitude of the NPC based on Figure 8 in Dollfus (1973) is 75.7° N. This is about 2° farther north than the 2009-2012 values and, hence, is consistent with an early separation of Olympia from the NPC in 1948.

The dark ring near 80° N is the North Polar Dune Field (NPDF), observed as early as 1918 (McKim 2005); McKim calls it the NPC Annular Rift. The *Mars Reconnaissance Orbiter* (Hansen *et al.* 2013), *Mars Global Surveyor* (James & Cantor 2001), and *Hubble Space Telescope* (Cantor *et al.* 1998) have all imaged this feature (Figure 1). Its mean latitudes in 2009-2012 were measured from images using *WinJupos*. As with the NPC, the northern and southern borders of the dune field were measured for each 15° longitude interval and mean widths were computed. In both 2009-2010 and 2012, the NPDF is 4° closer to the North Pole at 180° W than at 0° W, consistent with the findings of McKim (2005). Based on 2009-2012 images, the NPDF has a mean width of 3.4°. Images made in December 2009 show dark spots in the NPC, but Damian Peach's 2010 January 3 ($L_s = 32°$) image is the first one to show a recognizable NPDF. This feature is drawn as a faint ring in Figure 4 until $L_s = 34°$.

Mean latitudes of the NPC edge are summarized in Table 2. Each value is computed in the same way as illustrated in Table 1. The evolution of NPC latitudes in 2009-2010 for $22° < L_s < 70°$ followed a nearly straight line with respect to L_s, as was the case in 2012 for $50° < L_s < 70°$. After $L_s = 70°$, the 2012 cap latitude changes at a faster rate; this is also what it did in 2000 (James & Cantor 2001).

Table 3 summarizes linear relationships between L_s (*i.e.* Mars season) and the NPC latitude computed using a least squares routine. The high correlation coefficients are evidence the data fit the linear equations well. The low standard errors are encouraging, a confirmation of the technique illustrated in Table 1.

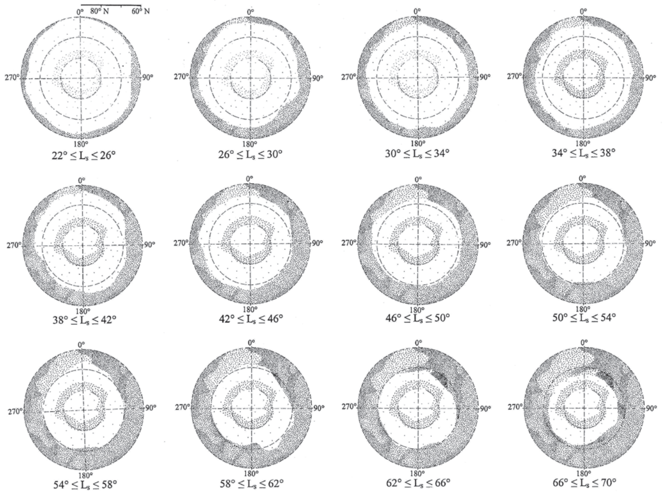

Figure 4 — Maps of the North Polar Cap constructed from images made between 2009 December 12 and 2010 March 25. The surrounding dark areas are from a map constructed by the author from images made in early 2012. The dark ring near the cap—the North Polar Dune Field—is based on several dozen measurements made from 2010 images.

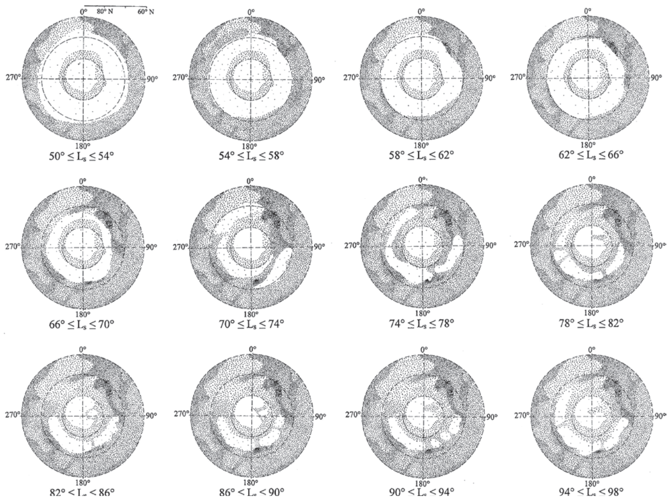

Figure 5 — Maps of the North Polar Cap constructed from images made between 2012 January 1 and 2012 April 16.

The Mars Observer Camera data collected over the range $-20° < L_s < 70°$ (James & Cantor 2001) were fit to a linear equation using a least squares routine. The resulting equation is

$$L_N = 58.8° \text{ N} + 0.206 \times L_s.$$

In this relationship, L_N is the mean latitude of the NPC edge and L_s is the areocentric longitude of the Sun as seen on Mars. The standard error is 0.44°. Figure 6 incorporates most of the 2000 data together with the 2009-2012 data. Before $L_s = 70°$, the mean latitudes shrink following a nearly linear trend for 2009-2012. At around $L_s = 70°$ to 85° the NPC begins to shrink at an accelerated rate due to the separation of Olympia/Ierne and the location of the NPDF.

One limitation in both the current study and the one carried out by Cantor *et al.* (1998) is the limited number of latitude

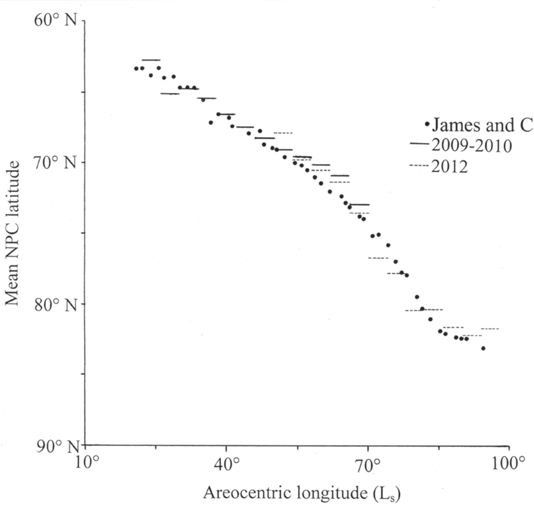

Figure 6 — Mean North Polar Cap latitudes from 2000, 2009-2010 and 2012. The data from 2000 are from James and Cantor (2001) and cover the range 20.8° ≤ L_s ≤ 94.5°. The data from 2009-2010 and 2012 are from Table 2.

values per year. To perform a statistical analysis, I have lumped all of the data collected between 1990 and 1997 (Cantor *et al.* 1998) into one group. I then computed mean latitudes for 2009-2012 from just the longitudes within 40° of the central meridian listed in Table 1 of Cantor *et al.* Wilcoxon Signed Rank Tests were carried out to compare the 2007-2012 data with the 1990-1997 data (Cantor *et al.* 1998), CCD image data from 1996-1997 (Iwasaki, Parker, Larson, & Akabane 1999), and *Mars Global Surveyor* data (James & Cantor 2001). The results are summarized in Table 4. It is concluded that some year-to-year latitude changes are detectable from Earth, whereas in other cases, difference cannot be detected. Table 4 also summarizes the mean differences in NPC latitudes between different years.

The 2009-2012 results are close to the mean latitudes reported by Fischbacher *et al.* (1969); however, the situation for 2007-2008 is different. The 3.0° difference in the location of the NPC edge is too large to be the result of random error.

The Runs Test for Randomness (Larson & Farber 2006) is a non-parametric test that is used to determine whether a data set is random or not; in this investigation, it is used to determine whether differences in NPC latitude at different longitudes in Figures 4 and 5 are real or are random fluctuations. Essentially, a radius at a specific longitude is compared to the mean radius. It may either be larger than (L), equal to (E) or smaller than (S) the mean radius. A "run" is defined as a set of consecutive L or S values. For example, if the radii alternate between L and S for the 24 longitude intervals there would be 24 runs, but if the radii are all S between 0° and 180° W and are all L between 180° and 360° W there would be only two runs. If random fluctuations dominate, the latitude values would show up as random (Figure 7). The test results for each L_s interval are listed in Table 2. The majority of the data in 2009-2010 and 2012 are non-random and so the irregularities in Figures 4 and 5 are not consistent with random fluctuations.

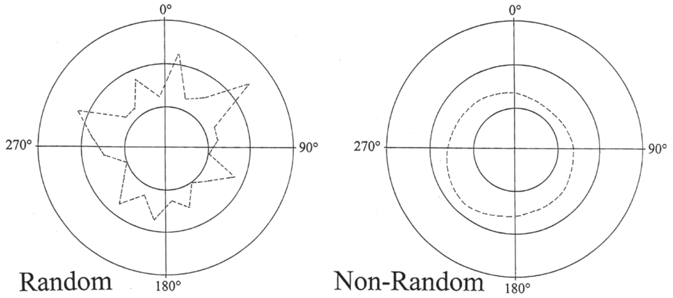

Figure 7 — The cap on the left has a lot of protrusions, alternating between being larger and smaller than the mean radius over a dozen times. Because of this, the data are considered random because there are too many runs. The cap on the right is not centred on the pole; nevertheless, it exceeds the mean latitude for latitudes between 180° and 360° and it is at or below the mean latitudes for the other longitudes. There are only two runs for this cap and, hence, the data are not considered random according to the Runs Test for Randomness (Larson & Farber 2006).

Summary

Maps of the NPC in 2009-2010 and 2012 are shown in Figures 4 and 5, respectively. These show that the NPC is not circular and is not always centred on the North Pole. Wilcoxon Signed Rank tests are generally consistent with the NPC in 2009-2012, extending farther south than in 1990-1997 and in 2000. In some cases, though, the changes in size for different years were too small to detect from Earth-based images. It is also concluded that the mean radius of the NPC shrank at a nearly linear rate with respect to L_s between 22° ≤ L_s ≤ 70°, consistent with the results of James and Cantor (2001) for the 2000 cap. ✶

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Endnotes

1 The areocentric longitude of the Sun as seen on Mars [L_s] defines the seasons on that planet; essentially the beginning of spring, summer, fall, and winter in the northern hemisphere are defined as $L_s = 0°, 90°, 180°$ and 270° [Carr, 2006].)

Longitude (° W)	**Jan. 1 J. Phillips**	**Jan. 1 F. Willems**	**Jan. 1 S. Ota**	**Jan. 3 G. Tarsoudis**	**Jan. 5 D. Kolovos**	**Mean**
0 – 15	—	67.8	64.2	—	69.7	67.2
15 – 30	—	68.7	65.8	—	69.5	68.0
30 – 45	—	—	65.6	—	71.0	68.3
45 – 60	—	—	67.3	—	69.7	68.5
60 – 75	—	—	66.4	—	69.5	68.0
75 – 90	—	—	68.3	67.9	69.7	68.6
90 – 105	—	—	—	68.0	68.4	68.2
105 – 120	—	—	—	67.7	67.5	67.6
120 – 135	—	—	—	66.8	67.4	67.1
135 – 150	—	—	—	67.9	68.8	68.4
150 – 165	—	—	—	68.9	—	68.9
165 – 180	70.1	—	—	67.5	—	68.8
180 – 195	69.1	—	—	67.8	—	68.5
195 – 210	67.9	—	—	67.1	—	67.5
210 – 225	66.5	65.9	—	—	—	66.2
225 – 240	65.8	66.8	—	—	—	66.3
240 – 255	66.5	68.1	—	—	—	67.3
255 – 270	67.2	68.6	—	—	—	67.9
270 – 285	67.9	68.9	—	—	—	68.4
285 – 300	68.0	69.1	—	—	—	68.6
300 – 315	68.3	69.2	69.1	—	—	68.9
315 – 330	68.4	69.4	66.7	—	—	68.5
330 – 345	67.8	68.8	64.7	—	—	67.1
345 – 360	—	68.5	64.2	—	—	66.4

Table 1 — Measurements of the North Polar Cap made between 2012 January 1 and January 5 covering the interval 50° < L_s < 54°. Mean for 50° < Ls < 54° 67.8° W

Study period	Interval of L_s (degrees)	Mean latitude of the edge of the NPC	Number of measurements	Random?
2007-2008	10-14	60.5	56	Y
2007-2008	14-18	61.8	51	N
2007-2008	18-22	61.9	43	Y
2009-2010	22-26	62.8	79	Y
2009-2010	26-30	65.1	99	N
2009-2010	30-34	64.8	94	Y
2009-2010	34-38	65.4	75	N
2009-2010	38-42	66.5	76	N
2009-2010	42-46	67.4	73	N
2009-2010	46-50	68.2	80	N
2009-2010	50-54	69.1	89	N
2009-2010	54-58	69.5	89	Y
2009-2010	58-62	70.1	74	N
2009-2010	62-66	70.9	95	N
2009-2010	66-70	72.9	86	N
2012	50-54	67.8	53	Y
2012	54-58	69.7	72	N
2012	58-62	70.5	78	N
2012	62-66	71.2	102	N
2012	66-70	73.6	83	N
2012	70-74	76.7	104	N
2012	74-78	77.8	85	N
2012	78-82	80.4	157	N
2012	82-86	80.4	163	N
2012	86-90	81.6	131	Y
2012	90-94	82.1	119	N
2012	94-98	81.7	144	N

Table 2 — Mean latitude of the North Polar Cap (NPC) during the three apparitions between 2007 and 2012. The mean latitudes in column three are probably accurate to 0.5°, which is a fraction of an arcsecond on an image. This high degree of accuracy is possible because the mean value is based on at least 43 measurements; see column four. In column five, an N means the data is not random according to the Runs Test for Randomness (Larson and Farber, 2006), whereas a Y means it is random according to this test. The symbol for the areocentric longitude of Mars is L_s and $L_s = 0°$ and 90° are the beginning of spring and summer in the northern hemisphere, respectively.

Year(s)	Range in L_s (degrees)	Equation	Correlation coefficient (r)	Standard error (degrees)[a]
2007-2008	10-22	L_N = 58.6° N + 0.175 L_s	0.896	0.49
2009-2010	50-70	L_N = 57.0° N + 0.225 L_s	0.947	0.56
2009-2010	22-70	L_N = 58.5° N + 0.201 L_s	0.987	0.39
2012	50-70	L_N = 50.9° N + 0.328 L_s	0.976	0.53
2007-2012	10-70	L_N = 58.1° N + 0.208 L_s	0.989	0.50

Table 3 — Least-squares solutions of the North Polar Cap latitude versus Mars's areocentric longitude (L_s) for the data in Table 2.

[a] Standard error is computed using the procedure in Larson & Farber (2006).

Apparitions	Ls interval (degrees)	Comment	Mean difference in NPC latitude[a] (degrees)
1990-1997[b] and 2007-2008	16-21	Fail to reject H_0; no difference is detected	0.9
1990-1997[b] and 2009-2010	24-65	Reject H_0; the NPC latitudes extend farther south in 2009-2010	1.1
1990-1997[b] and 2012	58-65	Reject H_0; the NPC latitudes extend farther south in 2012	1.3
2000[c] and 2009-2010	30-70	Reject H_0; the NPC latitudes extend farther south in 2009-2012	0.5
2000[c] and 2012	50-94.5	Fail to reject H_0; no difference is detected	0.3
1996-1997[d] and 2009-2010	31-70	Fail to reject H_0; no difference is detected	0.0
1996-1997[d] and 2012	51-70	Fail to reject H_0; no difference is detected	0.8
1905-1965 and 2007-2008	10-20	—	3.0[e]
1905-1965 and 2009-2010	30-70	—	-0.7[e]
1905-1965 and 2012	50-80	—	0.2[e]

Table 4 — Wilcoxon Signed Rank Test results for North Polar Cap (NPC) latitudes between 1991 and 2012 along with other relevant results. In all cases, the null hypothesis, H_0, states there is no difference in NPC latitudes between the two time periods listed in the first column.

[a] The mean difference is computed by subtracting the latitude of the later apparition in column 1 from the earlier one for each L_s value and then computing the mean.

[b] Cantor, Wolff, James, & Higgs (1998)

[c] James & Cantor (2001)

[d] Iwasaki, Parker, Larson, & Akabane (1999)

[e] Fischbacher *et al.* (1969) report mean latitudes at 10° intervals of L_s. In this study, cap latitudes are for a 4° interval of L_s such as $30° < L_s < 34°$. Therefore, when comparing results for $L_s = 30$, I took the mean of $26° < L_s < 30°$ and $30° < L_s < 34°$ values from this study. In the case of the $L_s = 70°$ value in 2012, I used the $66° < L_s < 70°$ value and scaled it to $L_s = 70°$ using the appropriate equation in Table 3.

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Exoplanet Transit Observations—Not Just for Large Telescopes

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Introduction

One of the most captivating topics in astronomy today is the detection of exoplanets: real planets orbiting stars far outside our own Solar System. Not so very long ago, the notion of such objects was just a theoretical hope. With the advancement of larger telescopes and more sensitive detectors, so many exoplanets have been discovered that trends in the structure of planetary systems can now be studied and the planets themselves classified.

The original detector of choice for exoplanet hunters was the spectrograph. The planet itself was not seen, but rather the gravitational influence of the planet on its host star was observed. The planet and its host star orbit their common centre of mass, and if the orientation on the plane of the sky is right, the star can be seen moving toward and away from us via the Doppler shift in its light. Canadian astronomers Bruce Campbell, Gordon Walker, and Stephenson Yang are commonly credited with finding the first exoplanet around Gamma Cephei using this radial-velocity method at the Dominion Astrophysical Observatory.

