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Journal

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PROMOTING ASTRONOMY IN CANADA

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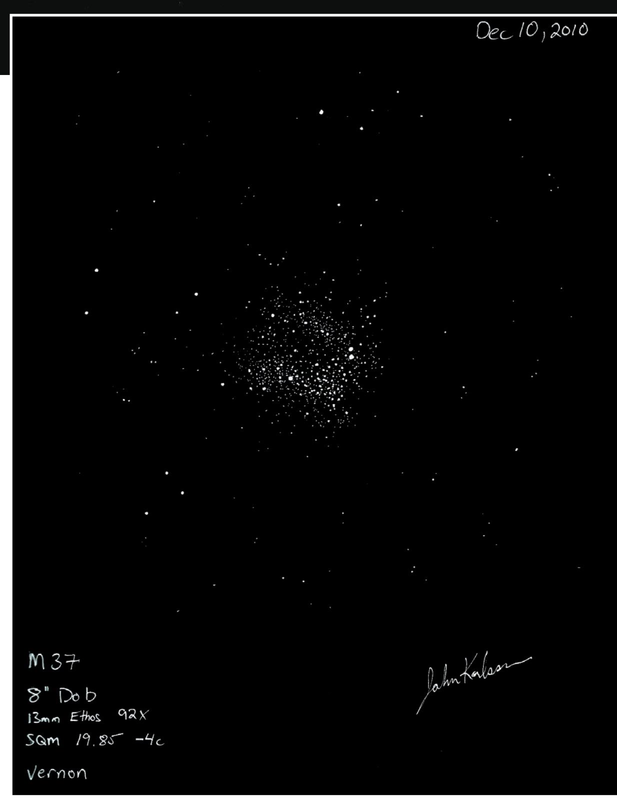
Inside this Transits of Venus themed issue:

The Pleiades as you've never seen them

Astrophotographers take note!

This space is reserved for your B&W or greyscale images; a new feature in the *Journal*. Give us your best shots!

Vernon's John Karlsson sent us two fine sketches when the Editor found his work in the Okanagan Centre Web pages and asked him to consider publishing in the Journal. *These contributions are superb examples of what a combination of good skies, large telescopes, experienced observer, patience, and artistic talent can do. We've had to enhance the contrast for publication; the originals are more delicate than you see here.*



Journal

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Société Royale d'Astronomie du Canada

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Front cover *— Sometimes familiar astronomical objects reveal a fresh personality when a terrific photograph captures new details. Tony Peterson created this image of the Pleiades (M45) with nearly 8 hours of exposure in RGB in late September from locations in Québec and Ontario. Tony used a Tele Vue 85 telescope and a Parsec 8300M CCD camera.*

Journal

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

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President's Corner

Mary Lou Whitehorne
President, RASC

This is an encore presentation of an Executive Perspectives column I wrote for the *Journal* 26 months ago. The message is important so it bears repeating from time to time.

Our Society is constantly changing, but in some ways, it stays the same. Members come and go. Ideas wax and wane. Some ideas are an ephemeral flash, while others persist tenaciously. Two years later, we have lots of new members. They may be struggling to understand the relationship between what appears to be two organizations: the local RASC Centre, and the national RASC. For this reason, I believe it is important to run this column again, to help members better understand our Society.

There is an old Chinese curse that says: "May you live in interesting times." There is more than one way to interpret this. No matter how you look at it, the last few years have been "interesting" for us. The Executive Committee is still busy juggling challenging issues. There just aren't enough hours in the day!

There remains a misperception about the "national RASC." Sometimes we hear comments referring to "us" (members and Centres) and "them" (the national arm of our Society). So I must ask the question: **what is the national RASC**? The answer is four-fold:

1. **National Office:** is the home of the day-to-day business of our Society. It is the RASC's physical address where records are kept and a lot of work is done. It is the hub for financial transactions with members, Centres, subscribers, customers, advertisers, printers, and everyone else with whom we do business. It is the nerve centre for production and distribution of publications, mailings, membership records, and donations. It's the place where phone calls and emails land. Our staff of three works here. It is a busy place! Despite rumours to the contrary, the president does not live or work here.

2. **National Executive Committee:** is a group of elected members of the Society. They can be from any RASC Centre, or be unattached members, from anywhere in Canada. They are unpaid volunteers who have spent years working at the Centre and national levels for the good of the RASC. They do not work out of the National Office. Most importantly, they are dedicated members of our Society.

3. **National Council**: is the governing body of the Society. It carries out the functions, and assumes the responsibilities, of a corporate board of directors. National Council is made

up of the national Executive Committee, the chairs of our national committees, plus the representatives from our 29 Centres. All of these people are volunteers, and they come from the Centres. ***Most of National Council is comprised of Centre reps.***

4. **National Volunteers**: Did you know that over 50 people volunteer each year to produce the *Observer's Handbook*, and the *Journal* has a volunteer staff of over 25? We also have a dozen national committees working on everything from the Society's observing certificate programs to developing and approving new Dark-Sky Preserves in Canada.

The point I want to drive home is this: ***the national RASC is its members!*** No more and no less. Almost everything done in this Society is done by members, for members. There is no "us" or "them." There is only "us."

I acknowledge that these are not readily self-evident truths. Our Society is large, with a long history. It has a complicated structure and operating system. All of it is described in our Letters Patent, our By-Laws, and in various policy documents, available to members on the members-only section of our Web site (www.rasc.ca/member-home). It's not exactly light reading! For those who care to, it is worth spending time with these documents to gain a deeper understanding of where we came from, how we got here, and how the RASC works.

We are deeply dependant on the generosity of our member volunteers, whether at the local or national level. The focus of effort, and the point of view, is different depending on whether you volunteer at the Centre (local) level or at the national level. For most of us, the action happens at the Centre level. From here, it's pretty easy to see what's going on, why it's happening, and how it works. Unfortunately, from the Centre level, much of what goes on at the national level is less clear and generally harder to fathom.

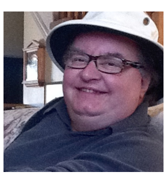
This is where your Centre's National Council representative comes in. He or she is a member of National Council. One of her or his chief responsibilities is to keep Centre members informed and up-to-date on the whys and wherefores of Society activity at the national level.