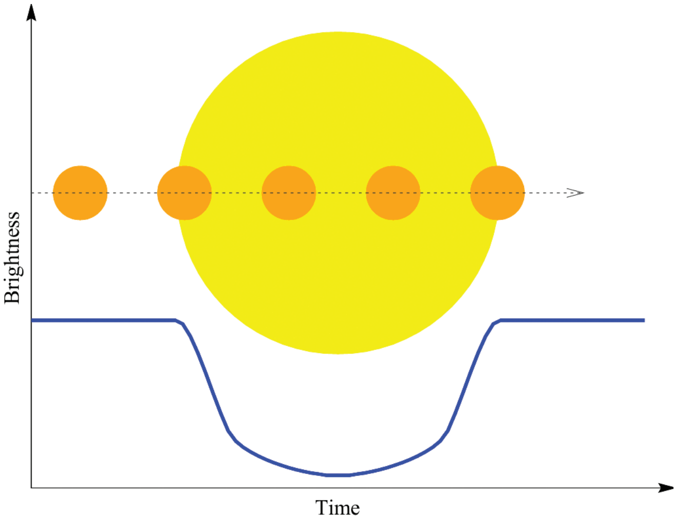

Figure 1 — Illustration of the light curve of an exoplanet transit event. As the planet passes in front of its host star, the measured brightness along our line of sight first decreases, then increases by a small amount.

Another detector for finding the signature of a planet orbiting a distant star is the CCD. Again, the planet is not imaged directly. Instead, the passage of the planet in front of its host star has a simple yet interesting influence on the amount of light collected by the CCD: when the transit occurs, the star dims. Figure 1 shows the essentials of what happens during an exoplanet transit from the vantage point of the Earth. As a potential method for detecting exoplanets, this idea probably precedes the radial velocity method, as it is similar to the light-curve analysis of eclipsing binary stars. It was not pursued first, however, because the anticipated drop in star brightness is so small that it probably would have defied detection.

Nonetheless, a massive attempt to observe exoplanet transits was made with the launch of the *Kepler* satellite in March 2009. As with all attempts to observe the details of the heavens in the optical regime, the atmosphere blurs the telescopic view. To obtain the precision necessary to detect exoplanet transits, astronomers went into orbit. *Kepler* did not disappoint. As of July 2013, *Kepler* had found 134 confirmed exoplanets in 76 stellar systems, along with a further 3277 unconfirmed planet candidates. The most famous are probably the very Earth-like Kepler-62e and Kepler-62f (http://kepler.nasa.gov/mission/discoveries/).

When a pair of enthusiastic astrophysics undergrads came to me (PL) to discuss an idea they had for their senior observing project, I was both intrigued and skeptical. Intrigued because they wanted to try to observe the transit of an exoplanet with the Rothney Astrophysical Observatory's (RAO) 0.4-m Clark-Milone Telescope (CMT)—something never attempted with RAO telescopes to date. Skeptical because, well, I had never heard of exoplanet transit detections from ground-based telescopes, except maybe from Gemini or Keck. I explained that what they were proposing was like trying to see the headlight of a car, 10 km down the highway with its high beam on and pointed right at them, dim ever so slightly as a small mosquito passed in front. But they had done their homework and found claims of exoplanet transit detections using moderately sized ground-based telescopes. For example, see Henry *et al.* (2000) and Charbonneau *et al.* (2000). So, a very challenging Astrophysics 507 project was born.

Target Selection

Bruce Gary, in his freely available book *Exoplanet Observing for Amateurs*, provides a list of the techniques, and their nuisances, in conducting observations with amateur equipment.
He also initiated the first Amateur Exoplanet Archive (http://brucegary.net/AXA/x.htm).

Very useful online resources are readily available to assist in determining potential targets. Examples include the Extrasolar Planet Encyclopaedia (http://exoplanet.eu/) and the NASA Exoplanet Archive (http://exoplanetarchive.ipac.caltech.edu/).

The latter currently lists 3589 confirmed exoplanets and unconfirmed exoplanet candidates. A subset of these is popularly coined the "bright transiting exoplanets." Indications are that a 0.3-m aperture is considered very capable for observation of these transits.

Another excellent online resource is The Exoplanet Transit Database (ETD: http://var2.astro.cz/ETD/). The ETD provides a convenient ephemeris of transit events for a large catalogue of objects based on an observer's latitude and longitude. The parameters of the transit and the object's position in the sky are also listed, saving time in deliberation. The NASA Exoplanet Archive provides an ephemeris service also, giving expected transit times computed from the latest available orbital parameters from the *Kepler* mission.

With these extensive lists and planning tools now available, many nights offer at least one opportunity to observe a recently revealed exoplanet candidate or a bright transiting exoplanet. One important consideration when planning such an observation is the apparent magnitude of the host star. If it is too faint, the likelihood of seeing the transit is low ("too faint" in the context of one's equipment). But this is not the primary consideration. The primary consideration is the depth of the magnitude decrease as the planet transits. Depending on the radius of the planet relative to the radius of the host star, the amount of light that is blocked might be so small that the host star's "blink" is imperceptible.

So in the planning of this Astrophysics 507 exoplanet transit observation attempt, a rather faint star was chosen. The host star of Qatar-2b has an untransited magnitude of $m_V = 13.3$, well within the reach of the CMT, and the predicted drop in apparent magnitude was a whopping 37 milli-magnitudes (0.037 mags). This exceptional decrease was the largest of the candidate stars available in the Winter Semester, making it an excellent choice for this pioneering run. In terms of the "mosquito in front of the headlights" metaphor, this exoplanet is more like a housefly. This small magnitude drop corresponds to less than a 4-percent decrease in radiative energy received by the CMT. We hope this tiny change would be observable.

Another consideration in the planning of an exoplanet transit observation is the duration of the transit, which depends on the distance of the planet from its host star. Some of the shorter predicted duration transits are several hours. For best results, one should include observations before and after the transit event, so as to observe the ingress and egress. Predictions might be off, and since a good measurement of the transit duration and light-curve shape is important to determine the radius of the planet and its orbital elements, short Canadian summer nights are not very conducive to the study of long-duration eclipses. And, as always, a night with a cloudless sky and photometric conditions is preferred.

Observations

Qatar-2b is a "hot Jupiter" and the corresponding short orbital period of 1.337 days provided flexibility in choosing an observing date (Bryan, M.L. *et al.* 2012). On the night of 2013 February 12, the Astrophysics 507 students remotely logged on to the *f*/5.2 CMT, in the hope of observing the first exoplanet transit with RAO telescopes. The CMT was slewed to Qatar-2b, located low in the sky in the constellation of Virgo, almost at the low-altitude limit of the CMT. Set-up images were taken in the "open" filter (filterless) to verify the star field and to check the focus. Since Qatar-2b is quite faint, it was decided that 120-second exposures would yield an ample signal-to-noise ratio. Dark-current images of equal duration were also taken with the SBIG STX-6303 camera with the temperature set to -10 °C. The star field around Qatar-2b is shown in Figure 2.

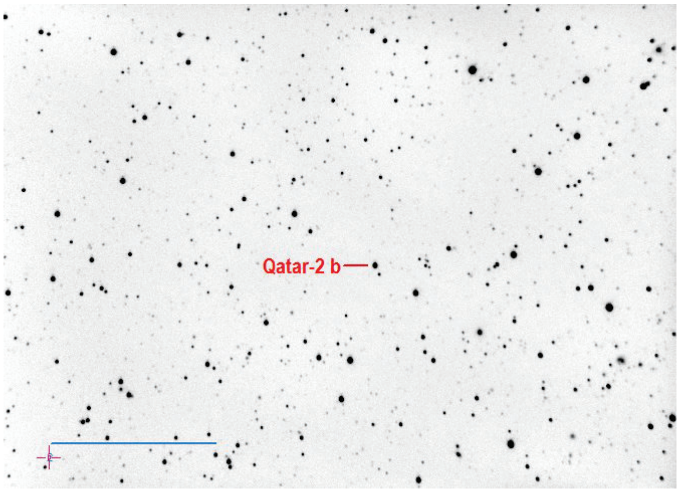

Figure 2 — The star field around Qatar-2b (GSC 4974 112). North is up and east is to the left. The length of the blue bar is 10 arcminutes. RA and Dec coordinates are 13h 50m 37.4s -06° 48′ 14.4″ (J2000).

On this long night of moonless winter observing, the transit was expected to begin at 2:54 a.m. and continue until 4:43 a.m. local time. Throughout the night, tensions were high as intermittent cloud cover drifted precariously close to the star field, threatening to interrupt the transit. The unfolding drama was captured with the RAO all-sky camera (a 60-second exposure from the all-sky camera, at the start of this observing run, is shown in Figure 3). Minutes after the expected end of the transit, the clouds came in earnest, putting a halt to further observations. Fantastic! The data was in hand!

Data Analysis

The apparent brightness of a star is affected by many things, most fundamentally, the extinction of light by the atmosphere. As Qatar-2b rose higher into the sky, past the meridian and

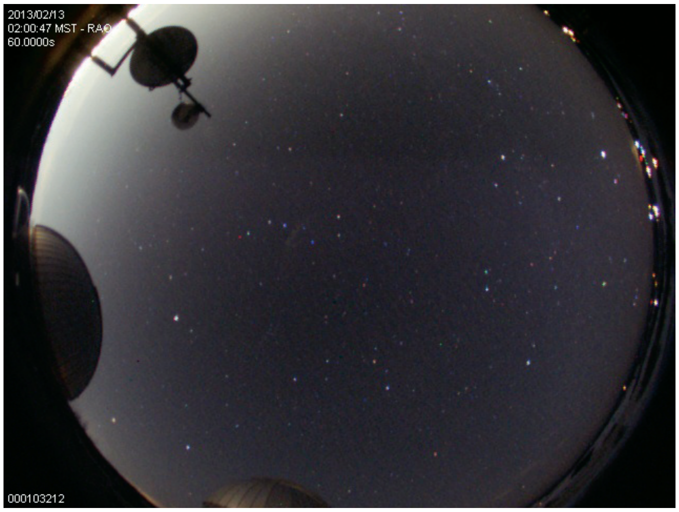

Figure 3 — The Qatar-2b data was obtained 2013 Feburary 12, 09:13:46 to 11:47:56 UTC. This image, taken with the RAO all-sky camera, shows the sky over the RAO at the start of the observation run. North is at the top, and east is at the left. Familiar constellations can be seen. The corresponding zenith-scanning Sky Quality Meter reading was 20.92 mag/arcsec^2. This was a very dark night by RAO standards.

then lower again as it moved down to the western horizon, its light passed through decreasing and then increasing amounts of atmosphere. Haze and thin cloud cover are the most obvious interfering culprits, but even if the sky remains dark and cloud free all night long, crispy, clean air still absorbs and scatters photons. To separate out time-varying effects due to the atmosphere from the actual transit, one employs a differential-magnitude method.

As the name suggests, "differential photometry" is the simple subtraction of the instrumental magnitudes of two stars. The premise is that whatever atmospheric effect is changing the amount of starlight entering the telescope, it is affecting the light from the target and reference stars equally. So, if the stars are shining with constant light intrinsically, but their magnitudes are going up and down in step with each other over time due to varying extinction, the difference in their magnitudes will remain unchanged, revealing their intrinsic constant light output. If the difference in magnitude does not stay constant, then it could be because one of the two stars is not shining with constant light.

The students analyzed the Qatar-2b data using the differential photometry tools in *MaxIm DL Pro*. Since any given 120-second image contains many stars, the difference in magnitude between Qatar-2b and many of its neighbours was calculated. Each individual magnitude measurement has an associated uncertainty, and the error in magnitude differences was calculated as the square root of the individual errors squared and added (the errors are added in "quadrature"). The final differential magnitude for a given image was found by averaging all the differential magnitudes from all the Qatar-2b star pairs in that image. Final errors are determined after including this averaging process. In the language of the American Association of Variable Star Observers (AAVSO), this is a "stochastic uncertainty." This analysis is repeated for all of the 120-second images taken over the entire observing run.

One important additional step in the analysis of the CCD images is to correct for imperfect telescope optics. The initial purpose of the CMT (long before it was christened the CMT) was to study variable stars using the Rapid Alternating Detection System (RADS). RADS employed a photomultiplier tube, a chopping secondary, and a mechanical aperture, all designed to measure starlight just one star at a time (Milone *et al*. 1982).

When RADS was replaced by a large format CCD camera, a significant amount of vignetting was revealed. Also, imperfections in the primary and secondary mirrors and dust specks on the CCD window all lead to light being lost, non-uniformly, across the image. To be able to detect the tiny variations in light output of Qatar-2b, the images would have to be corrected for this defect. To do this, a normalized flat-field image had to be created and employed.

There are several strategies one can employ to try to create a flat-field image, and each has its pros and cons. The basic strategy is to put perfectly uniform light into the telescope and take an image with the CCD camera. If the optics are perfect, the image will be equally bright across the entire frame. If there are areas that have higher and lower counts, then the telescope itself is affecting the transmission of the light to the camera sensor. The great thing is that these flat field images are digital, so the non-uniform surface can be "mapped" out and normalized to a value of one. Then, when the science images are taken, all of which include this inherent non-uniformity, one divides the images by the carefully crafted normalized flat. Areas of lower count are boosted and areas of higher count are reduced, resulting in a star image with a perfectly uniform background.

So what does one use as a source of "perfectly uniform" light for the creation of the normalized flat-field image? Some like to take "dome flats" by imaging an illuminated white screen mounted on the inside of the telescope dome. Some like to take "sky flats" by imaging the sky just after sunset or before sunrise, in that brief window of time where the sky is not too dark or too bright. With the Qatar-2b observing run, a "dithered" normalized flat was created. With the small amount of tracking error in the CMT drive, the stars are in slightly different positions on the CCD frame from one image to the next. That is, the images are inherently dithered. By median combining the large number of images taken over the entire observing run, the stars are essentially removed. But what is left behind is the background of non-uniform brightness that is the same in all the images; the flat field. The downside of making a dithered flat is that the source of "perfectly uniform" light is the dark-sky background. The counts are therefore low and the median-combined flat-field image is substantially noisier than either dome or sky flats. So using a dithered flat to flatten the images introduces additional noise, making the small blink of the star being transited even harder to see. So to eliminate this additional source of noise, the normalized median-combined dithered flat was fitted by a two-dimensional 9 × 9 polynomial surface using *Mira Pro UE*. Analysis showed that the residuals between the fit and the median flat were less than 0.1 percent on average, except very near the edges of the frame, far from where Qatar-2b was located on the images. The noiseless 9 × 9 polynomial fit image was successfully used to flatten the Qatar-2b images.

So with all the calibration and data collection work done, it was now time for the students to visualize their reduced data and plot their light curve. With high hopes of seeing the transit (and with course grades potentially on the line), anticipation of the results was at an all-time high. To their astonishment, the expected dip associated with the Qatar-2b transit was clearly visible! Not having used the *MaxIm DL Pro* suite of astronomical photometry tools myself, I re-examined the entire dataset again, including the error analysis, using *Mira Pro UE*, and obtained the same amazing results. The dip in the light of the host star of Qatar-2b was real, and there was no doubt that a planet was orbiting a star other than our Sun! The Qatar-2b light curve along with the stochastic uncertainty in the data points is shown in Figure 4.

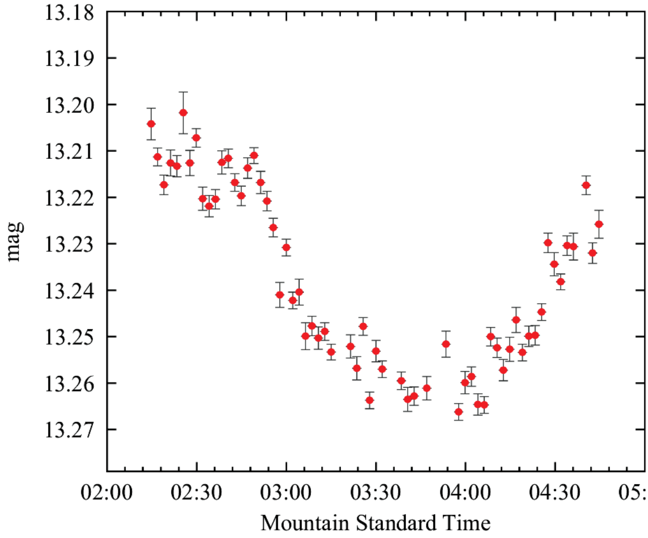

Figure 4 — The open-filter light curve of the Qatar-2b transit produced by the CMT. Data points are plotted along with the stochastic uncertainty in the measurements.

With the final light curve in hand, there was still more analysis that could be done. With a bit of work and a few simple assumptions about stellar and orbital parameters, the planetary radius could be estimated. But there are only so many hours in a busy semester for senior undergraduate students. Thankfully, the ETD Web site also provides a slick application whereby processed photometric data can be uploaded to the Transiting Exoplanets and Candidates (TRESCA) database. The uploaded data is automatically adjusted and fit to a transiting model that determines the depth and duration of the transit, and the planetary radius (Podanny *et al.* 2010).

Assuming the model was correct, the stochastic uncertainty was rescaled so that the error in the output parameters would be more accurately represented. The model fit to the data is shown in Figure 5, and can be found in the TRESCA database on the ETD Web site at http://var2.astro.cz/EN/tresca/transit-detail.php?id=136547448

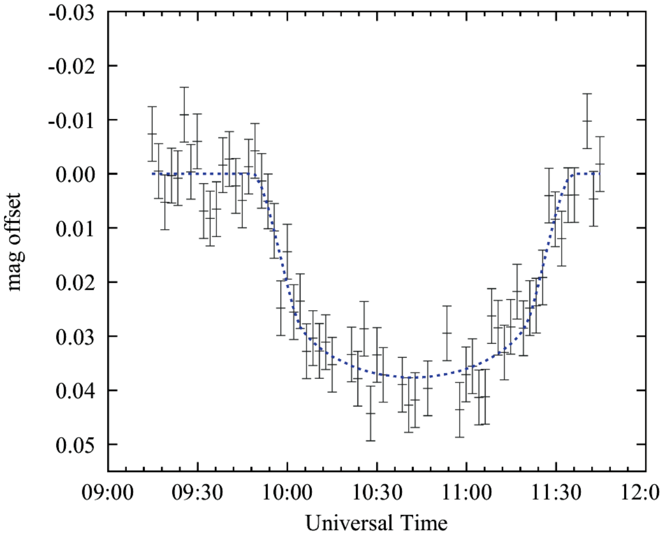

Figure 5 — The dotted trend line provided by the ETD model fit. The Qatar-2b data is plotted along with the rescaled stochastic uncertainty.

The online fitting tool gave the results that the depth of the transit was 0.0377 +/- 0.0018 magnitudes, the duration of the transit was 106.2 +/- 2.1 minutes, and the radius of the planet is 1.286 +0.030 / -0.031 Jupiter radii.

A Repeat Performance

The students had just demonstrated that a tiny dip in star brightness of only 37.7 milli-magnitudes was "easy-peasy" with the CMT, so a new challenge presented itself. To prove that the Qatar-2b exoplanet transit wasn't just a one-off lucky hit, and to push the equipment even further, a second exoplanet transit observation was attempted.

The exoplanet HAT-P-26b is located in the constellation Virgo. Its host star has an apparent visual magnitude of

m_V = 11.7. Its orbital period is 4.235 days and the anticipated brightness depth associated with this transit corresponded to only a 0.6-percent change in flux, or a very tiny 7.0 milli-magnitudes (Hartman *et al.* 2011). This is about five times smaller than the Qatar-2b transit. In terms of the "mosquito in front of the headlights" metaphor, this exoplanet is more like a fruitfly.

In the very late hours of 2013 March 24, the students remotely trained the CMT on HAT-P-26b. Predictions were that the transit was expected to occur starting at 4:22 a.m. and last until 6:49 a.m. local time. As with Qatar-2b, the open filter was used, but unlike the Qatar-2b observing session, exposures of just 60 seconds were taken. Since the error bars in the Qatar-2b light curve data points were typically +/- 3 milli-mags, and HAT-P-26b is more than 1.5 magnitudes brighter than Qatar-2b, halving the exposure time should yield error bars of comparable or smaller size. Also, since the data acquisition rate is essentially doubled by halving the exposure, the timing of the ingress and egress would hopefully be improved—should the transit be captured at all. The other differences between observing runs is that this time twilight sky flats were used, and the Moon phase was much less favourable.

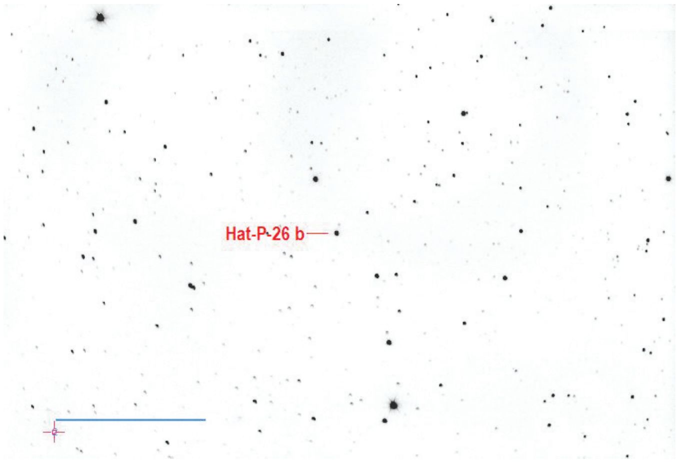

Figure 6 — The star field around HAT-P-26b (GSC 320 1027). North is up and east is to the left. The length of the blue bar is 10 arcminutes. RA and Dec coordinates are 14h 12m 37.5s 04° 03′ 38.9″ (J2000).

The star field around HAT-P-26b is shown in Figure 6. A 35-second exposure from the all-sky camera, at the start of this observing run, is shown in Figure 7. The light curve of the HAT-P-26b transit as revealed by the CMT data is shown in Figure 8. The model fit provided by the ETD Web site is shown in Figure 9 and can be found in the TRESCA database on the ETD Web site at http://var2.astro.cz/EN/tresca/transit-detail.php?id=1365403170.

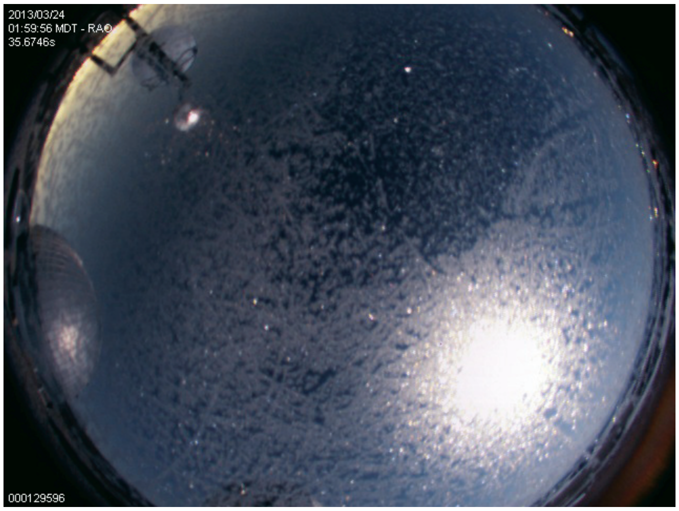

Figure 7 — The HAT-P-26b data was obtained 2013 March 24, 2013 08:00:48 to 12:14:52 UTC. This image shows the sky over the RAO, and a frosty Plexiglas cover over the all-sky camera, at the start of the observing run. The corresponding zenith-scanning Sky Quality Meter reading was 18.28 mag/arcsec². The sky continually darkened as the Moon steadily moved toward and below the western horizon.

Despite missing the end of the transit due to reaching the low-altitude limit of the CMT, the miniscule drop in star brightness was detected! According to the model fit, the depth of the transit was 0.0070 +/- 0.0012 magnitudes, the duration of the transit was 131.1 +/- 20.8 minutes, and the radius of the planet is 0.617 +0.051 / -0.055 Jupiter radii.

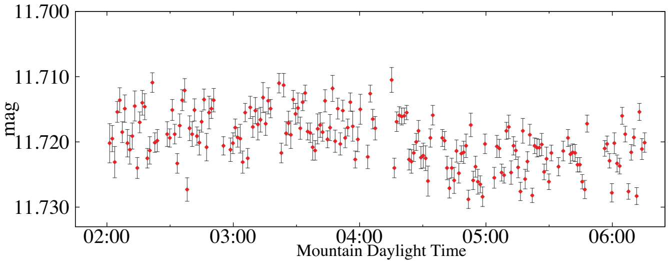

Figure 8 — The open-filter light curve of the HAT-P-26b transit produced by the CMT. Data points are plotted along with the stochastic uncertainty in the measurements.

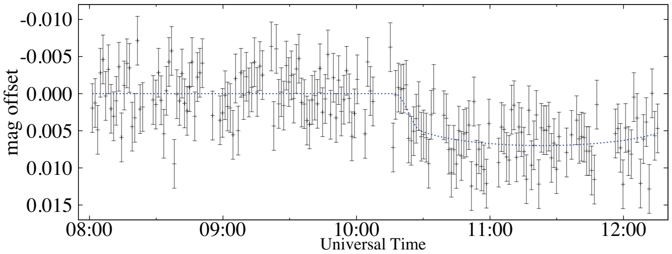

Figure 9 — The dotted trend line provided by the ETD model fit. The HAT-P-26b data is plotted along with the rescaled stochastic uncertainty.

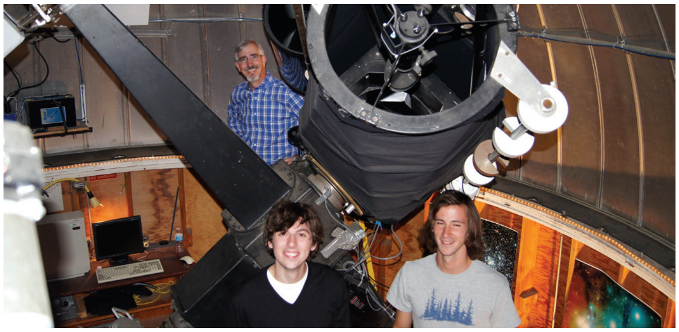

Figure 10 — The 0.4-m CMT used to observe exoplanet transits at the RAO. U of C students (JC and CP), who devised the senior observing project, and collected and reduced the data, are in the foreground.

Conclusions

Most amateur astronomers would find the prospect of observing an exoplanet transit an intriguing one. So it comes as good news, and a bit of a surprise perhaps, that such observations are not restricted to just those with access to space-borne or metre-class telescopes. The transits described here were made using a moderate 0.4-m telescope, and indications are that even smaller apertures can be used successfully. And with the aforementioned online resources and books providing a burgeoning wealth of useful information, I would recommend to anyone with the available equipment to plan and attempt such observations themselves.

In the context of this very interesting Astrophysics 507 observing project, the facilities at the RAO allowed students access to an invaluable hands-on observing experience, and provided an intuitive learning environment unique from that normally offered in the classroom. One student even declared (JC), "It was a memorable and fulfilling course. Observing the transit of an exoplanet discovered as recently as 2011 provided an exciting link with cutting-edge astrophysics and proved to be the most rewarding experience of my schooling career." ✶

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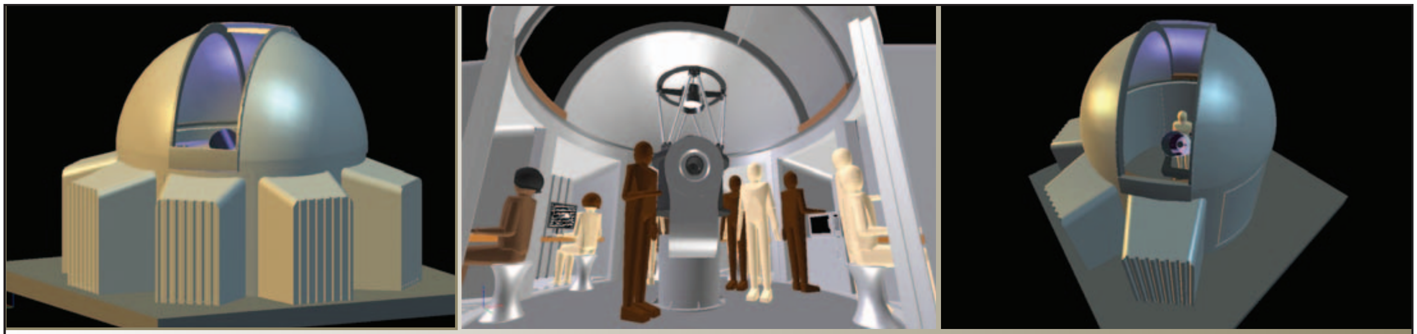

Orbital Oddities: Rhythmic Venus

by Bruce McCurdy, Edmonton Centre
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Every summer at the Public Observatory at the TELUS World of Science Edmonton, Venus is one of the main attractions. The second planet always hangs within 45° or so of the Sun, so tends to be high in the sky in the afternoon hours where it is generally an easy find with one or more of the battery of telescopes at the deck. Visitors are always pleasantly surprised to learn that it's possible to see a planet in the daytime, and especially that it's so bright and easy to see.

It is interesting to follow the evolving phase of Venus from week to week, waning as it approaches Earth on the eastern (evening) side of the Sun, waxing as it recedes on the western side. Close observation on a daily basis is warranted around the times of three of its geocentric phenomena: maximum elongations to the east or west of the Sun when the planet is about half-illuminated and can be monitored for the famous Schröter effect; or inferior conjunction when Venus passes between the Sun and Earth. On the other hand, superior conjunction results in many long weeks where Venus is impossible or unsafe to observe as it creeps around the far side of our star.

These geocentric phenomena are defining events that govern the summer observing program. Only recently, however, did it occur to me that every summertime geocentric phenomenon in my nearly two decades on the job has occurred about the third week of August—every last one of them, no exceptions.

This includes the inferior conjunctions of 1999 August 20 and 2007 August 18, when I observed the slender crescent Venus pass about 8° below the Sun right on the day of conjunction. In more recent years, we had one such event around the same date three years in a row: Eastern Elongation on 2010 August 20; Superior Conjunction on 2011 August 16 (when we didn't look at Venus throughout August due to its extreme proximity to the Sun); and finally the Western Elongation of 2012 August 15.

The reasons for this coincidence are subtle. The synodic period of Venus is within half a day of being exactly 1.60 years. Five such yields a near-integer number of years (8 years minus 2.4 days), an extremely reliable period that is manifest in near repetitions of Venus's position in Earth's sky at 8-year intervals (Figure 1). We have examined the effect of this eight-year cycle in previous columns discussing both occultations by, and transits of, the Sun (McCurdy 2000, 2004). At present, both of those events occur in early June, when both Sun and Venus are in the constellation of Taurus. (I also heartily recommend the outstanding JRASC article by Roy Bishop (2012) on this general subject.)

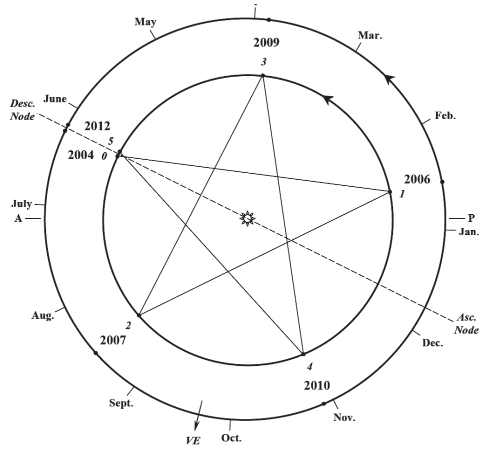


Figure 1 — The synodic period of Venus is 1.6 years = 2.6 revolutions of Venus. After five such periods, the two planets have completed a near integer number of orbits (13 for Venus, 8 for Earth) and have returned to very near their initial positions. A sequence of consecutive inferior conjunctions of Venus as shown here, inscribes a near-perfect pentagram that rotates extremely slowly over a period of centuries. Image: Bishop (2012).

But what happens within each eight-year cycle? While the intervals are slightly variable due to the eccentricities of the two orbits, for "back of the envelope" purposes, the 584-day synodic period can be split into about 142 days from eastern to western elongation (effectively the crescent phases, ignoring the previously mentioned Schröter effect), and 442 days from west back to east (gibbous phases). Since the conjunctions occur midway between the elongations, these intervals can further be divided in half: 2×71 and 2×221 days.

Let's use the annotation *abCD*, where *a* and *b* are the 71-day intervals and *C* and *D* the 221-day intervals. The following sequences must occur, beginning for illustration purposes at eastern elongation:

> *abC* ≈ 363 days ≈ 1 year minus 2 days
>
> *Dab* ≈ 363 days ≈ 1 year minus 2 days

This is the sequence from eastern elongation to superior conjunction, and then to western elongation. Thus three events around the same date in successive years, as we saw in August 2010-12. From there:

> *CDabCDa* ≈ 1097 days ≈ 3 years plus 1 day

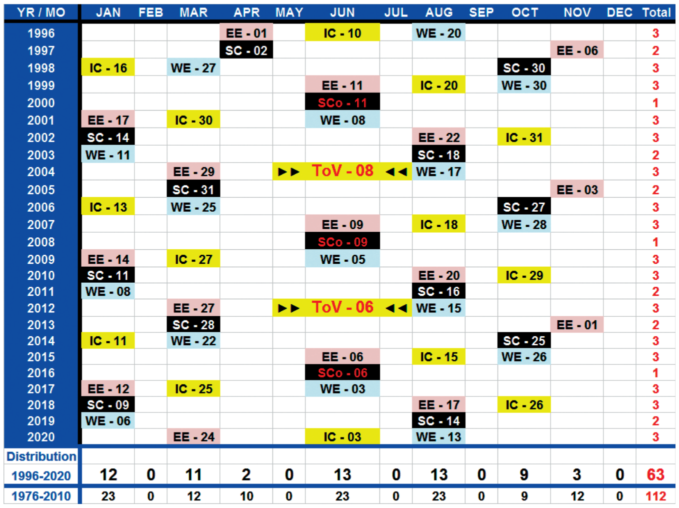
to inferior conjunction, then

> *bCDabCD* ≈ 1097 days ≈ 3 years plus 1 day,

which takes us back to eastern elongation.

Add up all the periods and we find 5×(*abCD)* ≈ the familiar 8 years minus 2 days.