From the national perspective, everything is done for the benefit of the Society as a whole. That includes our 29 Centres, without whom there would be no RASC. The point-of-view is necessarily different, because the RASC is a federally incorporated body that is a registered charity. We are held to a very high standard and we have to abide by the rules as dictated by Canadian law. (Federal legislation governing charities is changing, and it will impact the way we do things in the future!) National Council, led by the Executive Committee, works to ensure the Society does what it is supposed to do, and maintains its reputation, integrity, legitimacy, and assets. National Council is responsible for the financial well-being of the entire Society, as well as its future stability, growth, and success.

I hope this helps clarify who and/or what the "national" RASC is. Simply put, it is ***us.*** I invite you to delve into our governing documents. You will find a treasure trove of information about us, our history, objectives, what we do, how we do it, and why. Read and enjoy, for someday you may be National President during interesting times!

Quo Ducit Urania!✶

News Notes / En manchettes



Compiled by Andrew I. Oakes
(copernicus1543@gmail.com)

Rosetta-Philae speeding towards encounter with Comet 67P

While the Earth's atomic clocks tick towards the year 2014, a European Space Agency spacecraft, currently on an encounter trajectory with a distant comet, is in hibernation awaiting a wake-up call on or about New Year's Day 2014. Called *Rosetta*, the spacecraft is scheduled to intercept Comet 67P/Churyumov-Gerasimenko in August 2014. It will enter orbit around comet 67P's nucleus and descend as low as 1 km to deploy a lander named *Philae* after a site is chosen.

Once *Rosetta* is stirred to life, it will begin a months-long program of self-checkups before its historic encounter and *Philae*'s planned landing. The spacecraft's goal is to learn the comet's primordial story as it heads on its journey to the Sun and begins to break apart. 67P/Churyumov-Gerasimenko will be undergoing the usual comet metamorphosis as its orbit swings it closer to the Sun. *Rosetta* will have a front-row seat as 67P evolves on its way towards the Sun and back out again.

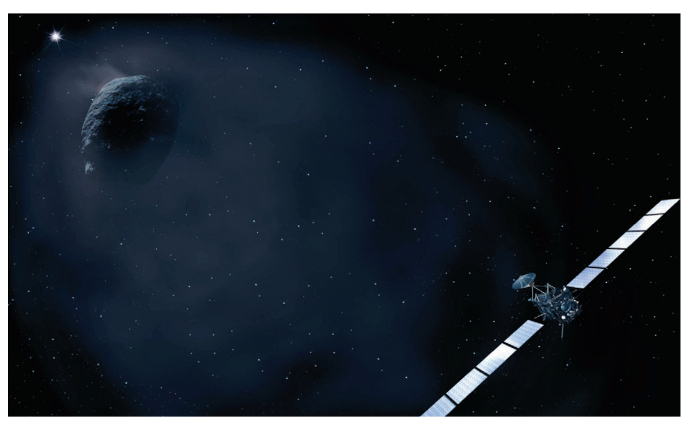


Figure 1 — An artist's impression of Rosetta *waking from deep-space hibernation to rendezvous with Comet 67P/Churyumov-Gerasimenko in 2014. Credits: ESA, image by AOES Medialab.*

Figure 2 — The Philae *lander at work on Comet 67P/Churyumov-Gerasimenko—while* Rosetta *studies the comet from close orbit,* Philae *will obtain measurements from the surface. The minimum targeted mission time for* Philae *is one week, but surface operations may continue for many months. Credits: ESA / AOES Medialab.*

Primitive leftovers from the Solar System's formation some 4.5 billion years ago, comets are well preserved primordial conglomerations, having spent much of their time in the deep freeze of the outer Solar System. They offer significant science research opportunities for those astronomers seeking to understand conditions at Solar System's formation.

Rosetta, launched in 2004 with U.S. instruments on board, will orbit 67P for 17 months, during which time the comet will be impacted by increasing solar heat, causing it to change from a distant nugget in space to a traveller with trailing vast tail. *Philae* is expected to make a controlled touchdown on the comet's nucleus in November 2014, which conceivably could already be active at the time. With little gravity on the comet, the lander will anchor itself with harpoons, and begin a first-hand study of the comet's nucleus.

Philae, named after an island in the Nile—the site of an obelisk that helped decipher the Rosetta Stone—will gather samples for examination by automatic onboard microscopes and take panoramic images of the comet's terrain from ground level. The orbiting *Rosetta* spacecraft will map the comet's surface and magnetic field, monitor its erupting jets and geysers, and measure outflow rates. A first-ever 3-D picture of the layers and pockets under the surface of a comet will be assembled.

Rosetta will be the first space mission to journey beyond the main asteroid belt and rely solely on solar cells for power generation, rather than the traditional radio-isotope thermal generators. The new solar-cell technology used on the orbiter's two giant solar panels allows it to operate over 800 million kilometres from the Sun, where sunlight levels are only 4% of those on Earth.

Neutron star moving 4.8 M kilometres per hour

A compact object within supernova remnant G350.1-0.3 is raising some intriguing questions among astronomers. Evidence from both the *Chandra X-ray Observatory* and from European Space Agency's *XMM-Newton* telescope suggests that the compact object within G350.1-0.3 may be the dense core of the star that exploded. The position of this likely neutron star (see accompanying image) is located well away from the centre of the X-ray emission. This means that if the supernova explosion occurred near the centre of the X-ray emission, then the resulting neutron star must have received a "powerful kick" in the explosion. If the estimated location of the explosion is correct, this then means that the neutron star has been moving at a speed of at least 4.8 million kilometres per hour since ignition.

A second intriguing aspect of supernova remnant G350.1-0.3 is its unusual shape. While many supernova remnants are nearly circular, G350.1-0.3 appears asymmetrical. This morphology recorded by *Chandra* is also being traced via infrared data from NASA's *Spitzer Space Telescope*. Astronomers are speculating that the asymmetrical shape is due to the stellar debris field expanding into a nearby cloud of cold molecular gas.

It is unlikely that anyone on Earth would have seen the supernova explosion due to the obscuring gas and dust that lies along Earth's line of sight to the remnant. ✶

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

Figure 3 — Data suggest this supernova remnant is between 600 and 1200 years old. If the estimated location of the explosion is correct, this means the neutron star has been moving at a speed of at least 4.8 million kilometres per hour since the explosion. Image credits: X-ray: NASA/CXC/SAO/I. Lovchinsky et al.*; IR: NASA/JPL-Caltech.*

Transits of Venus

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Abstract

Several features of the pattern of transits of Venus are described in terms of the orbital motions of Venus and Earth.

Introduction

On June 5/6 this year, for more than six hours Earth will be immersed in the penumbral shadow of Venus, an event that will not happen again for more than a century. Beginning at 22:10 UT June 5 (geocentric), weather permitting, the first portion of the passage of Venus across the solar disk will be visible from all of Canada, but for most of North America sunset will occur with the transit still in progress. It is primarily a western-Pacific event. Observers in much of Canada's Arctic, in the Yukon, Alaska, Hawaii, Japan, New Zealand, and parts of Australia and eastern Asia will witness the entire transit. For detailed predictions concerning the visibility and times of the transit, see the *Observer's Handbook 2012* (Chapman 2011).

With a transit of Venus only 8 years ago (see Figure 1) and another one this year, there is no shortage of accounts of this singular phenomenon—in periodicals, in books, and on the Internet. References during the past 134 years include: Newcomb 1878, Ball 1897, MacPike 1932, Hogg 1947 and 1976, Woolf 1959, Beaglehole 1974, Toomer 1984, Chapman 1986, Meeus 1989, Maor 2000, Broughton 2003, Chapman 2011, Bishop 2011, Pasachoff 2012, and the Web site www.transitofvenus.org. Transits of Venus are of great interest because of their rarity, because of their role in establishing the scale of the Solar System during the 18th and 19th centuries, and because of the motions that generate the pattern of transits. In this article, I address the latter topic. The orbital dynamics underlying transits of Venus are often ignored, or treated in a cursory manner.

The Pattern of Transits

Between AD 1500 and 2500, Venus transits the Sun 18 times:

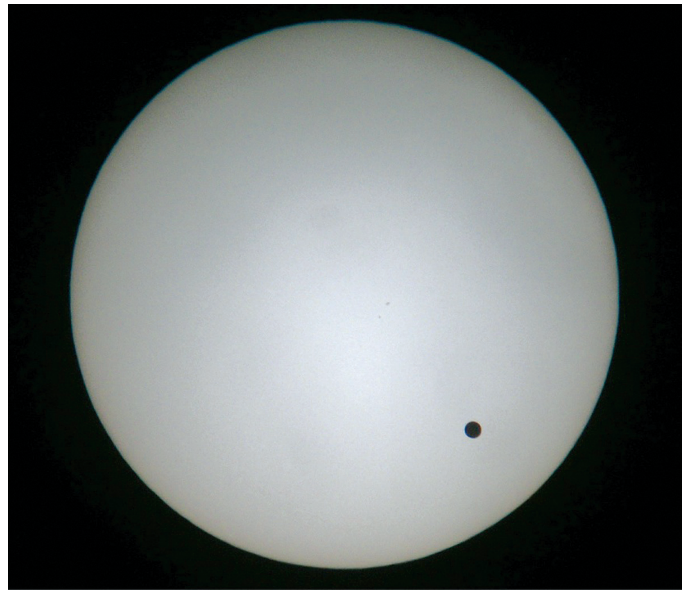

Figure 1 — Venus in transit, 2004 June 8, from Crete. Photo by Murray Paulson, St. Albert, Alberta, Canada, with a Takahashi 90-mm "Sky 90" telescope.

1518 May 26	**2012 June 6*****
1526 May 23	2117 December 11
1631 December 7*	2125 December 8
1639 December 4**	2247 June 11
1761 June 6	2255 June 9
1769 June 3	2360 December 13
1874 December 9	2368 December 10
1882 December 6	2490 June 12
2004 June 8	2498 June 10

* *The first transit to be predicted*
** *The first transit to be observed*
*** *June 5 in North America!*

The tracks of Venus across the solar disk for 12 of these transits are shown in Figure 2.

Upon careful inspection, 11 features of this millennium of transits are obvious:

1 Transits occur only in June or December. (The two May dates are an artifact of the Julian calendar that preceded the Gregorian calendar. A 10-day shift occurred with the adoption of the Gregorian calendar in 1582.)

2 The transits occur in pairs.

3 The tracks of a pair of June transits are closer together than for a pair of December transits.

4 The two transits of a pair are separated by 8 years.

5 The second of a pair of June transits occurs further north on the solar disk, further south for a December pair.

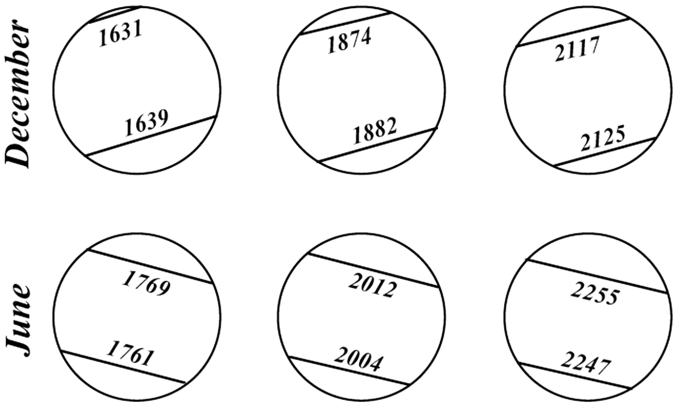

Figure 2 — Venus's transit tracks across the solar disk during the years 1631 through 2247. The members of each pair are separated by 8 years, and 243 years separate the tracks in the horizontal direction. North is up. The slope of the tracks makes it obvious that December transits occur at the ascending node of Venus's orbit, June transits at the descending node. Earth's orbital motion causes the slopes to be considerably larger than the 3.4° inclination of Venus's orbit. The data used to draw Figure 2 are from Meeus 1989.

6 The second transit in a pair occurs 2 or 3 days earlier in the year.

7 The pairs alternate June/December.

8 The pattern repeats with a period of 243 years.

9 Successive transits at 243-year intervals occur 1, 2, or 3 days later in the year.

10 Transit tracks at 243-year intervals occur further south on the solar disk.

11 The sequence of years separating successive transits, beginning with the first member of a pair of June transits, is 8, 105.5, 8, 121.5, and then repeats.