Figure 2, derived from Meeus (1983), shows a table of all conjunctions and elongations for the 25-year period 1996-2020 and confirms a clustering of such events in five tight windows spread across the calendar. In each instance, we find slightly different sequencing with the consecutive events occurring a day or two "early" or "late." In November and January, we can find up to a week difference between



YR / MO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
1996				EE - 01		IC - 10		WE - 20					3
1997				SC - 02							EE - 06		2
1998	IC - 16		WE - 27							SC - 30			3
1999						EE - 11		IC - 20		WE - 30			3
2000						SCo - 11							1
2001	EE - 17		IC - 30			WE - 08							3
2002	SC - 14							EE - 22		IC - 31			3
2003	WE - 11							SC - 18					2
2004			EE - 29		►►	ToV - 08	◄◄	WE - 17					3
2005			SC - 31								EE - 03		2
2006	IC - 13		WE - 25							SC - 27			3
2007						EE - 09		IC - 18		WE - 28			3
2008						SCo - 09							1
2009	EE - 14		IC - 27			WE - 05							3
2010	SC - 11							EE - 20		IC - 29			3
2011	WE - 08							SC - 16					2
2012			EE - 27		►►	ToV - 06	◄◄	WE - 15					3
2013			SC - 28								EE - 01		2
2014	IC - 11		WE - 22							SC - 25			3
2015						EE - 06		IC - 15		WE - 26			3
2016						SCo - 06							1
2017	EE - 12		IC - 25			WE - 03							3
2018	SC - 09							EE - 17		IC - 26			3
2019	WE - 06							SC - 14					2
2020			EE - 24			IC - 03		WE - 13					3
Distribution 1996-2020	12	0	11	2	0	13	0	13	0	9	3	0	63
1976-2010	23	0	12	10	0	23	0	23	0	9	12	0	112

Figure 2 — Geocentric phenomena of Venus for the period 1996-2020 are clustered in five distinct groups across the calendar. The totals in the very bottom line of the table incorporate all such events back to 1976, as published in the first edition of Meeus (1983).

consecutive EE and WE, but just three days in June. In April, we see that SC occurs one year *plus a* couple of days after EE, while in November that same sequence is one year *minus a* week or so. These relatively small effects would be due to eccentricities in the orbits, primarily that of Venus (given Earth is always around the same place on a given date). This little bit of jitter notwithstanding, by and large the clumpings hold remarkably true to the five-fold quasi-symmetry that characterizes the Earth-Venus relationship.

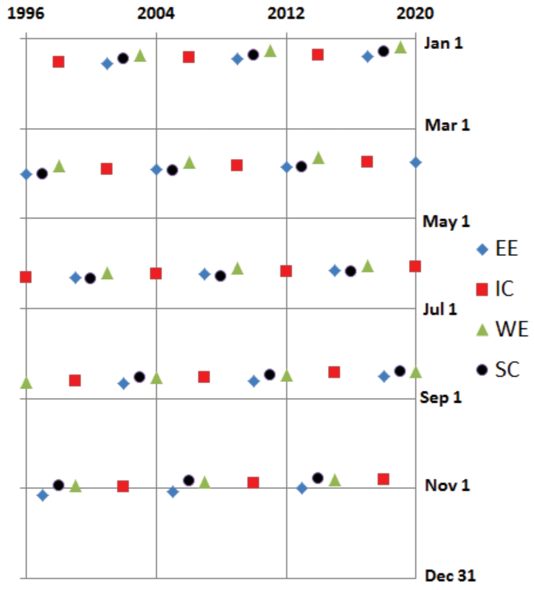


Figure 3 — Geocentric phenomena of Venus for the period 1996-2020 displayed graphically. The nearly horizontal lines show the various phenomena all clustered around the same dates, with a very gradual forward shift. Note the blue diamond on 2013 November 1; there will be no more events in the last two calendar events until the western elongation of late December 2042. EE: eastern elongation; WE: western elongation; IC: inferior conjunction; SC: superior conjunction.

In more general terms, the spacing of clusters at intervals of about 1/5 of a year can be explained by the fact that the intervals under study, namely 71 days and 221 days, are fairly close to 0.2 and 0.6 years respectively. Thus any combination of them can only lead to intervals with mantissas of about 0.2, 0.4, 0.6, 0.8, or of course 0.0!

Thus in the past four decades, there has not been a single event of any of the four types in February, May, July, September, or December. Eventually, of course, the entire series will gradually "rotate" forward by a couple of days every eight years, and in time, such events will cluster in those months while the current windows of high activity will lie fallow. Indeed, one such transition is just about to occur as this issue of JRASC goes to press: the Eastern Elongation of 2013 November 1 will be the last geocentric event in November for well over a century.

This effect is represented graphically in Figure 3. The years are represented vertically and reflect the eight-year repetition: note, for example, how the years 1996, 2004, 2012, and 2020 display nearly identical sequences. In the figure, calendar dates are represented horizontally, with the five active windows of activity each presenting a tightly constrained "line" of events that is shifting forward, by about one week in the 25 years depicted. After a full "Cytherean Cycle" of 243 years, the entire pattern will have shifted forward by 1/5 of a year, and we can look forward to a repeat of the recent circumstances, including another pair of June transits of Venus in 2247 and 2255.

Dedication: This article is dedicated to RASC Honorary Member Jean Meeus, a giant in the field of mathematical astronomy who has served as both inspiration and mentor to the writer. His profound understanding of orbital mechanics coupled with prodigious computational skills is manifest in many books and publications, notably the *Mathematical Astronomy Morsels* series. He has also proven to be extraordinarily generous with private correspondence on a wide variety of subjects, buttressed by requested data sets, some of them mammoth ones. Jean, who turns 85 in the month of this issue, has been cited some 70 times in 30 different Orbital Oddities columns over the years. ✶

Bruce McCurdy was a Contributing Editor to JRASC during the decade 2000–2009, during which time almost 50 Orbital Oddities columns were published. While he now writes professionally on another subject, he hopes to contribute occasional such pieces in the future. He has telescopically observed Venus on the day of its inferior conjunction for every such event this century, including the Transits of 2004 and 2012.

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Murder at the Observatory: A Forgotten Chapter in the Legacy of Alvan Clark & Sons

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Abstract

During the celebrated history of Alvan Clark & Sons, founded by the legendary lens- and telescope-making family, there was a stunning chain of events that had a profound impact on the business and its future prosperity. Although many of the details were of a highly personal nature, they were not ignored by the newspapers. Among the incidents was an alleged kidnapping within the family, followed shortly thereafter by a death near the Clark's observatory that led to a sensational murder trial. A series of other litigious matters continued to trouble the family and keep them in the public consciousness for more than a decade. Here, we examine the personal events and the impact they had on the viability and future ownership of the business.

Introduction

Alvan Clark & Sons was one of the most celebrated names in the world of optics and telescope making. The firm was founded by Alvan Clark Sr. and his two sons George Bassett, and Alvan Graham. For most of their professional careers, their home, and the business they built, existed on what is called the Clark estate.

The Clark telescope-making facility was a self-contained estate on a 0.75-hectare tract of land located close to the Charles River on Brookline Street in Cambridge, Mass. Built in 1860, it included a substantial workshop, observatory, "testing tube," and large houses in which, over the years, various family members resided.

Perhaps the most striking feature within the neighbourhood was the ever-present testing tube. The tube was housed on a two-storey pier described as "a mighty cylinder of iron" that had become coloured red from rust. It was used to test many of the lenses made at the factory. One of those tested was the18.5-inch lens for the Dearborn telescope at Northwestern University in Evanston, Ill. Alvan G. Clark inadvertently discovered the companion star to Sirius (Sirius B) in 1862 while testing the Dearborn lens.

Alvan Clark & Sons was renowned for its superb quality lenses and telescopes. The firm's reputation, quite early on, was strong even in Europe, especially in England and France. In particular, William Rutter Dawes (1799-1868), the British astronomer, was highly impressed by the telescopes made by the firm. As a result, some smaller refractors built by the Clarks can be found in Europe. The company's legacy continued long after the death of Alvan Clark Sr. and his two sons. Many of the great refractors on Earth can claim to have had their lenses figured at the Clark estate during its 70-year history.

Alvan Graham Clark

The untimely death of Alvan Graham Clark was not only a tragedy, it was a significant international event. Headlines from all over the world told of the great loss to science and of Clark's personal achievements in astronomy. On 1897 June 9, Alvan G. Clark, the last surviving original member of the famous telescope-making firm, Alvan Clark & Sons, suffered a fatal stroke while in his home.

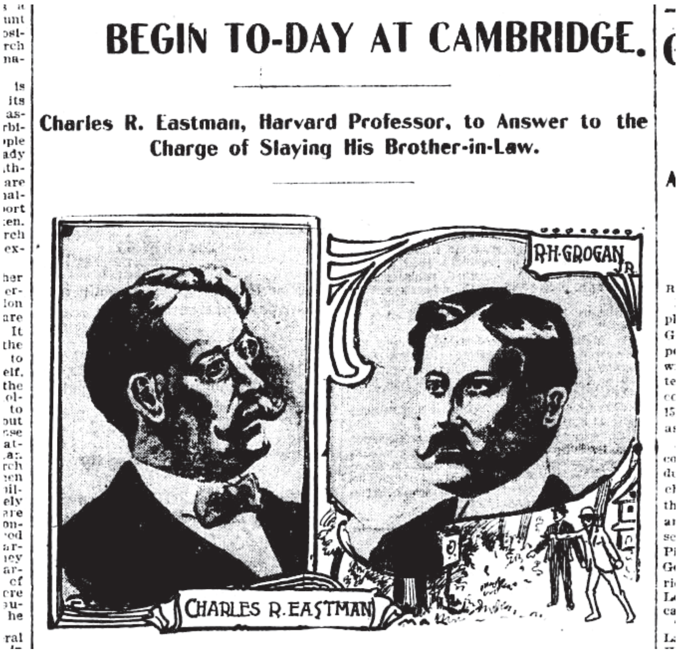
A private service was held at his home on the Clark estate. Later, a public service with over 200 in attendance was held at the Austin Street Unitarian Church, also in Cambridge. Among the pallbearers were the high-profile astronomers E.C. Pickering from Harvard, Asaph Hall, the discoverer of Mars's two moons, and the eccentric Percival Lowell, the founder of the Lowell observatory in Flagstaff, Arizona.

This youngest of the Clarks, Alvan Graham, expected that he would eventually succumb to apoplexy, because one of his two sisters, and his brother George, had both suffered that fate. In the weeks prior to his death, Clark was mindful of apoplectic tendencies and was even "temporarily prostrated."

To those who were unaware of Clark's health problems, his death would have come as a complete surprise. Less than a month before his death, Clark had been very busy preparing the newly completed 40-inch lens for shipping to the Yerkes observatory in Williams Bay, Wis., for the University of Chicago. In 1897 May 19, Clark arrived at the Yerkes observatory after carefully escorting the lens by rail from his shop in Massachusetts. Joining him was his trusted employee and skilled lens-maker Carl Lundin. The Yerkes telescope would become what is to this day still the largest refractor on Earth.

An element of his tragic death was that Clark would never see the fruits of his greatest optical accomplishment. However, he was privy to a small group that would test the new optics at Yerkes on 1897 May 22. William Harper, president of the University of Chicago, was the first to view the heavens through the great new telescope. Jupiter was selected as the first target. Others that joined for a view that night included the director of the Yerkes observatory, George E. Hale, and astronomer E.E. Barnard. The consensus from the various observers was that the telescope was superb.

However, a serious mishap occurred at the Yerkes observatory a week later. On 1897 May 29, the elevated floor at the Yerkes telescope collapsed. An inspection revealed that the collapse fortuitously did not damage the great lens or mounting. An



BEGIN TO-DAY AT CAMBRIDGE.

Charles R. Eastman, Harvard Professor, to Answer to the Charge of Slaying His Brother-in-Law.

Figure 1 — Charles R. Eastman and Richard Grogan; both sons-in-law of Alvan G. Clark. The story appeared on the day the murder trial started. Note the sketch on the lower right of the two men firing pistols at a target set up in the back of the Clark estate. (1901 April 22) ***St. Louis Republic***

article written shortly afterwards suggested that Clark was "lucky" that his life-work, the 40-inch lens, was not destroyed. Four days after the article appeared in print, Clark was dead.

The Children of Alvan Graham Clark

Alvan Graham Clark was survived by his three daughters, all of them married at the time of his death. Caroline A. Clark, the oldest of his daughters, married Charles R. Eastman on 1892 June 27, five years before Alvan died. The wedding celebration was short lived, as Alvan Clark's wife, Mary Willard Clark, died in July of 1892. The newly wedded couple learned the tragic news while on their honeymoon in Washington, D.C. The middle daughter, Elizabeth W. Clark, married Richard H. Grogan the following year, and the youngest daughter, Mary T. Clark, married Sumner R. Hollander in early 1897.

With the death of Alvan Graham Clark, the last of the great lens-making family had no heirs to continue the legacy. George Bassett, older brother of Alvan, had died six years earlier and, although married, did not have children. Alvan Graham had envisioned that his son, Alvan Willard Clark, would carry on the tradition of highly skilled lens making within the family. However, Alvan died in youth (1870-1885), a loss that the youngster's mother, Mary Willard, would endure the rest of her life. The elder Clark, among his many talents, was a skilled portrait painter and completed a portrait of his deceased grandson from memory shortly before his own death in 1887.

Extraordinary Developments

Within a year of Alvan Graham Clark's death, a stunning story emerged in *The San Francisco Call* (1898 April 16). The story alleged that the youngest daughter of Alvan Clark, Mary Theodora, still a young college student at the time, had eloped and secretly married Sumner R. Hollander in an attempt to avoid the ritual of seeking parental consent. After three months of marriage, the newlyweds confessed to their secret matrimony and were accepted by friends and family alike. The couple could finally settle down contentedly.

Just three weeks of their confession, the father of the bride, died. Clark's will left the bulk of his wealth to Mary Theodora, while one of the other sisters was left with a small sum, and the third was left out completely. It was suggested that this turn of events led to a feud among the three sisters.

A few weeks later, Sumner R. Hollander came home from work to find that his wife, Mary Theodora, who had been recovering from a serious illness, was missing. The wealthy Hollander family hired detectives to find her. A successful search discovered her about three weeks later in the unlikeliest of all places, a farmhouse in North Dakota. The couple returned to their Cambridge home only to experience further drama.

Several months later, after Hollander had been called away on business for two days, he returned home to yet again find her missing. Another bizarre search ensued, this time to find her hidden in a ranch house near Willows, California. After another brief attempt failed to keep her hidden, she was reunited with her husband at the Palace Hotel, a luxury hotel in San Francisco. This last kidnapping ordeal lasted about four weeks.

The motive behind these incredible events was blamed on Mary Theodora's sister, Elizabeth W. Grogan, and Elizabeth's husband. It is alleged that, because Elizabeth had been disinherited from her father's will, a kidnapping had been arranged to extort money from the sister.

Many of the details from the story above are difficult to corroborate. However, the events that follow clearly indicate that an incredibly confrontational and dysfunctional relationship existed between the three daughters of Alvan Clark and their spouses. Among these events is a lawsuit filed in April 1898 by Hollander against his brother-in-law, Charles R. Eastman, seeking $75,000. The suit claims that Eastman was guilty of "abduction, alienation and conspiracy."

This lawsuit was quite sensational within the city of Boston. Charles R. Eastman was a professor at Harvard College. Sumner R. Hollander was a member of one of the wealthiest and most respected families in Massachusetts. The two family names were well known in Boston social circles. To further

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Pen & Pixel

Figure 1 — Lynn Hilborn tried for something a little different this summer and focused on Abell 85, a delicate supernova remnant in Cassiopeia lying about 9800 light-years distant. Abell 85 emits much of its light in Hα light, but is intrinsically faint and requires long exposures. Lynn used a TEC 140-mm refractor at ƒ/5.3 with an FLI ML8300 camera; exposure was 15×30 minutes in Hα binned 1×1 and 8×30 minutes in OIII binned 2×2. According to Lynn, "...this object is often considered as one of the most challenging for visual observation and remains a good test for CCD photography."

Figure 2 — James Black uses his ƒ/2.0 14″ Hyperstar-Celestron CGE to capture wide-angle views of the deep sky such as this image of M106 and NGC 4217 in Canes Venatici. Exposure is 12×10 minutes using a Starlight Express SXVF-M25C camera from Pitt Meadows, B.C. M106, one of the brightest galaxies at 9th magnitude, contains a very active supermassive black hole at its core. The galaxy is unusual in that it seems to have four spiral arms instead of the usual two.

Figure 3 — In winter, galaxies rule. Dalton Wilson has captured several of Leo's winter showpieces in this image of M105 (right), NGC 3379 (top), and NGC 3389 (below). Dalton used an AstroTech 10″ Ritchey-Chrétien and a QSI 540wsg camera from his observing site at Didsbury, Alberta. The exposure was 4×900 s in R, G, and B. M105, discovered by Pierre Méchain in 1781, lies at a distance of 38 million light-years; it has a visual magnitude of 10.

Figure 4 — Kerry-Ann Lecky Hepburn likes to photograph the unusual, and this month she provides us with this image of the reflection nebula IC 5076 in Cygnus. Kerry-Ann used an AT8RC telescope with an SBIG ST8300M camera; exposure was 12×10m in L, 5×10m in R, 3×10m in G, and 5×10m in B.

Continued from page 249

complicate this affair, Mary Theodora Hollander is alleged to have said that she was the victim of blackmail on the part of her husband, and she sought protection from him.

Murder at the Observatory

The events of 1900 July 4 would promote the family affair from an intriguing story to a national sensation. In the late afternoon, after members of the Clark family had enjoyed some Independence Day fireworks in Cambridge, Mr. Grogan and Mr. Eastman went to the back of the Clark estate on Brookline Street to engage in some target shooting. A target had been set up near the observatory, and various revolvers were fired as the two men practised their skills. During the course of the target shoot, Richard Grogan was shot. He died about ten minutes later.

There were many accounts in the media of the events of that day. Among them was a version that eyewitnesses had heard Mr. Grogan alerting to anyone within hearing distance that not only had he been shot, but it was murder (presumably Mr. Grogan knew he had suffered a fatal wound).

Other variations insisted that it was an accident. It was the view of one eyewitness that an "old fashioned brass mounted revolver" that had not been fired since last Independence Day was not firing for some reason. Shortly afterward, the testimony maintained, the gun fired unexpectedly, and the bullet struck Mr. Grogan just above his heart. As Mr. Grogan fell, he simply exclaimed that he had been shot. The revolver that Mr. Grogan was holding fired as he fell, hitting Mr. Eastman in the right thigh; Eastman's wound was superficial.

On the night of 1900 July 4, Charles R. Eastman was arrested for the murder of Richard Grogan. What a story: a son-in-law of Alvan Graham Clark had been arrested for the murder of another of his sons-in-law. Headlines in newspapers, both locally and nationally, would follow the developments incessantly until the conclusion of the trial some ten months later.

The Courts

On 1900 July 18, a district court judge acquitted Eastman. Judge Almy denied a grand jury hearing by stating that the shooting was accidental rather than pre-meditated murder. Eastman was free to go. However, as was their option, police obtained "a network of evidence" that would necessitate a grand jury hearing. In 1900 Oct 25, the grand jury concluded that a trial should be granted. Eastman was imprisoned without bail until the conclusion of the trial.

In early January 1901, three months before the trial would commence, Grogan's body was exhumed, and a fragment of the bullet lodged inside him was examined. It was determined that the weapon that fatally wounded Grogan was not the old gun as the defence had claimed, but rather, a modern weapon.

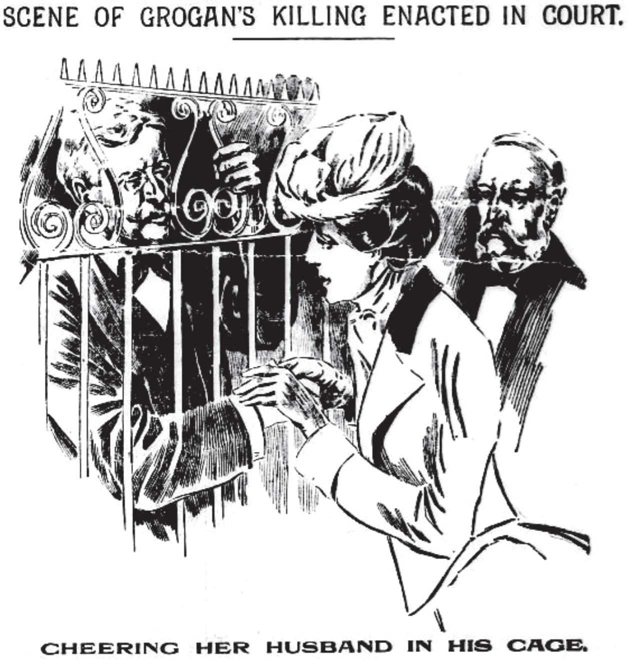

Figure 2 — Charles R. Eastman waits in prison for the conclusion of his trial while his wife Caroline (eldest daughter of Alvan G. Clark) visits. (1901 April 28) ***St. Louis Republic***

The trial presided by Judge Aiken started on 1901 April 22. Over the course of three weeks, about 40 witnesses would be asked to testify. Among the most sensational moments of the trial was a decision by the court to declare that eyewitness testimony stating that Mr. Grogan had said he had been murdered would be inadmissible in court. This ruling was considered a blow to the prosecution.

The highlight of the trial was Mr. Eastman's taking to the stand to tell his own story. Eastman insisted that it was the old antique revolver that had misfired and struck Grogan above his heart.

Eastman's testimony was in stark contrast to the prosecution's evidence that the bullet that struck Grogan was from a modern revolver. The bullet extracted from Grogan's exhumed body contained tin. Had this bullet been from the older revolver, it would have produced only lead fragments. This evidence was clearly a setback for the defence.

The trial finally came to an end on 1901 May 11. The verdict from the jury was "not guilty." A cheer surged through the 150 spectators in the courtroom as Eastman supporters celebrated. The commentary that followed largely accepted the decision, believing that reasonable doubt still existed, and that the shooting was accidental. Some observers, however, raised the spectre of class favouritism, suggesting that a Harvard professor would never be found guilty. One editorial declared the trial to be "one of the most remarkable murder trials in jurisprudence history." Had Eastman been found guilty of murder, he may well have been sentenced to hang.

The Aftermath of the Trial

Although the trial was clearly the most dramatic incident in this chain of events, it by no means concluded the affair; far from it.

A long series of lawsuits continued to keep the family in the news. All together, more than a dozen lawsuits would be filed by the various parties, ranging from the egregious to the frivolous over a time frame continuing well beyond the end of the decade. Among them was a lawsuit filed in September 1901 by the now-widowed Elizabeth Grogan alleging damages from state and county officials for exhuming her husband's body from the Clark tomb at Mount Auburn Cemetery in Cambridge. Other lawsuits included disputes over the value of property sold and disputes over the original will of Alvan G. Clark.

Perhaps the most distressing of all, at least symbolically, was a case involving possession rights to a valuable ring originally belonging to Mary Willard, the deceased wife of Alvan Graham. This lawsuit also included the disputed ownership of the Rumford medals (a medal was awarded to Alvan Clark Sr. as recipient of the Rumford Prize in 1866 for his work in optics). This particular case emerged in April 1913, more than 15 years after the death of Alvan Graham.

Still other lawsuits and trials were of a more personal nature involving automobile accidents and divorce.

Charles Rochester Eastman

Before his arrest, Charles R. Eastman taught geology and paleontology at Harvard. In 1910, he left Harvard to become an instructor at the Carnegie Institute in Pittsburgh. His association with the Clarks ended a few years later, when Caroline filed for divorce. Eastman later worked for the American Museum of Natural History in New York. A naturalist of international reputation, Eastman wrote dozens of papers on fossil fishes. Eventually, he resigned from the Museum to work for the War Trade Board in Washington, D.C. After becoming ill with the influenza in 1918, Eastman went to rest at a resort in Long Island, New York. While recovering from his illness, it was believed that he collapsed, fell into the ocean, and drowned.

Alvan Clark & Sons

The ascribed events had a disruptive effect on the Clark's telescope-making business. Richard H. Grogan was believed to be getting settled into the management of the business when he lost his life, and it was noted that his death was yet another setback in the viability of the business. Perhaps it was no surprise, then, that a story emerged that some people close to the Clark family were planning to buy the firm and make it a stock company. The buyout rumour became reality in the winter of 1901, while Eastman awaited his trial in prison.

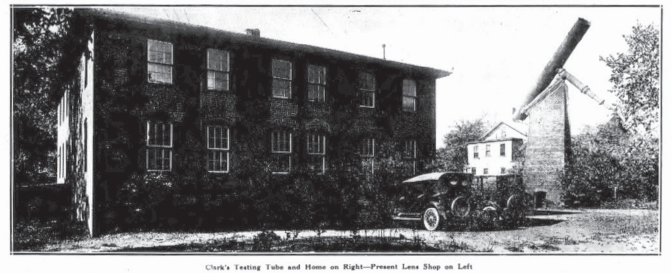

Figure 3 — The picture shows the Clark estate on Brookline Street in Cambridge, Mass., as it existed in 1923. To the right is the "testing tube" and at the left is the lens shop. The accompanying story indicates that all could be lost if no action was taken to preserve the site. At this time, the Ford Motor Company had a plant that built Model T cars that was adjacent to the Clark estate. (1923 December 15) ***Cambridge Tribune***

Within a month of the conclusion of the Eastman murder trial and certainly not coincidentally, the telescope-making business was incorporated, with a capital of $50,000. The new officers and directors were "well known in social circles and in the world of science." The company concentrated on upgrading the equipment and doing everything possible to retain the reputation of the firm. This latter effort included keeping Lundin as the chief optician—his reputation was that of the best optician in the world. He had been with the Clarks for 27 years.

In spite of all of the turmoil, Alvan Clark & Sons, now incorporated, continued to produce outstanding lenses. It has been suggested that some of the best work the company ever produced was done during this period. With Lundin at the helm, two 24-inch mirrors for Harvard, a 16-inch lens for the University of Cincinnati, and an 18-inch lens for Amherst College were among the projects completed by the company in the early part of the new century. It was clear that any distractions that the last few years had brought to the company had been set aside.

Lundin stayed with the company until his own death in 1915. In the meantime Lundin's son, C.A. Robert Lundin, had learned the craft and carried on with the business.

In 1913, the Ford Motor Company bought the land adjacent to the Clark estate, and the next year, a factory built at the site started to manufacture the Model T car. There was some rumour that the Ford Motor Company wanted to buy the land on which the Clark estate stood. However, in 1922, an editorial was printed in a Cambridge, Mass., newspaper in which a plea was presented to preserve the Clark estate. It was implied that the current owners would either sell the land or tear down the buildings. The editorial was written in reaction to this implication, and said that the site contained historic structures within Cambridge that were worthy of preservation.

These rumoured land transfers did not come to light. By 1926, Ford moved production elsewhere; the original Ford building is still standing. The Clark telescope-making business continued to operate at the Brookline Street location until 1936, when the business was finally relocated. The company ceased to exist in 1958. Today nothing exists of the Clark estate. ✶

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Cosmic Contemplations

Making an Electrically Powered, Height-Adjustable Pier for Less!

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

Mounting a long, heavy telescope like a big refractor on a pier is common practice. It eliminates collisions of the tube with any tripod legs, and it elevates the position of the eyepiece to a comfortable viewing level. For people with permanent observatories, a pier is the preferred mounting solution. I don't have one, and I like to bring my big scope to public star parties, but even lifting it onto my EQ6 on a pier of modest height is a challenge for two people.

The perfect product for making a portable pier is the Tri Pier 2 made by Pier Tech, an American company that got its start manufacturing roll-off-roof observatories that occupy a very small footprint. The Tri Pier 2 adds short, stabilizing legs to a height-adjustable pier made from a pair of nested aluminum rectangular tube extrusions. An electrical actuator (a motor-driven screw that pushes a sliding extension out at low rpm and very high torque) inside the pier slides the outer extrusion up and down relative to the inner extrusion. Not only are you able to easily mount your scope when the pier is at its lowest position, but people of different height can observe in a relaxed standing position by tailor-made height adjustments. Pier Tech retails this for $3200. (www.pier-tech.com/tri-pier_2_telescope_pier.htm)

Linak is a family owned Danish company that specializes in making electrical actuator devices for many applications, including for the health care (adjustable hospital beds) and furniture (adjustable work stations) industries. Their Desklift DL2 lifting column is capable of hoisting 250 kg and looks remarkably like the Pier Tech pier (www.linak.com/products/Lifting-Columns.aspx?product=DL2). It's common knowledge that Pier Tech merely repurposes the DL2 for their application. I discovered a trove of brand new DL2s for only $250 each, including the important control box, from a custom furniture manufacturer in Michigan who wanted to liquidate his inventory. Steve Raymonds of Stone Dimensions has graciously agreed to share his contact information, so get them while you can (steve.raymonds@stonedimensions.com).

The DL2 can be used right out of the box as a permanent pier, as it comes with predrilled top and bottom plates for bolting into the floor and into your mount. Because I wanted it to function as a portable pier, I had to add four stabilizing legs from some aluminum purchased at Metal Supermarkets (www.metalsupermarkets.com). Since the walls of the extrusions are not flat, there was room for flat-head machine screws to attach the legs from within the pier. I also made locking struts for each leg with screw-in levelling feet affixed to the bottom of each leg. The legs were not designed to bear the load of the pier, just to provide light ground contact and prevent tipping.

Figure 1 shows the final result with the 8.5″ achromatic refractor on a CGE mount. I am able to observe comfortably in a standing or sitting position, and the scope never hits the pier even when pointing at the meridian. ✶

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

Figure 1 — Several views of the pier, compact and extended.

Through My Eyepiece

Comets Past and Present

by Geoff Gaherty, Toronto Centre
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By the time you read this, we should know whether Comet ISON has survived its close encounter with the Sun and is either the Comet of the Century or just another fizzle. However it turns out, it will be interesting, like most comets. It's ironic that these small, seemingly insignificant bodies, no more than a few kilometres in diameter in their quiescent state, should produce some of the most spectacular astronomical shows.

It was the appearance of a bright comet, Arend-Roland, in 1957, that first piqued my interest in astronomy, even though I never saw it. I went out to look for it and found Jupiter instead, but I was hooked on astronomy. A few months later, I made an independent discovery of another bright comet, Mrkos. Spotting Mrkos hanging in the northern sky above our cottage in the Laurentians is one of my all-time most vivid astronomical recollections.

After two close brushes with comets in 1957, I thought they were common, but it was many years before I saw another.

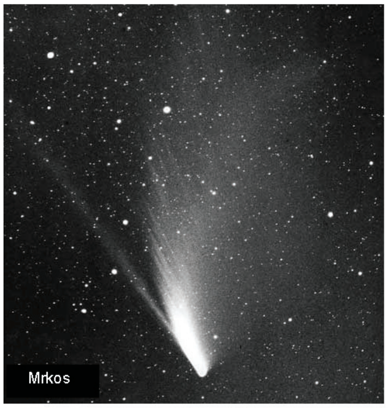
In 1986, a friend who was a pilot and I decided to try observing Comet Halley from his small plane. We flew around for a while, but the reflected light from the instruments in the cockpit were bright enough to make it impossible to see Halley, which was around fifth magnitude at the time. Finally my friend needed to answer the call of nature, so he landed the plane at Peterborough airport. While he took care of his business at the edge of the runway, I finally located Halley with my 7×50 binoculars, but my friend wasn't able to see it.

Many years later, I watched with my 20-cm Schmidt-Cassegrain as Comet Shoemaker-Levy 9 gave my beloved Jupiter a black eye. I always thought this was David's revenge on me for a cruel remark I made to him decades before, when he asked me about becoming a planetary observer. At the time, we had no idea what would happen when the comet impacted. Some thought Jupiter would swallow it up without a trace; others thought there might be serious permanent damage. In the end, there was a series of intensely dark scars, which gradually faded away over the next few months.

A couple of years later, I observed Comet Hyakutake from my cottage near Picton. The next year, while I was in New York City, I looked up from my hotel window on 57th Street to see Comet Hale-Bopp hanging high over the skyscrapers. This last was probably the key event in restarting my current astronomical career. It got me reading the magazines again and moved me to set up my telescope for the first time in years. Within a few months, I'd rejoined the RASC and was out observing every clear night.

Since then I've observed many more comets and have found each one unique in some way. Although all have been beautiful sights, none has had quite the magic of my first: Comet Mrkos hanging above Beaven Lake 56 summers ago. ✶

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



Mrkos

Halley

Arend-Roland

Hyakutake

Variable-Star Astronomy

A Pro-Am Partnership Made in Heaven

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

Amateur astronomers have a sparkling array of astronomical interests: learning more about astronomy, navigating around the sky, chasing eclipses (or deep-sky objects), making and using instruments, astrophotography, computing, dark-sky preservation, public education, and serving societies such as the RASC. Around the world, several thousand of them also contribute to astronomical *research* by observing and analyzing *variable stars*—stars that change in brightness. Amateurs have contributed to variable-star astronomy for centuries (think William Herschel), but their role increased dramatically with two things. One was the encouragement of the famous astronomer Friedrich Argelander (1799–1875) who exhorted "Could we be aided in this matter by the cooperation of a goodly number of amateurs, we would perhaps in a few years be able to discover laws in these apparent irregularities (of brightness) and then in a short time accomplish more than in all the 60 years that have passed since their discovery." The other was the founding of the American Association of Variable Star Observers (AAVSO) in 1911 by amateur astronomer William Tyler Olcott and Harvard College Observatory director Edward C. Pickering. The history of the AAVSO is wonderfully captured by Thomas Williams and Michael Saladyga in their centennial history of the AAVSO, *Advancing Variable Star Astronomy* (Cambridge University Press, 2011). The AAVSO exists to guide and coordinate variable-star observation and analysis (primarily by amateur astronomers), to collect and archive data, to foster collaborations, and to promote scientific research, education, and outreach.

Canadians have figured prominently in variable-star astronomy, and the AAVSO. Helen Sawyer Hogg (1905–1993), Canada's best-known and most beloved astronomer, was an expert on variable stars, especially those in globular star clusters. She was also AAVSO president, as were Frank DeKinder, Charles Good, George Fortier, and me. David Levy was a prolific observer of variable stars, and the author of several books on the topic. David Turner (Saint Mary's University), Doug Welch (McMaster University), and Gary Billings (Calgary) are among the many Canadian professional and amateur astronomers who are active in the AAVSO. The September 2013 *Bulletin of the RASC* pointed out that, of 320 observers of Nova Delphini 2013 worldwide, 34 were Canadians—a good proportion.

Why do variable-star astronomy? Scientifically: because variable stars give us unique information about the nature and evolution of the stars and the processes going on within them. Then, there is the excitement of doing real science, with real data, and seeing your measurements on-line in the AAVSO database and used by researchers. And variable stars are "action in the sky"! Finally: you will be joining a worldwide community of variable-star observers, held together by organizations such as the AAVSO. Many observing projects are carried out in small groups, often in direct collaboration with a professional astronomer or even with a satellite mission.