Orbital Motion and the Pattern of Transits

A transit can occur only when Venus is at *inferior conjunction*, when it passes between Earth and Sun. Inferior conjunction is defined as the instant when Venus has the same apparent celestial longitude (eastward position along the *ecliptic,* the plane of Earth's orbit) as the Sun, as viewed by a hypothetical observer at Earth's centre. Venus passes through inferior conjunction about every 19 months; however, at most inferior conjunctions, a transit does not occur.

Venus's orbit is tilted 3.4° relative to that of Earth, and the two orbital planes intersect along a *line of nodes* (see Figure 3). At inferior conjunction Venus is close to Earth, consequently it can pass as much as 8° north or south of the 0.5°-diameter Sun. Thus transits occur only when both Earth and Venus are near the line of nodes on the same side of the Sun. The ascending node (at which Venus passes to the north side of the ecliptic) lies between Earth and Sun in early December, the descending node lies between Earth and Sun in early June.

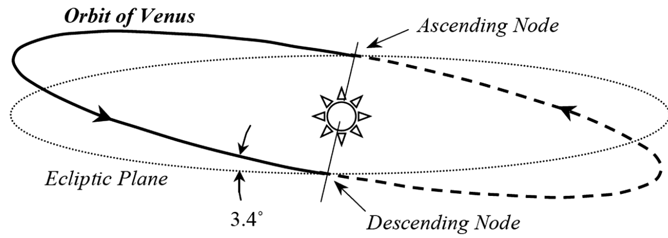

Figure 3 — An oblique view of Venus's orbit and the ecliptic plane, from the north side. The arrowheads indicate the direction of orbital motion. The plane of Venus's orbit and the plane of Earth's orbit (the ecliptic plane) intersect along the line of nodes (the straight line passing through the Sun).

Thus transits can occur only in June or December (Feature #1 listed above).

The *sidereal period* of a planet is the time required for it to complete one orbit relative to the distant stars. These are:

for the Earth-Moon centre of mass: E = 365.256 367 8 d

for Venus: V = 224.700 800 5 d

where E and V denote the respective sidereal periods, and d = day = 86 400 s exactly. These values of E and V are calculated from the centennial rate of change of the mean longitude of each planet given in Table 5.8.1 of the *Explanatory Supplement to The Astronomical Almanac* (Seidelmann 1992). The data in that table are at epoch J2000, are with respect to the mean ecliptic and equinox of J2000, and are average values for the period 1800–2050. The time for the completion of any one orbit varies slightly from these values due to the gravitational interaction of one planet with another.

Accepting the *Explanatory Supplement* data as presented, I have retained ten significant figures in the above average values of E and V. In subsequent calculations involving E and V, I retained all significant figures, rounding answers to fewer significant figures to minimize clutter when higher precision is not essential.

If Venus is at inferior conjunction, after a further time interval known as the *synodic period* (S), Venus will have gained one lap on Earth and the next inferior conjunction will occur. During this time interval, Earth will have completed S/E orbits and Venus will have completed S/V orbits where:

$$S/V = S/E + 1$$
$$\text{thus} \quad S = EV/(E - V)$$
$$= 583.921\,361\,5 \text{ d} \approx 1.60 \text{ yJ}$$

That value of S is an average. Because the orbits are not circular, the time from any one inferior conjunction to the next can differ by several days from the average value. Also, yJ = *Julian year* = 365.25 d exactly. Use of the Julian year avoids the peculiar pattern of leap years of the Gregorian calendar in which century years that are not a multiple of 400 are not leap years; however, the Gregorian calendar must be used when determining actual dates of events after AD 1582.

Earth's orbit has an *eccentricity* 0.0167, Venus's orbit 0.0068, so compared to Earth's orbit, Venus's orbit may be considered to be circular (The eccentricity of an ellipse is the distance between its foci divided by the length of its major axis. Thus a circular orbit has eccentricity zero). At the time of a June transit, Earth is near *aphelion*, its furthest point from the Sun. Hence Venus is further away than it is at the time of a December transit when Earth is near *perihelion*, closest to the Sun. Thus the angular diameter of Venus at a June transit is smaller than it is at a December transit (58″ versus 64″), and the 8-year pair of paths Venus traces across the solar disk in June are closer together than those in December (Feature #3 listed above).

An 8-year Cycle in terms of E, V, S, and yJ

The relationship between the synodic period of Venus and the sidereal period of the Earth is given by:

$$5\text{ S} = 8\text{ E} - 2.44\text{ d} \qquad (1)$$

Thus five synodic periods span nearly 8 Earth orbital periods, the 5th inferior conjunction occurring only 2.44 days (on average, and rounding to three significant figures) before Earth completes its 8th orbit. This 8-year repetition of the apparitions of Venus is well known. The 2.44-day inequality causes the successive 5th, 10th, 15th, *etc.* inferior conjunctions that occur near a node to shift progressively past the node by (8E – 5S)/E x 360° = 2.41°. As mentioned, the 3.4° inclination of Venus's orbit results in approximately an 8° amplitude for its range of geocentric ecliptic latitude when at inferior conjunctions. Beginning with a hypothetical transit that crosses the centre of the solar disk, the maximum number (N) of 2.41° steps before the track of Venus misses the solar disk (0.27° radius) is given by: 0.27° = 8° Sin 2.41°N. Thus N = 0.80, and a central (or near-central) transit is single (*i.e.* not a member of a pair or a triplet). For non-central passes such as are occurring during the 1600-year span AD 1400 to 3000, two transits 8 years apart can fit in the (2 x 0.80 x 2.41°) angular window available (Features #2 and #4 listed above).