Getting Started

Whether you want to observe or analyze variable stars, or just find out more about them, there is a gold mine of information on the AAVSO Web site (www.aavso.org): about the AAVSO, its history and people; about the different kinds of variable stars and what they tell us about the nature and evolution of the stars; everything you need to know about observing variable stars using visual, photoelectric, or CCD techniques; data and software for displaying and analyzing the data; and a whole section on "getting started with variable stars," including a ten-star tutorial on visual observing, and a five-star tutorial on analysis. I particularly enjoy going to the data page and using the Light Curve Generator to show how different variable stars have behaved over days, years, and decades. The free, on-line *Journal of the AAVSO* (that I edit) contains many articles on variable stars, especially in the 600-page *Centennial Issue*, volume 40, number 1. Among other things, this issue contains a series of short reviews of all the types of variable stars and how amateurs can contribute to understanding them. And if that isn't enough information, you can read my book *Understanding Variable Stars* (Cambridge University Press, 2007).

Visual Photometry

Visual estimates of variable-star brightness are made by comparing the brightness of the variable to that of comparison stars of known and constant brightness, by eye. The estimates are accurate to 0.15–0.30 magnitude and are simple to make—no special equipment needed except a suitable star chart.

There are periodic suggestions that, in the age of automated sky surveys, visual observing is dying, or dead. That's not true, as I explain in a recent review (Percy 2012a). In the first quarter of the Space Astronomy Age (1975-2000), when requests for AAVSO visual observations were being logged manually, and published every year, they went up by a factor of 25—mostly because visual observations played an essential role in high-energy-astrophysics satellite missions.

Individual visual observations are less accurate than photometric ones, but if the star's amplitude is large (as in a Mira star), this is not a big problem. And if they are sufficiently

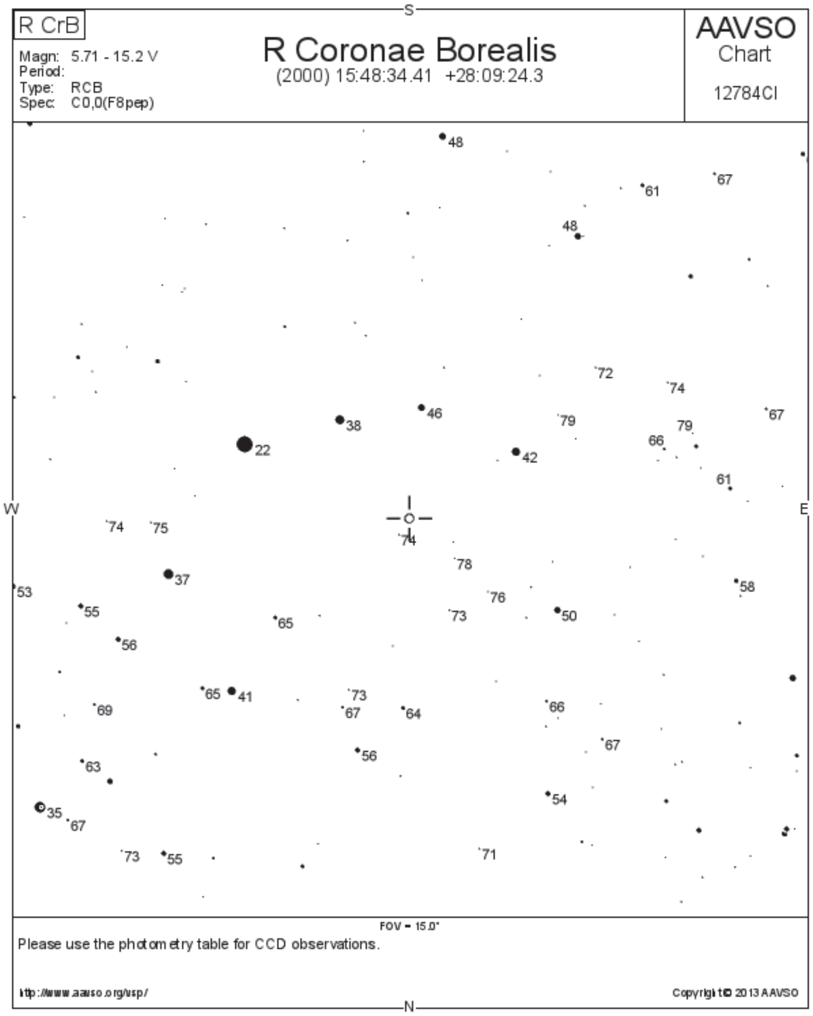


Figure 1 — Finder chart for R CrB (open circle in crosshairs) in Corona Borealis. Compare its brightness with those of the comparison stars; the decimal points of these have been omitted. There are more variable-star charts in the Observer's Handbook. *Source: American Association of Variable Star Observers.*

numerous, they can be combined into more accurate averages, or analyzed using time-series analysis, which can extract small signals from noisy data. Light curves for thousands of stars go back for many decades, so visual observations are also uniquely useful for studying the long-term behaviour of stars. They can be used to detect the unpredictable outbursts of novae or the fadings of R CrB stars (Figure 1). For decades, they were used to time the semi-predictable minima of eclipsing binaries, or maxima of RR Lyrae stars, though most of these observations are now done with CCD photometry.

Most of all: visual observations provide a direct connection between you and the star. There's no black box in between.

Photographic Photometry

Between the middle of the 19th century and the end of the 20th, photographic techniques were widely used by both professionals and amateurs. Amateurs made stunning astrophotographs, perhaps unaware that there were variable stars on the image whose brightness could be measured. Professionally, variable stars were being extensively studied at centres such as Harvard College Observatory, which accumulated a collection of half a million photographs. A few amateur (as well as professional) astronomers travel to the HCO archives to mine this unique collection. Now, many of these photographs are being digitized for wider availability and use[1]. Some of the variable-star measurements made from these images a century ago are being entered into the AAVSO International Database, so the database is being extended backward in time, as well as forward!

Photoelectric Photometry

The golden age of photoelectric photometry was the 1980s. Prior to that time, photometers were mostly made by hand, by those with an interest and aptitude for electronics. In a way, it paralleled the interest in amateur telescope-making. In the 1980s, Optec Inc. came out with an off-the-shelf photometer (the SSP3) based on a simple photodiode detector. The International Amateur-Professional Photoelectric Photometry organization was founded; books and journals on PEP were published; conferences and workshops were held; and there were exciting scientific projects for amateur photometrists to join, such as the AAVSO PEP program, and the study of RS CVn stars—ultra-spotted, ultra-active sunlike stars. See Percy (2012b) for a review of the science and sociology of amateur PEP observing. PEP observations are accurate, typically to 0.005–0.02 magnitude, and are still an excellent tool for precision observation of brightish variable stars, but PEP has largely been supplanted by CCD photometry.

CCD Photometry

CCD photometry enables a suitably equipped (telescope + CCD camera + computer) observer to study variable stars as professionals do. CCD cameras are panoramic; they can capture many variables and comparison stars simultaneously, and can repeat the observations as fast as the camera and computer can process them. The AAVSO offers both on-line tutorials, and opportunities to participate in communal observing projects—although many observers prefer to carry out and publish their own projects, on their own stars. CCD photometry is especially useful for studying the rapid variations in fast pulsating stars, and cataclysmic variables, which are close binaries with a white dwarf or neutron star component that is surrounded by an accretion disc. Amateurs even contribute to research on exoplanet transits.

A recent development is DSLR photometry, using a DSLR or even a point-and-shoot camera. Most amateur astronomers already have access to one of these. Like CCD photometry, DSLR photometry requires various forms of data reduction; these are described in a convenient new tutorial on the AAVSO Web site.

Variable-star Analysis

Not only are there more than 24 million variable-star measurements (as of September 2013) on the AAVSO Web site, but there are millions more in databases from robotic photometry projects such as MACHO, OGLE, and ASAS. And only part of the science has been extracted from these data—sometimes none! So there is still much that an amateur astronomer, with some understanding of science and statistics, can do. Everything that you need to learn is at www.aavso.org/analyze-data. There's a five-star data analysis tutorial for the beginner, and an excellent tutorial by Matt Templeton at a more advanced level. Then there is the software that you will need, both for displaying light curves (you should always do this before starting the formal analysis!) and for analyzing them. My favourite is the new VSTAR package, developed for the AAVSO's IYA project *Citizen Sky*. It determines the period(s) in the data and then, using wavelet analysis, shows how the period(s) and amplitude of the variability are changing.

Variable-star analysis can be quite challenging (it's been described as a black art), and therefore interesting, since the data can be noisy, and the stars' behaviour may be complex. But the more complex it is, the more it can potentially tell us about the star.

Education

Back in the 1990s, my dear friend and colleague AAVSO Director Janet Mattei and I independently realized that variable-star observation and analysis would be a wonderful tool for high school and university students to develop and integrate their skills in science, math, and computing. Supported by a grant from the US National Science Foundation, we developed *Hands-On Astrophysics*, a set of tools through which students could develop skills, motivated by the excitement of doing real science, with real data. Curriculum specialist Donna Young played a crucial role by integrating the tools into an engaging, user-friendly, pedagogically appropriate package. She then oversaw the conversion of *HOA* into a Web-based package *Variable Star Astronomy (VSA)* (www.aavso.org/education/vsa) and, in her role as Lead Educator for the *Chandra* satellite mission, became active in the US Science Olympiad program. As such, she exposes thousands of high school students to *VSA* and the excitement of variable stars.

I have supervised dozens of students—undergraduates, and outstanding senior high-school students in the University of Toronto Mentorship Program—in variable-star projects that are subsequently published in research journals with them as co-authors. All of the recent projects use long-term visual data, and are published in the *JAAVSO*, *e.g.* Percy and Abachi (2013). They are a win-win-win proposition: useful science gets done and published; students develop their high-level analytic skills; the observers see how their measurements contribute to both science and education.

Conclusion

Is variable-star observing by amateurs useful? One measure is the number of requests for AAVSO data, which was 5106 in 2011–2012 and rising. Another is the number of research papers that have used AAVSO data. According to www.aavso.org/aavso-print, about 100 research papers use AAVSO data each year. And that does *not* include papers in the *JAAVSO* or papers that use non-AAVSO data from amateurs, data that is used in conference presentations or posters, or research that is published in more informal ways. Very impressive! Therefore: join the VSOers (and the AAVSO)! Contribute to science! Engage with the "action in the sky"! ✶

Acknowledgements

I am grateful to Dr. Matthew Templeton, Science Director of the AAVSO, for reading a draft of this article, and providing many useful comments. I also thank all the people of the AAVSO, for everything that they contribute to astronomy, for making much of my research possible, for enriching the education of my students, and for providing me with 35 years of pleasurable collaboration and company.

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Endnotes

1 See Josh Grindlay's DASCH project: http://dasch.rc.fas.harvard.edu/

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Modifying a Celestron NexImage Lunar/Planetary Camera

by Rick Saunders, London Centre
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The Celestron NexImage Lunar/Planetary camera is and was a great camera for both planetary imaging and guiding—as long as you were running *Windows XP*. The NexImage (NI), basically a Philips ToUCam Pro, lacks usable native *Windows 7/8* drivers. The drivers released by Philips are buggy when used with the NI and at times don't work at all. So, in this project, we will replace the sensor in the NI with a more modern camera that will use available *Windows 7/8* drivers. After much searching, I selected the Logitech C310 HD camera, available from TigerDirect.ca for about $49.

The Logitech camera is small and the board carrying the sensor will fit inside the NI case nicely. It has a 1280×960 colour sensor with 2.5µm square pixels. It can be "binned" to either 640×480 or 320×240, but for guiding, it's best to go with the raw sensor specifications. The C310 is a UVC (Universal Video Class) camera and therefore has drivers for just about any operating system. It works perfectly under *Windows7* and *Linux*, and I would assume that Mac and Android will also recognize it.

Tools needed for this modification:

- Small Philips screwdriver
- Small flathead screwdriver
- Dremel tool with small grinder
- Soldering iron with a fine tip
- De-soldering tool
- Hot-glue gun

The first step is to take apart the NexImage, a fairly straightforward task:

- Unscrew the two Philips screws on the back of the camera.
- Using the flathead screwdriver, press in on the joint between the halves at the opposite end to spring them free
- Undo the four Philips screws holding the two circuit boards and lift the boards out.

Now disassemble and prepare the Logitech C310:

- Using the flathead screwdriver pry off the top cover.
- Unscrew the three Philips screws holding the top plate
- Unscrew the two Philips screws holding the circuit board in the body
- Using the flathead screwdriver, pry off the C-clip that is holding the cable in place
- Using the flathead screwdriver, disconnect the white connector on the board
- Unsolder the large, black ground wire from the circuit board
- Unsolder the microphone from the circuit board. Use a fine tip, as there are little parts around the leads
- Remove the cable from the C310's case
- Resolder the ground wire onto the board
- Reconnect the white connector (it's keyed, so it only easily fits one way)

Now prepare the NexImage case for the C310 board.

The C310's board has to lie in the NI case so that the sensor is centred in the cutout that allowed light into the original sensor. This means that you'll have to remove material in the rectangular "box" where the original sensor board sat. The top and bottom of the box will both have to have material ground away. Start with the "bottom" end of the box and remove enough material for the board to sit centred in it. This means that you'll have to grind away half of one of the screw-mounting posts, but as it will never be used again, that's not an issue. Check the diagram provided (Figure 1); the red areas in the box need to be removed. Take them down right to the floor of the case.

Notice that the sensor end of the C310 board is steeply angled. Use the angle as a "stop" and grind away only enough material from the "top" of the box to allow the board to bring the sensor into the centre of the sensor cutout when the board is slid up against the top of the box. Again, check the diagram (Figure 1).

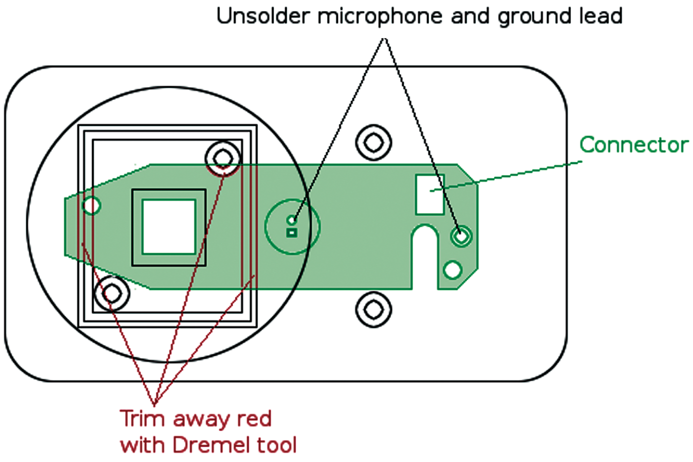

Figure 1 — A schematic diagram showing the modifications necessary to adapt the NexImage case.

Once the material is removed, you can place the board in the NI case and, holding it firmly, put generous blobs of hot-glue in place to hold the board. Let the glue harden. Then place more hot-glue under the board to provide some support; let it run over the top of the board and again, let it harden.

Now place the cable in the strain-relief cutout on the bottom of the NI case with some hot-glue to hold it there. Clip the other half of the NI case back on and replace the two screws you removed on disassembly. Then fill the hole around the cable with more hot-glue and you're done. If you've been careful, the C310's sensor is in the middle of the cutout and you are ready to go. ✶

Rick Saunders became interested in astronomy after his father brought home a 50-mm refractor and showed him Saturn's rings. Previously a member of both Toronto and Edmonton Centres, he now belongs to the London Centre, and is mostly interested in DSLR astrophotography.

Society News

by James Edgar
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The RASC Board of Directors (me included) met in Toronto for a day-and-a-half retreat over the September 14/15 weekend. At the meeting, the board formulated the latest long-range goals in our Strategic Plan, soon to be released to the National Advisory Council and then to members. Our first attempt at this task three years ago can be viewed as a success, since we attained about 80 percent of our goals. However, some of those remaining goals were somewhat lofty, and, as we discovered, unattainable. Consequently, the new plan was put together according to the precepts of "SMART" goals (http://en.wikipedia.org/wiki/SMART_criteria), with emphasis on the "A" for attainable.

Yours Truly also had the great pleasure of visiting the Halifax Centre and attending their September 20 meeting. Not only was it a great opportunity to meet and make new friends, I got to visit with some of the "old" ones (not that they're all grey-haired male geeks!). To prove my point, Kathryn Aurora Gray was there with her dad, Paul Gray. At the meeting, Dave Lane was presented with his President's Award by NAC Rep, Pat Kelly (Figure 1). Dave wasn't in Thunder Bay to receive the award at the GA, so Pat Kelly took it home to be presented later, and this was that very event! Later, we were treated to short talks by my host, Dave Chapman; by Quinn Smith; and by Dave Turner. Most enjoyable!

Without letting any premature cats out of the bag, my visit to Halifax Centre was the first in one of our Strategic Plan goals—that at least 80 percent of the Society's 29 Centres would be visited by a member of the Board before the end of July 2014. Look for a member of the Board of Directors coming to a Centre near you! ✶

Figure 1 — Pat Kelly presents the President's Award to Dave lane at the Halifax Centre meeting.

Rising Stars

Jim Kendrick Went to Church and Came Out an Astronomer

by John Crossen
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Jim Kendrick's conversion wasn't quite that brisk. Going from an artist—designing, building, and restoring stained-glass windows—to the owner of a globally known astronomy company might seem to be a journey of light-years. But imagination, design, and craftsmanship was a common thread in both enterprises, ending in the tidy little knot called Kendrick Astro Instruments.