Because every 5th inferior conjunction occurs a bit sooner relative to the node, the second transit of a pair of June transits (which occur near the descending node) occurs further north on the solar disk. Similarly, the second member of a pair of December transits (which occur near the ascending node) occurs further south on the solar disk. (Feature #5 listed above). Hence the 2012 transit crosses the northern portion of the Sun.

$$5\text{ S} = 8\text{ yJ} - 2.39\text{ d} \qquad (2)$$

Thus five synodic periods also span almost eight calendar years, the 5th inferior conjunction occurring 2.39 days earlier in the calendar year (Feature #6 listed above). If a century year that is not a leap year intervenes, the shift is –1.39 d on the Gregorian calendar. The 2.39 d inequality is an average. Due to orbital eccentricities and perturbations, the actual inequality varies about ±0.1 d from this value.

$$8\text{ E} = 13\text{ V} + 0.94\text{ d} \qquad (3)$$

$$\text{or} \quad 8\text{E/V} \approx 13 + 1/240$$

Thus after 8 Earth orbits, Venus has orbited 13 times and has had 0.94 day to move ahead of Earth. Venus has lapped Earth (13 – 8) = 5 times and is already into its 14th orbit. It was this mismatch that led George Biddell Airy (1801-1892), England's Astronomer Royal from 1835 to 1881, to deduce a significant, long-period (about 240 years) perturbation in the relative motion of Earth and Venus (Airy 1832, 1896). For that work, in 1833 Airy was awarded the Gold Medal of the Royal Astronomical Society.

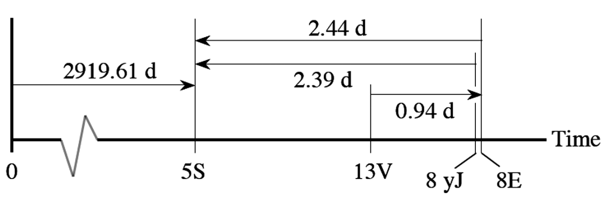

Figure 4 — A time diagram of equations (1), (2), and (3), displaying the 8-year time relations of Earth (sidereal orbital period E) and Venus (sidereal orbital period V). S is the synodic period, and yJ = 365.250 000 d, the Julian year.

Figure 4 displays the 8-year time relations of equations (1), (2) and (3).

Equation (1) and a Star-Figure

Equation (1) may be represented as part of a diagram (Figure 5).

In 1595, Johannes Kepler drew such a construction for successive conjunctions of Saturn and Jupiter, producing "quasi-triangles" (Kepler 1621, Etz 2000). Bruce McCurdy has done the same for Earth and Venus, producing the quasi-pentagram (McCurdy 2004a). *Google* gives numerous references to Venus and the pentagram, many occult, a few not. However, as indicated by equation (1), conjunction #5 occurs 2.44 d earlier in an Earth sidereal year than conjunction #0, so the quasi-pentagram does not close. Thus it is not a pentagram. I shall call it the *star-figure*. The *raison d'être* for introducing the star-figure in this paper is that it greatly aids visualization of the complex dynamics of the sequence of transits.

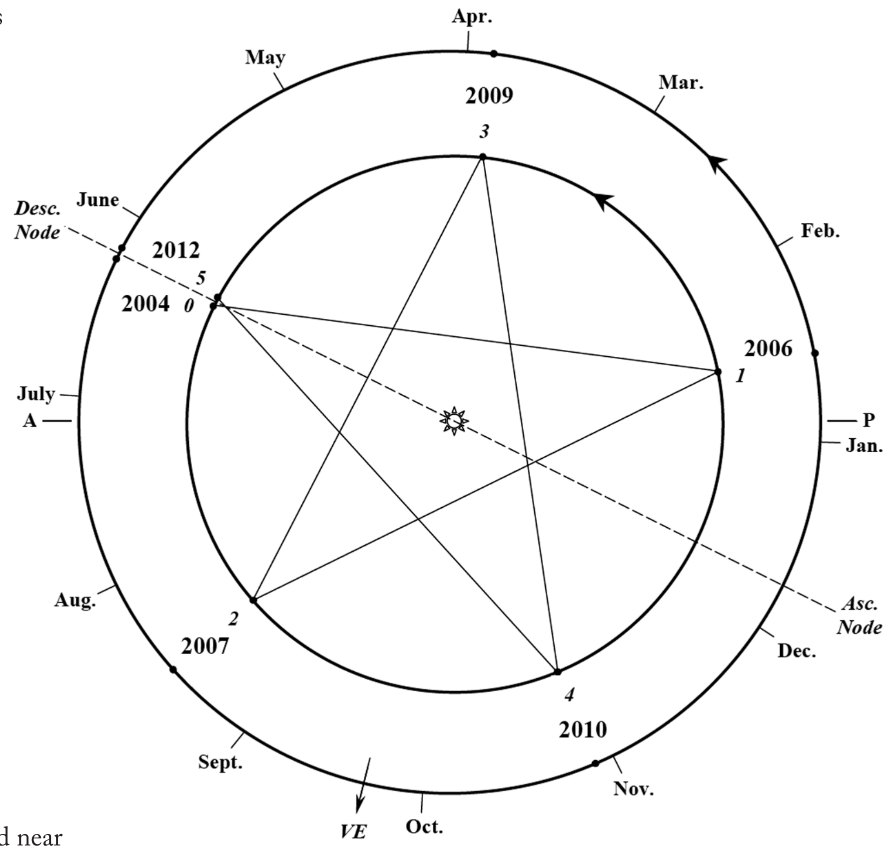

Figure 5 — The "Star-Figure." The two circles represent the orbits of Venus and Earth to scale with the Sun at the centre, as viewed from the north side of the Solar System. The planets orbit counterclockwise, as indicated by the arrowheads. The position of Earth at the beginning of each month of the year is indicated. The black dots represent Earth and Venus at 6 successive inferior conjunctions (numbered in sequence: 0, 1, 2, 3, 4, 5) beginning with the transit conjunction of 2004 June 8, and ending with the transit conjunction of 2012 June 5/6. Straight lines connect the positions of Venus at successive inferior conjunctions, resulting in the 5-pointed star-figure. From one conjunction to the next, Earth and Venus have completed S/E = 1.60 and S/V = 2.60 orbits, respectively (it is an instructive exercise to trace those motions with two fingers on the diagram). Earth's orbit is considerably more eccentric than that of Venus, so the circle representing Earth's orbit is displaced toward its aphelion "A" to approximate what should be its elliptical shape. "P" indicates Earth's perihelion, thus AP is the line of apsides (not drawn in), the major axis of Earth's orbit. The line of nodes is shown (the dashed line). The portion of Venus's orbit below the line of nodes in the diagram lies south of the ecliptic plane, as indicated by the labelling of the ascending and descending nodes. The arrow near the bottom indicates the direction of the vernal equinox (VE), the zero point of heliocentric longitude, which is measured eastward around the ecliptic (counterclockwise in the diagram).