Jim was born in North Bay, Ontario, after his parents moved to Canada from England, married, and had a family. Seventeen years later, they moved back to England, where Jim attended South Devon Polytechnical Institute and studied graphic art. After graduating, Jim moved back to Canada and took up residence in Toronto.

He started a one-man company that specialized in building and restoring stained-glass windows. Among his clients were churches, historical buildings, and private homes. An early interest in astronomy also took firmer roots in Canada. Unfortunately, it did so under the moisture-rich skies of southern Ontario. Jim quickly learned the value of a dew shield for holding the moisture at bay for a few more precious minutes. But, there had to be a better way.

At the time, a few amateurs were fiddling around with toaster wires as dew heaters. Their idea was good, but sloppy execution often led to fried wires, fried fingers, and the occasional fried scope. Despite its downfalls, Jim saw promise in the concept and began working on ways to make the system controllable, efficient, and reliable. The result was a series of dew straps that wrapped neatly around the telescope tube or eyepiece and fastened in place with Velcro tabs. Add in the simple control unit, and observers could dial the temperature up or down as needed. Not only did it solve one of amateur astronomy's major problems, it was made in Canada—something that is still true today.

My wife Deb and I first met Jim at StarFest in 1990. As the owner of an 8-inch SCT, dew prevention was a major concern, so Jim's table, heaped with dew shields, dew straps, and controllers became ground zero for me. I was a relative newbie, and Jim seemed open to conversation. I hogged a fair bit of his time that day.

Figure 1 — Jim Kendrick

We met again on the way home from Orangeville. Jim was coming through the screen door of a mom-and-pop store, his pockets bulging. He looked up, patted his pockets and shouted "They liked them, they liked them!" If he had grinned any harder, the top of his head would have fallen off.

Spurred on by his initial success, Jim began expanding his product line to include more sophisticated controllers, dew straps with better quality wiring, and power packs for field use. While you might think he would farm a lot of his production out to foreign manufacturers, all his dew straps and controllers are still assembled in his shop in downtown Toronto. It has been a family business from the start with products designed by Jim and manufactured by his wife Luda and their two sons. Today, the boys have moved on to employment of their own, but Luda continues to help with the assembly, in addition to keeping the company books.

Like many astro-entrepreneurs, Jim also tried his hand at running a retail outlet. But, with the advent of Internet shopping, he realized that a Web site and a warehouse with a computer were all that you really needed, even with the challenge of dealing with other manufacturers. After five years of struggling in a tight market with even tighter margins, Jim went back to what he knew best—engineering and manufacturing products that solve problems for amateur astronomers.

In addition to designing astronomical accessories, Jim also likes to build telescopes for himself. His latest pet is a home-built, truss-tube scope with an 8-inch Royce mirror.

I had the opportunity to view Jupiter through it, and Jim's scope will give many a triplet refractor a run for its money. Jim also recently finished a computerized 14.5-inch Dobsonian, built from scratch. On the drawing boards now is a 10-inch Newtonian astrograph that he hopes to have finished for next spring.

Jim is an avid astro-imager. According to him, it was just the challenge he needed to renew his vigour for astronomy, which had flagged due to the demands of running his astro business. If the past is any indication of things to come, there will soon be some new gear for astro-imagers on the growing Kendrick product list. In the meanwhile, the list of Kendrick-originated products stretches from astro-imaging tents to observing chairs, power packs, and dew-resistant couplers. Jim was instrumental in the design of the AstroTrac imaging unit, which he introduced to Canada and the world market via his advertising. Most recently, he helped engineer the rotation-control units for SkyShed's upcoming new POD Max.

Today, Kendrick Astro Instruments is a well-known name in the global astronomical community. Many an observing and imaging run has been saved thanks to the company's dew-prevention accessories. Jim's view of the future through a stained glass window many years ago has served him and the astronomical community very well. ✶

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.

Great Images

Ian Steer waited for just the right alignment to catch the conjunction of Venus and the Moon on the evening of September 8. This is Ian's "first ever" published astronomical image—welcome to the club, Ian. He notes that the image has lots of action: "...a flock of birds flying left of, plus an airliner flying right of, the CN Tower, all at the exact moment that the Tower's nav lights are fully illuminated." A good start for an astrophotography hobby.

Astronomical Art & Artifact

Lost in the Realm of the White Squirrel: Plans for the RASC's First Observatory

by R.A. Rosenfeld, RASC Archivist
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Sir Wilfrid Laurier (1841-1919), Canadian Prime Minister and apostle of national progress, liberally prophesied in 1905: "It has often been observed on the floor of this House [of Commons], as well as outside of this House, that as the nineteenth century has been the century of the United States, so the twentieth century will be the century of Canada" (Wood 2010, 281). In 1903, the star of The Royal Astronomical Society of Canada was in the ascendant, or so it might have seemed to its members in their colonial corner of the Universe, some of whom, with an early Edwardian optimism equal to that of their Prime Minister, may even have thought the sky was the limit. In February of that year, the Toronto Astronomical Society had received the King's gracious permission to add the prefix "Royal" to its name, thereby encouraging an essentially regional group to regally affect national pretensions (Rosenfeld 2013). Only three years had passed since the Society had been revived from its "near-death" experience, to use the words Don Osterbrock (1997) applied to Yerkes Observatory after 1903. The RASC seemed to be flourishing and in the best of health. Many of the turn-of-the-century's greatest names in astronomy were honorary members: the Astronomer Royal William Christie, Sir William Huggins, George Darwin, Sir Robert Ball, Camille Flammarion, Agnes Mary Clerke, Maurice Loewy, Paul Henry, Samuel Pierpont Langley, Simon Newcomb, John Brashear, and Yerkes' George Ellery Hale, Sherburne Wesley Burnham, and Edward Emerson Barnard. Several of the professionals among the RASC's Canadian membership, aided ably by Uncle Johnny Brashear, were involved with the planning, design, and equipping of the new Dominion Observatory—Canada's modest answer to Greenwich, His Majesty's Observatory at the Cape, and the United States Naval Observatory (King 1906). Only one thing seemed to be missing; a civic observatory in the place where the RASC was conceived, born, and refused to die.

In the later 19th and early 20th centuries, an observatory was a symbolically prestigious ornament for the civic or college landscape, irrespective of the science it was intended to harvest (Aubin, Bigg, & Sibum 2010, 22; Loomis 1846, 287, 291-292—but with an eye to the science). In RASC circles throughout the 1890s, this material symbol of scientific prestige in otherworldly pursuits led to several observatory initiatives, but none made it very far down the road to reality (Chant 1940, 300-301). Dr. William Frederick King (1854-1916), the Chief Astronomer of the Dominion of Canada, is reported in *The Selected Papers and Proceedings* of the RASC for 1903, as hoping that: "... before long 'some of our wealthy men may emulate the example so many in the United States have set, of building observatories for the study of this branch of science. There should be not one public observatory in Canada, but many. Much is heard just now of public libraries; may not the cities of Canada extend their ambition still further?'" (Anon. 1904, 57). Alas for the Great White North, for the Canadians who could have played a Lick or Yerkes role preferred to sit atop their piles of wealth like Tolkein's Smaug the Golden.[1] These dragons were no patrons of astronomy.

As if in answer to the call of the Chief Astronomer of the Dominion of Canada, the RASC struck a committee to investigate the feasibility of an official observatory for the RASC, and by extension, a civic observatory for Toronto. It was christened with the prosaic name "the Observatory Committee" (one of the initiatives of the 1890s had even got this far, but the harvest of that committee was disappointment; APST minutes 1898 July 19). The minutes of the RASC Council establishing the Committee are lost, so we neither know when it was established nor its exact terms of reference. The Observatory Committee, or what looks like the Observatory Committee, is first documented in minutes of March 6. It comprised the RASC President Frederick Stupart (1857-1940), director of the Meteorological Service of Canada; Allan Miller (1851-1947), one of the first Canadians to do astrophysics and a correspondent of Hale's, and who was to join Hale in the IAU (he was an amateur, but clearly a presentable one); George Lumsden (1847-1903), a fellow of the Royal Astronomical Society, and a RASC past president; and Captain John G. Ridout (1840-1911), also a past president. Ridout was head of the Committee (Ridout *et al.* 1903, 5). To the average member and citizen, these men must have appeared the very acme of substance and sense; the first was the head of a federal government scientific service, the second the chief financial officer of a major hospital, the third a provincial deputy minister, and the last a noted patent lawyer and retired military officer. Surely these were the men and this was the committee to bring Toronto's observatory from desire to fulfilment, evidence and agent of Canada realizing its century.

Between early March and early May, the Observatory Committee produced a report on: "... the ways and means for providing suitable Headquarters for the Society, including an Observatory and a large telescope" (Ridout *et al.* 1903, 1). The Society, newly minted as *Royal*, desired accommodation "suitable and attractive," "... including observatory, reading room, lecture room, [and] social rooms...with furniture." Their aperture fever was satisfied with a 12″ objective.[2] The projected cost for all this? The building and appurtenances would run upwards of $12,000 or $13,000, and the telescope $10,000 to

$12,000, giving a total of no more than $25,000 (Ridout *et al.* 1903, 1; one assumes the telescope price is for the OTA *and* the mount). Astonishingly enough, $25,000 is the same face-value figure Ormsby McKnight Mitchel quoted to the Dudley Observatory trustees a half century earlier (in 1851; Wise 2004, 13). For what it's worth, a conversion of 1903 Canadian dollars into 2013 American dollars, using historical wage and price tools, pegs this at approximately $500,000 (one *could* pretend that the databases used for the conversion include the historical costs of scientific equipment, services, and wages, but that's like believing the Moon is made of green cheese, and every comet will blaze forth visible the naked-eye...).

Other projected expenses include the ongoing conduct of Society business, a caretaker, and maintenance, which were estimated at $2,000 per annum, or $40,000 in today's funds (Ridout *et al.* 1903, 2). The Report frankly admits that the RASC possessed neither the necessary reserves nor the cash flow to undertake such a project, but that reality didn't prevent the Observatory Committee from suggesting ways and means towards the goal. One was "a canvas for direct subscriptions in all the more important Canadian cities" (Ridout *et al.* 1903, 3-4). Such a proposal would be unlikely to meet much success now; would it have fared any better a century ago? Another suggestion was to form a "Joint Stock Company," which "would erect the building and lease it to the Society at a rental.... Then, some means might be devised whereby the Society could purchase a certain amount of stock from the company every year" until the observatory would enter the Society's full possession, "...affording the Royal Astronomical Society of Canada the status and dignity it ought to enjoy" (Ridout *et al.* 1903, 4). With what would the Society purchase the stock, if it had insufficient cash reserves and insufficient cash flow in the first place? "Some means might be devised" seems a plan scarcely better than trying to purchase observatory stock with starlight, earthshine, or "lunar deeds." To cover ongoing costs:

> *We would recommend an associate membership fee of $10 per annum, without limitation as to numbers, with provision made for, say, 100 active members at the present fee of $2 per annum. Your Committee is of the opinion that at least one or two hundred men could be found in Canada who would be quite willing to help in promoting the study of Astronomy by payment of a $10 associate membership fee. The Society would of course have to maintain their interest by the issue of publications from time to time, and by public meetings and lectures, to which at least one eminent astronomer from England or elsewhere should be brought every year (Ridout* et al. *1903, 5).*

Is this not in fact a proposal to charge the local observational astronomers a discounted fee, and the armchair astronomers located elsewhere 2.5 times as much for a lesser category of membership? Would the "one or two hundred men...in Canada who would be quite willing to help in promoting the study of Astronomy" not realize that they were paying for the privilege of subsidizing the dome and gear of a select group of Torontonians? There seems to have been some awareness on the Committee's part that the RASC would owe its prospective associate members something in return, even if that something consisted of tokens and gestures. Would the issuance of occasional publications of an unspecified nature, and the convening of meetings and lectures prove sufficiently attractive to anyone who didn't already dwell in proximity to Toronto?

The Committee's most sensible proposal concerned the site. The estimated $25,000 expenditure did not cover the purchase or lease of land: "Your Committee...consider that unless a free site can be obtained[,] it is useless to try to go on with the scheme at present" (Ridout *et al.* 1903, 2). Here the RASC enjoyed a spot of luck. One of its members was the Rev'd Dr. T.C. Street Macklem (1862-1944), who also happened to be Provost of Trinity College (1900-1921). It was not unusual at the time for Anglican clergy to successfully cultivate astronomical interests, and the Rev'ds T.W. Webb, T.H.E.C. Espin, and T.E.R. Phillips, readily come to mind. The report mentions how desirable it would be if the RASC could enter into a long-term lease for space on the Queen St. grounds of Trinity College at $1 per annum. Should the arrangement come to pass, the design of the observatory building would be subject to the College's approval, and the RASC would allow the "students in Astronomy [to] have access, under proper restrictions, to our instruments" (Ridout *et al.* 1903, 3; while physics was nominally offered at Trinity College, there were certainly no students in astronomy at that time!). The site was not entirely unfavourable; while located within the city's bounds, it was set in the north end of a park with some foliage to mitigate ambient Edwardian light (Kenrick 1903). And at least some members of Trinity thought the institution was planning on expanding and rebuilding its present facilities on that campus.

At the May 6 Council meeting, the report was adopted in its entirety, and the Committee reappointed (RASC Minutes 1903, *n.p.*). At the regular meeting of May 12, Council recommended that the Committee's report be approved (RASC Minutes 1903, *n.p.*). John A Paterson (1846-1930), another past president and current member of Council, moved that the report be amended to "recommend that negotiations be opened up with the Authorities of Toronto University and Trinity University so as to have the question of [a] possible site definitely settled" (RASC Minutes 1903, *n.p.*). Paterson's amendment was defeated, and Council's majority recommendation was approved. The next day the RASC President formally made the proposal known to the Provost of Trinity, and the following day the Corporation of Trinity approved it without a trace of dissension (RASC Minutes 1903, correspondence Macklem to Stupart 1903 May 14; Trinity College 1903, 392-393). A ground plan has recently come to light for the redevelopment of Trinity College by Frederick G. Todd (1876-1948), landscape architect of Montreal, and

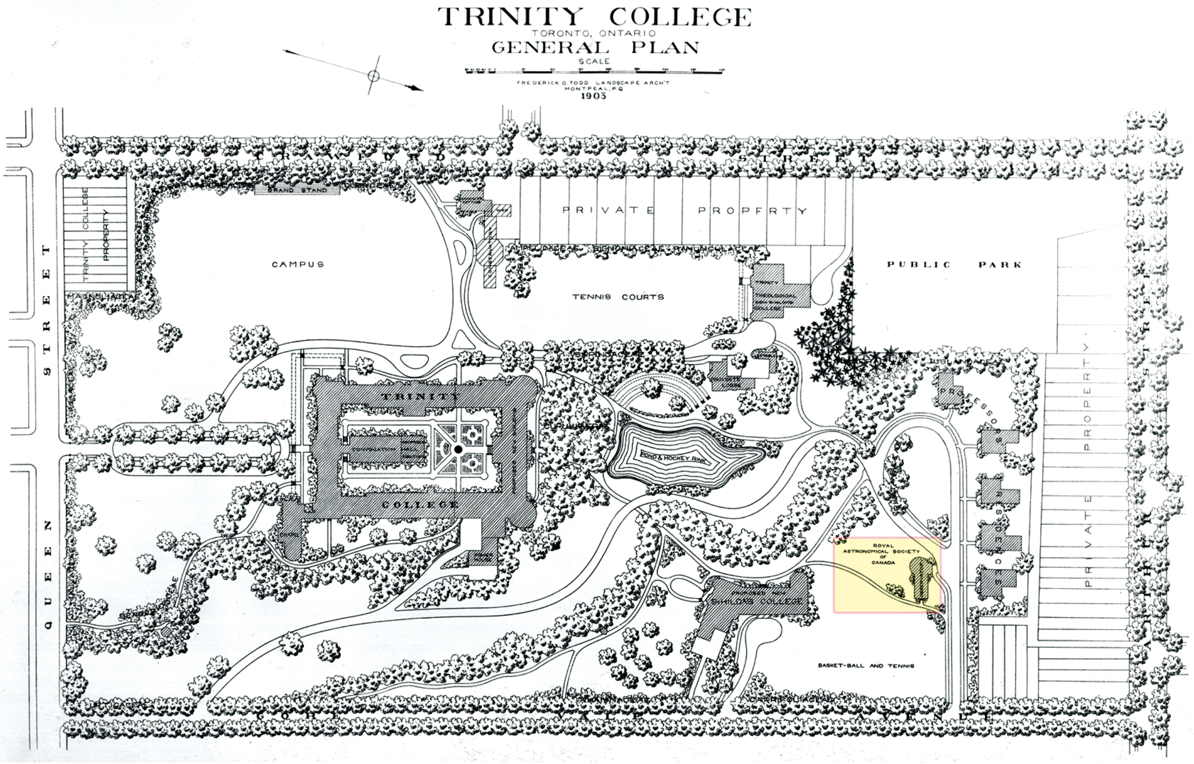

Figure 1 — 1903 ground plan for the redevelopment of Trinity College on Queen Street by Frederick G. Todd. The RASC's Observatory is highlighted at the lower right. Reproduced courtesy of Trinity College Archives, Architectural Records Collection, A1903(01).

it duly shows the projected RASC observatory; it must have been drafted in the immediate aftermath of these events (Figure 1). Todd was the first resident landscape architect in Canada, and had trained under the Olmsted family of American landscape architects, who had designed the grounds of Yerkes Observatory. The College's approval should have accelerated the process of the creation of the RASC's first observatory, and a civic observatory for Toronto and the University community. It didn't. Nothing happened, and the project seemed to vanish during the summer months of 1903. What happened?