Because only one point of the star-figure can be located near a node at a time, none of the four conjunctions between the years 2004 and 2012 could produce a transit (consistent with Feature #4 listed above). Nevertheless, each of the other four points of the star-figure is of interest. For example, for observers in the Northern Hemisphere a repeat of the spectacular 2001 late-winter evening-sky apparition of Venus occurred almost exactly 8 years later, in 2009, during the couple of months preceding the inferior conjunction at point #3 in Figure 5. Also, as specified by equation (2), the 2009 conjunction occurred about 2.4 days earlier in the year (2009 March 27 at 19:24 UT compared to 2001 March 30 at 04:16 UT).

Because the star-figure does not close, as the diagram is extended forward in time beyond 2012, the entire star-figure slowly rotates clockwise. The period (P) of the rotation is

$$P = \text{(Time for point 0 to step to point 5)/(Fraction of one rotation involved)}$$
$$= 5S / [(8E - 5S) / E]$$
$$= 1194.56 \text{ yJ}$$

The rotation is *alternating-digital* (for lack of a better adjective), rather than smooth. The points of the star-figure take small, 2.4° steps relative to the conjunction at that position 8 years earlier, one after another, according to the numbered conjunction sequence. If the star-figure were a starfish on the sea floor, the starfish would shift every second arm (in the clockwise sense) slightly clockwise, one after another in sequence, one arm shifting every 1.60 years, as it imperceptibly rotates.

Because of the rotation, the 2009 inferior conjunction (star point #3) occurred further from the line of nodes than did the conjunction at that point of the star-figure 8 years previously, in 2001. Hence Venus passed even further north of the Sun in 2009 (8° 10′) than it did in 2001 (8° 01′).

Figure 6 shows an octennial conjunction pair (see the caption).

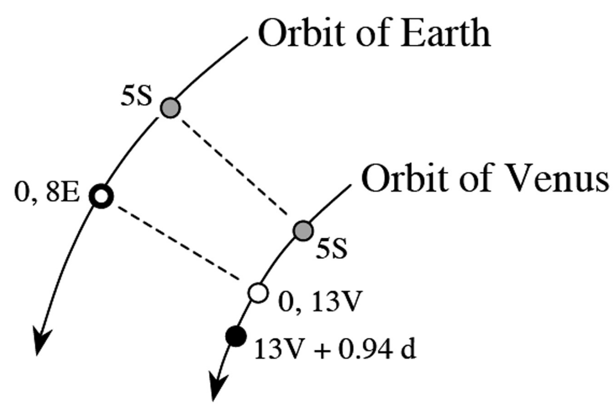

Figure 6 — An octennial conjunction pair, such as the 2004/2012 pair in the upper-left portion of Figure 5. To facilitate labelling, unlike Figure 5, Figure 6 is not to scale. Whereas Figure 4 is a time diagram of equations (1), (2), and (3), Figure 6 is a space diagram of equations (1) and (3), showing where Earth and Venus are located along their orbits at an initial inferior conjunction (open circles), at five inferior conjunctions later (gray circles), and finally an additional 2.44 days later when Earth has completed eight orbits (dark circles, which for Earth is the open circle with the heavy dark border). Beside each planet position is the clock time on that planet when at that position. Not shown in Figure 6 is an indication of where Earth and Venus are located when their clocks read 8 yJ (almost at the dark circles), as specified by equation (2).

Repetition of Pairs of Transits

The next pair of transits after the June transits of 2004/2012 will be a December pair when point 1 of the star-figure reaches the ascending node, the star-figure having rotated 1/10th of a turn (see Figure 5). A full cycle requires another 1/10th of a turn, 1/5th of a turn in total, when point 2 will have rotated to the vicinity of the descending node and another pair of June transits will occur. Thus pairs of transits alternate between June and December (Feature #7 listed above).

One-fifth of a turn requires P/5 = 238.91 yJ. When point 2 of the star-figure arrives near where point 0 was one transit period earlier, an integral number (n) of 5S time intervals plus 2S will have passed (see Figure 5). Thus: n(5S) + 2S = P/5 giving n = 29.49. But n is an integer. For n = 29, point 2 will fall (0.49 x 5S)/P of a rotation (1.18°) short of the former location of point 0. Eight years later when n = 30, point 2 will fall (0.51 x 5S)/P of a rotation (1.23°) past the former location of point 0. Of course, 1.18° + 1.23° = 2.41°, the average displacement of inferior conjunctions 8 years apart (see the paragraph following equation (1)).

n = 29 gives a transit period of 147S. However, the actual transits indicate otherwise. For example, the most recent first transit of a pair of June transits (point "0" in Figure 5) and the next predicted such transit span a time interval (involving 58 leap years) of: (2247 June 11, 11:42 UT) – (2004 June 8, 8:20 UT) = 243.001 yJ = n(5S) + 2S, which gives n = 30.0000, and a transit pattern period of 152S (243.001 yJ) (Feature #8 listed above). Thus the n = 29 inferior conjunction (2239 June 13) misses the solar disk, even though it will occur slightly closer to the former location of point 0 than does the n = 30 event. Hence the line of nodes *cannot* be stationary, but must rotate clockwise (retrograde). The 152S (243-year) transit period so indicates!

Values of the heliocentric longitude of the ascending node of Venus appear on page E4 of the annual *Astronomical Almanac*. Data extending over several decades indicate that, relative to the vernal equinox of date, the ascending node drifts prograde at a remarkably steady average rate of 32.4″ per year. That figure agrees with the mean centennial motion of the node given in the 1961 edition of the *Explanatory Supplement* (see the references). The equinox itself precesses retrograde by 50.3″ each year. Thus relative to the distant stars, the line of nodes rotates retrograde (clockwise in Figure 5) 50.3″–32.4″ = 17.9″ per year. In one transit pattern period, that tiny annual shift amounts to 17.9″ x 243 = 1.21°, which closely matches the displacement of point 2 of the star-figure past the former location of point 0 (1.23°). Thus, remarkably, the line of nodes approximately tracks the "152S" successive points of the star-figure, allowing a transit series to persist for many cycles. (Is this linkage of the line of nodes to a 152S transit series the "about 240-year perturbation" that Airy discovered theoretically in his monumental paper (Airy 1832)? I leave the answer to someone who better understands Airy's paper.)

The angular speed of the star-figure is 360°/1194.56 yJ = 1085″ per year, about 60 times faster than that of the line of nodes (1085″/17.9″ = 60.6). In terms of angular speed, the star-figure is to the line of nodes as the second hand on a clock is to the minute hand. The star-figure rotates once in about 1200 years; the line of nodes rotates once in about 72,000 years (if it maintained its present angular speed).

With transits presently occurring in 8-year pairs, and successive pairs alternating June/December, there are now four 243-year series running. The 1769 and 2012 transits are successive ones in the "second June" series. One transit period ago, James Cook and his astronomer Charles Green were in Tahiti, with *His Majesty's Bark Endeavour* anchored in Matavai Bay.

The 243-Year Cycle in terms of S, E, V, and yG

$$152\ S = 243\ E - 1.25\ d = 395\ V - 0.77\ d = 243\ yG + 2.12\ d \quad (4)$$

where yG = average Gregorian year = 365.2425 d exactly. Thus when the 152nd inferior conjunction occurs, Earth is 1.25 d short of completing 243 orbits, and Venus is 0.77 d short of completing 395 orbits (and 1.25/E = 0.77/V = 1.23°, as calculated five paragraphs above). Also, the Gregorian calendar date has advanced an average of 2.12 days; however, depending upon the number of February 29ths spanned, the actual advance of the calendar date in the 243-year period of the pattern of transits can be 1, 2, or 3 days (Feature #9 listed above).

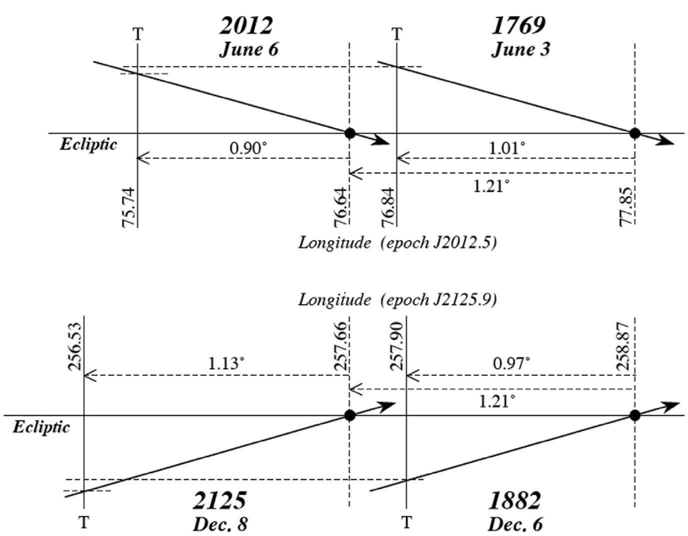

Figure 7 — A June 243-year cycle and a December 243-year cycle displayed according to ecliptic longitude. The heavy lines show the path of Venus as it crosses the plane of the ecliptic. For clarity, the inclination of the paths is shown larger than the actual 3.4° inclination of Venus's orbit. The four black dots mark end-on views of the line of nodes. North is up. The ecliptic longitudes increase toward the right because the tracks of Venus are on the near side of the Sun, whereas the longitude scale (which increases toward the left, or eastward) is beyond the Sun at an infinite distance (See Figures 3 and 5). The vertical lines "T" indicate the longitude of Venus and Sun at transit. Note the southward shift of both June and December transits after 243 years (indicated by the pairs of dashed lines in the upper-left and lower-left portions of the figure, respectively), and refer back to Figure 2. The December shift is larger than the June shift, resulting in fewer cycles in a December transit series.

Duration of a 243-Year Series

A 243-year series of transits lasts for several thousands of years. For example, the "first June" transits of –2127 (*i.e.* 2128 BC), 2004 and 3462 (spanning 24 cycles) are in the same series (Meeus 1989). However, during the millennium that is the main focus of this paper (AD 1500 to 2500), the paths of Venus across the Sun at 243-year intervals shift progressively southward (see Figure 2) terminating a 243-year transit series after approximately 20 cycles for a December series, and a few more cycles for a June series.

The termination is caused primarily by the varying speed of Earth in its eccentric orbit. At the time of a June transit Earth is near aphelion and moving slower than average. At the time of a December transit, Earth is near perihelion and moving faster than average. Figure 7 shows how that causes the southward drift (and thus eventual termination) of both June and December 243-year series of transits (Feature #10 listed above).

The southward drift is thus due to Earth's line of apsides (AP in Figure 5) lying not far from the line of nodes, with aphelion being near the descending node. Earth's line of apsides presently is rotating counterclockwise (prograde) about 11″ per year relative to the distant galaxies. Thus the angle between the line of apsides and the line of nodes (now about 27°) is growing 11″+ 18″ = 29″ per year. At that rate the two lines will be at 90° to one another in about 8000 years, at which point the southward drift of the various 243-year series will cease and then possibly become a northward drift. The numbers generated by Jean Meeus for transits in the interval 1500 BC to AD 3500 show such a trend (Meeus 1989).

The Pattern of Transits within the 243-Year Period

If the orbits of both Earth and Venus were circular (zero eccentricity), the time pattern between transits would be: 8, 113.5, 8, and 113.5 years. Earth's orbit is considerably more eccentric than that of Venus, so it is primarily Earth's non-uniform motion (Kepler's second law) plus the fact that Earth's line of apsides does not coincide with the line of nodes that skews the time pattern to: 8, 105.5, 8, and 121.5 years.

Earth's eccentric orbit is also the main cause of a slight distortion of the star-figure. The central pentagon of the star-figure (Figure 5) is not centred on the Sun; it is displaced toward Earth's aphelion "A". As the star-figure rotates clockwise its centre remains displaced toward "A". As a consequence, each of its five points takes larger steps every 8 years when nearer perihelion than it does when nearer aphelion. Hence the time interval separating a pair of June transits from the next pair of December transits will be shorter than the December-to-June time interval: 105.5 years versus 121.5 years (Feature #11 listed above). This brief argument establishes only that the first interval is shorter than the second, not their actual integer values (105 and 121). The decimal portions must be ".5" since this is the June/December interval, and the sum of those two intervals must be 227 years, 2 x 8 years less than the pattern period.