At present, it is hard to know with any degree of certainty. Many of the relevant documents have disappeared from the RASC Archives, and possibly from Trinity's Archives as well. Around the time when both institutions approved the plan, Trinity had been engaged in renewed discussions regarding federation with the University of Toronto for several years, which caused considerable dissension within College circles (Reed 1952, 128; Friedland 2002, 136).

The Trinity official who led the effort for federation was none other than Provost Macklem, who had been appointed to office to shepherd that very project. It is possible the size of the undertaking and the political engagement it required diverted attention and energies from the observatory project. That is certainly what C.A. Chant implies when reviewing the history of the Society nearly four decades after the event, but his treatment of the 1903 Observatory project is most cursory and sheds little illumination on reasons and motives (1940, 304-305). It is most curious, however, that three years before reaching agreement with the RASC, Trinity had passed a resolution agreeing to the sale of its current Queen Street site and a relocation to "Queen's Park" contiguous to the University of Toronto, provided a suitable site and compensation from the provincial government were forthcoming (Reed 1952, 124). This fell through at the time, but a mere couple of months after offering the RASC the use of land for its observatory on the Queen Street site, Trinity, the University of Toronto, and the Provincial Government agreed to "...the provision of a suitable site, free of charge, on or near Queen's Park on which to erect a building to serve as a centre for Trinity students" (Reed 1952, 127). One architectural historian has noted that: "The [College's old] Queen Street buildings were showing signs of wear at the end of the century, had little or no electricity and generally inadequate facilities" (Owen 1977, 64). Was there something Provost Macklem wasn't telling his RASC colleagues about the future of the land they thought they were securing? Whatever the case, the RASC still had enough confidence in the Provost to secure his place on Council in 1905, *after* the failure of the observatory project (he had served previously in 1902; TTAS 1902, vi, & RASCSPP 1905, iii).

What does the defeat of Paterson's amendment recommending that the RASC negotiate with both Trinity *and* the University of Toronto suggest about the acumen of the RASC's Observatory Committee? Hindsight suggests Paterson was wise, and his colleagues foolish. It may not be incidental that Paterson was the University of Toronto's solicitor at the time (Broughton, PATERSON). Is it possible that the Observatory Committee members, men well placed in the province's and the city's legal and political spheres, wouldn't have known about Trinity's ultimate plans to abandon Queen Street? Where the Committee may have been at a disadvantage is in the lack of strong, direct Trinity connections (Captain Ridout may have had indirect family connections). Further archival work may resolve some of these unknowns.

It is also possible the project foundered because the RASC's fund-raising schemes were unrealistic. There may, however, be another shoal upon which the RASC observatory foundered. The RASC's plans for an observatory "affording the Royal Astronomical Society of Canada the status and dignity it ought to enjoy" are singularly undeveloped regarding instrumentation beyond the desire for a "large telescope" with a 12″ objective. It is venturing little to speculate the instrument would have been a long-focus achromat, and the contract would most probably have gone to Brashear in collaboration with Warner and Swasey (Brashear was an enthusiastic honorary member who had been contracted to supply the Dominion Observatory's 15″), and the observatory would probably have been indistinguishable from countless North American university observatories of the time. The most disappointing part of the RASC's observatory plan is its lack of purpose beyond self-aggrandisement; it is entirely devoid of a research or public outreach agenda, lacunae which could account for its vagueness in regard to instrumentation. How can any observatory fund-raising project be expected to succeed if its proponents want to shake rich men down, but apparently haven't realized it's the patrons' glory they need to stoke, and not their own? That wouldn't be easy without a convincing purpose, such as a plan of work (*e.g.* G.B Airy's "meridian grind," or double-star astrometry, or daily sun-spot counts, or areographic cartography), or a prospective discovery program (*e.g.* asteroids, comets, planetary moons, meteor showers, double stars), or an undertaking to venture into the "new astronomy" (photographically aided spectroscopy, photometry), or a proposal for an attractive education and public outreach program *à la* John Pringle Nichol or Ormsby McKnight Mitchel. In connection with an earlier drive for an observatory in 1898, Paterson rather gloomily stated that "...canvassing for subscriptions would not succeed where the object was a scientific one" (Chant 1940, 301). He knew his city—perhaps presenting prospective upper- and middle-class donors with a well-conceived potential scientific program would not have helped. Neither could the RASC urge civic pride in size to call forth donations, for what was a 12″ O.G. against the Lick's mighty 36″, to say nothing of the Yerkes 40″? (Nor were naming rights seemingly on offer.) There is little evidence the RASC was properly prepared to sell the idea of a civic observatory for Toronto. The project may have come to nothing because the RASC was naïve about its ability to raise the necessary funds.

A monograph on the Dudley Observatory wisely remarks: "Civic astronomy is an idea whose time almost, but never quite, came" (Wise 2004, 1). This lapidary epigraph worthy of a Douglas Adams can also serve as a neat summation of the RASC's first planned observatory venture.[3] The whole undertaking proved in the end sadly ephemeral.

The site where the observatory was going to be built is now known as Trinity-Bellwoods Park. Its present fame derives from its population of white squirrels. Perhaps it's better that way.[4]

Acknowledgements

The author wishes especially to thank Sylvia Lassam, Rolph-Bell Archivist of the University of Trinity College in the University of Toronto for ready access to archival material and her permission to publish some of the College's holdings. Thanks are also due to Bart Fried, Ken Launie, and Perry Remaklus for comments on a version of this paper presented at the 2013 ATS Convention at the Washburn and Yerkes Observatories. Peter Broughton provided a timely reference. This research has made use of NASA's Astrophysics Data System. Any errors remaining are the author's sole responsibility.

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Endnotes

1 Smaug tops the Forbes list of the 15 richest fictional characters; Forbes.

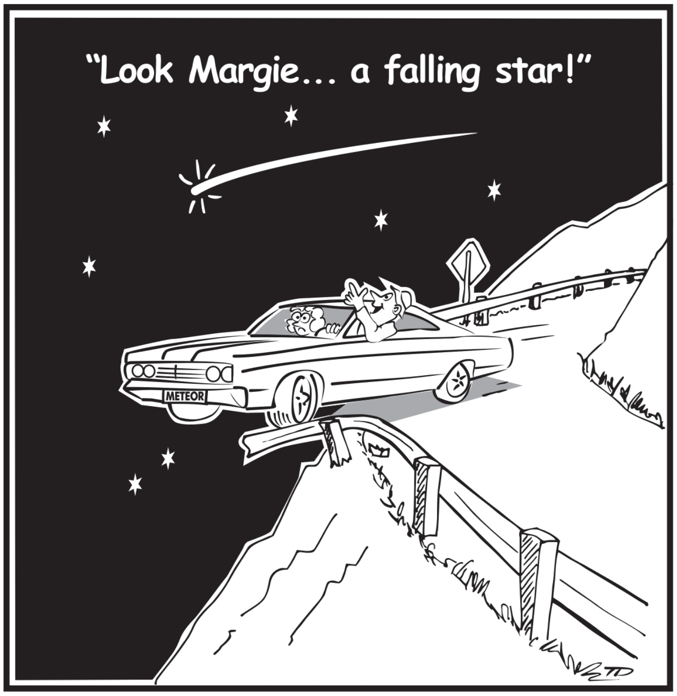
2 A refractor seems more likely to have been in the Society's sights than a reflector. Also note that the printed prospectus for the Society's abortive observatory project of 1898 specifies that: "The principal telescope to be approximately the size and power of those now used for the international photographic survey of the heavens" (Lindsay 1898). The Carte du ciel (founded 1887) telescopes were double astrographs each consisting of a 13″ O.G. photographic refractor married to a 10″ O.G. guide scope.

3 Readers may well ask "What is, or is not, a civic observatory?"—it would seem for example that the Calton Hill Observatory in Edinburgh was, then wasn't, then was again "civic" (Hutchins 2008, 38, 50, 180, 286). Historical use seems to have been flexible; "civic" could mean an observatory within the precincts, or near the region of a city regardless of who established, owned, or operated it, or it could refer to an observatory planned, built, and run by a private body of citizens, or by the civic corporation itself, or it could refer to an observatory chiefly dedicated to education and public outreach (EPO) serving an urban population, or one with an EPO program supplementing its primary research mission, or any combination of the above. The term "popular observatory" was used several times in RASC discussions of the 1890s (Chant 1940, 30-301).

4 Had the 1903 observatory been built, would C.A. Chant have been moved, like G.E. Hale, to eventually seek a larger instrument? Would Chant, like his friend J.S. Plaskett, have been able to have a large reflector built even though a good size classical refractor was available? Would the existence of the RASC Observatory have affected the nature of the David Dunlap Observatory, or even precluded the latter from being conceived, financed, and built? We will, of course, never know.

It's Not All Sirius

by Ted Dunphy



Astrocryptic Answers

by Curt Nason

1 N	E	2 W	C	3 O	M	4 B	■	5 E	D	6 G	A	7 R
A	■	H	■	R	■	I	■	L	■	A	■	A
8 S	H	I	F	T	■	9 A	S	E	L	L	U	S
I	■	T	■	H	■	N	■	C	■	L	■	C
10 R	O	M	E	O	■	11 C	Y	T	H	E	R	A
■	■	A	■	■	■	A	■	R	■	■	■	L
12 F	I	N	L	13 A	Y	■	14 T	A	U	15 R	U	S
E	■	■	■	L	■	16 S	■	■	■	O	■	■
17 S	E	18 R	O	N	I	K	■	19 C	A	S	C	20 A
T	■	E	■	I	■	Y	■	H	■	E	■	I
21 O	R	B	I	T	A	L	■	22 A	L	T	A	R
O	■	E	■	A	■	A	■	I	■	T	■	E
23 N	O	R	S	K	■	24 B	A	R	N	A	R	D

Second Light

Rethinking the Most Luminous Supernovae

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

Core-collapse supernovae happen when the energy generated in the centres of massive stars ceases to be sufficient to support the surrounding gas against gravitational collapse (type Ia supernovae, used for cosmology, blow up for an entirely different reason). It has recently become clear that there are "superluminous" supernovae, with peak luminosities about a hundred times greater than normal core-collapse ones (and ten times brighter than those that are type Ia). Some have been proposed to arise from the pair-instability mechanism, which is expected to arise in extremely massive and metal-poor stars in the early Universe, though superluminous events have been found down to redshifts of just z~0.1. New observations of two super-luminous supernovae, by Matthew Nicholl of Queen's University Belfast and his collaborators around the world, have called into question just how many superluminous supernovae can be caused in the local Universe by the pair-instability mechanism (see the October 17 issue of *Nature*).

The most common supernovae occur as the fusion process starts making elements heavier than iron, which is an endothermic reaction. Heavy elements take energy to produce, unlike when hydrogen nuclei (protons) fuse together to form helium. When the heavy elements form, there are no longer sufficient photons generated to provide the pressure to support the surrounding star, and the core of the star collapses to form a neutron star. Because the stars are in some phase of being a giant, the outer atmosphere does not "know about" the collapse until the explosion throws material against it from the inside, in a shock wave.

More recently, it was discovered theoretically that in very massive stars (initial masses of 140-260 solar masses), the photons generated in the fusion process are sufficiently energetic that they spontaneously form electron-positron pairs, provided the stars have very low initial abundances of elements heavier than helium, a core made of carbon and oxygen, and a mass of 65–130 solar masses. This also removes the photon pressure. As the core contracts, it heats up until runaway oxygen burning begins, leading to a detonation—a fusion bomb—that leaves behind no remnant (no black hole or neutron star). Because it is expected to occur only in very massive stars, and the only way to make those is in a metal-poor environment, it was thought to be common only in the early Universe, before the gas had been enriched with the debris from supernovae and winds from massive stars. Some superluminous supernovae at redshifts >2 (see Cooke *et al.* in the 2012 November 8 issue of *Nature*) supported this interpretation. It was a surprise, then, when superluminous events looking like pair-instability supernovae were seen at z~0.1-0.3, which is relatively nearby in cosmological terms (see, for example, Gal-Yam *et al.* in the 2009 December 3 issue of *Nature*).

Two facilities now running—the Palomar Transient Factory (http://ptf.caltech.edu/iptf) and the Panoramic Survey Telescope and Rapid Response System (http://pan-starrs.ifa.hawaii.edu/public)—are designed to find transient objects in the sky and near-Earth asteroids respectively. But the Pan-STARRS database is proving to be very useful for finding transient objects, too. The supernova PTF 12dam was discovered on 2012 May 23, and Nicholl and his collaborators rapidly got spectra using telescopes on La Palma, in the Canary Islands. They searched the Pan-STARRS database and found the supernova between 2012 April 13 and 29, which gave them the early-time light curve. They were already working on other transients and had found one that had occurred on 2011 January 2 and subsequently named PS1-11ap, but they did not know what it was until PTF 12dam came along. The redshifts of the host galaxies were determined to be ~0.11 and ~0.52. The high luminosity and slow decline of the light curves made these supernovae similar to the one found by Gal-Yam (SN 2007bi), and therefore potentially pair-instability objects.

SN 2007bi was discovered well after the peak of the light curve, but the Pan-STARRS data had captured PTF 12dam and PS1-11ap at 50 and 35 days respectively before the peak, so the rise times are very well known. In both cases, the rise times are a factor of two too fast to be pair-instability supernovae. Pair-instability events generate large amounts of ^{56}Ni, which decays to ^{56}Fe. The decay process provides the photons that power the luminosity (just as in type Ia supernovae), and is relatively well understood, so the fact that the light curves increase too quickly rules them out as pair-instability events. This leaves the status of SN 2007bi up in the air. Its later light curve and spectrum resemble those of PTF 12dam and PS1-11ap, therefore I am inclined to agree with Nicholl that it is of the same class, but, of course, with no early light-curve data, the argument is not conclusive.

If these superluminous supernovae are not pair-instability events, what are they? Nicholl suggests that the ejecta may be re-heated by the spin down of a "magnetar"—a neutron star with an extremely strong magnetic field. This is not a new suggestion, and in fact was already proposed as an explanation for SN 2008bi. Nicholl compares magnetar models to the observed light curve for PTF 12dam and finds that a magnetic field of ~10^{14} Gauss and a spin period of 2.6 milliseconds provide the best fit, with an ejecta mass of ~10-16 solar masses.

This leaves no unambiguous candidates for pair-instability supernovae at redshifts <2, and with three years of the Pan-STARRS medium-deep survey data already collected, Nicholl estimates that the rate of pair-instability supernovae must be less than a tenth the rate of superluminous supernovae for $z<0.6$.

This seems plausible to me, because of the need for a low-metallicity environment to produce the kinds of stars that explode in pair-instability supernovae. We are finding that galaxies in the early Universe (redshifts ~6) are already well enriched with metals, which will reduce the scope for forming the kinds of stars that lead to pair-instability supernovae.

Astronomers are still searching for the signatures of the first stars. Will we eventually see one as a super-superluminous supernova? Watch this space. ✶

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.*

Call for Nominations for RASC National Awards

by Mary Lou Whitehorne,
Awards Committee Chair
(mlwhitehorne@hfx.eastlink.ca)

Do you know someone who has done outstanding work in the RASC? Do they qualify for one of the RASC's national awards? A list of national awards is given below. Please look within your Centre, and among our unattached members, for those bright and shining stars that deserve recognition. Go to www.rasc.ca/awards to check the requirements for these national awards, think about the contributions of those hard-working RASC members that you know, and nominate them for an award. Now is the time! Nominations are due on 2013 December 31.

RASC National Awards

The RASC sponsors several annual national awards that recognize achievement or service by our members. These include:

The **Chant Medal** is awarded, not more than once a year, to an amateur astronomer resident in Canada on the basis of the value of the work carried out in astronomy and closely allied fields, for original investigation, and specifically not for services to the Society, worthy though these may be.

The **Ken Chilton Prize** is awarded annually to an amateur astronomer resident in Canada, in recognition of a significant piece of astronomical work carried out or published recently.

The **Qilak Award for Astronomy Outreach and Communication** recognizes individual Canadian residents, or teams of residents, who have made an outstanding contribution, during a particular time period, either to the public understanding and appreciation of astronomy in Canada, or to informal astronomy education in Canada, and to promote such activities among the members of the sponsoring organizations.

The **Service Award** is given to members in recognition of outstanding service, rendered over an extended period of time, where such service has had a major impact on the work of the Society and/or of a Centre of the Society.

The **Simon Newcomb Award** is intended to encourage members to write on the topic of astronomy for the Society or the general public, and to recognize the best published works through an annual award.

More detail, including eligibility and nomination requirements for each award can be found at www.rasc.ca/awards. Click on the links to individual awards for full information.

The deadline for nominations is **2013 December 31**. Send your letters of nomination or questions about the awards program to Mary Lou Whitehorne, Awards Committee Chair, at mlwhitehorne@hfx.eastlink.ca ✶

Mary Lou Whitehorne
Past President & Chair, Awards Committee
The Royal Astronomical Society of Canada.

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Journal

Great Images

The combination of the North America Nebula and the Pelican Nebula never fails to please when early fall places Cygnus high overhead in the evening skies. Klaus Brasch turned his TMB-92 ƒ/5.5 refractor and a modified Canon 6D to the pair in late September. Exposure for each member of the composite was a surprisingly short 2×3 minutes at ISO 3200 through an IDAS LPS-V3 filter. Klaus comments, "Note the absence of significant noise even at this high ISO. Great camera."