We happen to live in an era when the pattern of transits is pair-pair-pair- …. Other possible sequences are pair-single-pair-single, … , or single-single-single, …. For the thousand years prior to the transit of AD 1518, for example, the sequence alternated single-pair with the intervals between transits being 113.5, 121.5, 8, and then repeating (once again, a 243-year period) (Meeus 1989).

Over many thousands of years, perturbations of the orbits of Earth and Venus, by their mutual interaction and by the other planets, appreciably alter their eccentricities, inclinations, and the orientations of the line of nodes and the lines of apsides. Although uncertainties increase as calculations are extended further from the present, predictions of Venus transits have been extended for 100,000 years (McCurdy 2004c). The inclination of Venus's orbit will decrease over that interval, leading to triplets of transits and later to even more consecutive transits at 8-year intervals. Predictions for the eccentricities and inclinations of the orbits of Earth and Venus over several million years reveal large, quasi-periodic variations in both parameters for both planets (Laskar 1988). Moreover, there is good evidence for coupling of the variations between Earth and Venus (Murray and Dermott 1999). "The orbits of the two planets are continuously evolving, so that any patterns of repetition are ultimately transitory." (McCurdy 2004b). In summary, the description of the relative orbital dynamics of Venus and Earth given in this paper is but a first-order treatment, approximately valid for no more than a few thousand years at best.

Finis

After observing the transit of 1882, Sir Robert Ball, the Victorian Sir Patrick Moore, wrote:

> "*The intrinsic interest of the phenomenon, its rarity, the fulfillment of the prediction, the noble problem which the transit of Venus enables us to solve, are all present to our thoughts when we look at this pleasing picture, a repetition of which will not occur again until the flowers are blooming in the June of A.D. 2004.*"

AD 2004, so remote for Sir Robert Ball, has already come and gone. I was clouded out during the transit that June, but mindful of Sir Robert's words I took a photo while Earth was immersed in the Cytherean penumbral shadow (Figure 8).

Figure 8 — Flowers immersed in the penumbral shadow of Venus, North Grand Pre, Nova Scotia, Canada, 2004 June 8, 10:37 UTC.

Acknowledgements

Thanks to Dr. James Hilton (U.S. Naval Observatory) for helpful comments concerning orbital data, to John Jarvo for a copy of his notes concerning the long-term variations in the tracks of Venus across the solar disk, to Bruce McCurdy for his fascinating articles in this *Journal*, and to David Chapman for the inspiration of his long-term interest in the dynamics of the Solar System. ✶

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The Mistranslation of Jeremiah Horrocks's *Venus in Sole Visa*

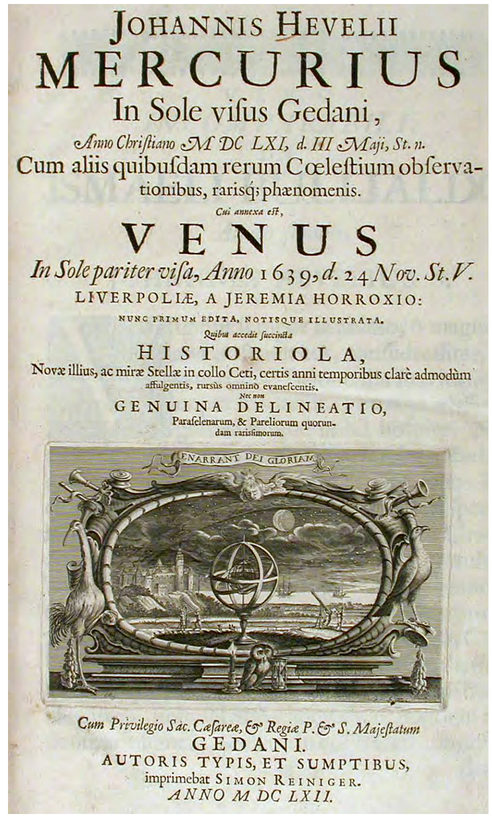
by Mark Edwards
Committee member, Coventry and Warwickshire Astronomical Society

On 1639 November 24, Jeremiah Horrocks (1618-1641), a young astronomer from Toxteth, Liverpool, made the first recorded observation of a transit of Venus. Written in Latin, his record of this historic sight was published by the Polish astronomer Johannes Hevelius in 1662 and translated into English in 1859 by the Rev. Arundell Blount Whatton. This latter version is regularly quoted by authors, but a critical examination of the translation reveals that in places it has changed the meaning of the Latin text. This paper discusses those changes and also notes an important discrepancy in the Latin version itself.

Jeremiah Horrocks was born in 1618, the first son of James Horrocks, a watchmaker, and Mary Aspinwall. He spent his early life living with his parents in Toxteth, Liverpool, but at the age of fourteen, he left home to continue his education at Emmanuel College, Cambridge, being admitted on 1632 May 18 as a sizar [1]. Three years later, he returned to Toxteth without a degree, but with a determination to study astronomy. From then until the end of his short life, he undertook a systematic study (through his own observations) of the motion of the Moon and planets. When he was twenty-one, he spent a year (1639 June 7 to 1640 July 17) at Hoole (present day Much Hoole), near Preston[2]. It was during that time that he realized a transit of Venus would occur on 1639 November 24[3].

Horrocks described his observations of the transit and his deductions from it of the size of the Solar System in a paper, written in Latin, entitled *Venus in sole Visa* (Venus seen on the Sun). However, he died suddenly on 1641 January 3 before it could be published[4]. Many years later, several incomplete copies of the paper were found in the study of his friend, William Crabtree, by Dr. John Worthington, Master of Jesus College, Cambridge, who sent two of the latest copies to Samuel Hartlib on 1659 April 28 for publication[5]. He in turn sent them to the mathematician Nicolaus Mercator so that they could be combined into one document. However, it would appear that they were never published.

All was not lost, as Christian Huygens had obtained an earlier version of the *Venus* from Sir Paul Neile (a founding member of the Royal Society), who passed it to the Polish astronomer Johannes Hevelius[6]. By the time that Hevelius received the copy, he himself had observed a transit of Mercury on 1661 May 3, so he added Horrocks's account as an annex to his


JOHANNIS HEVELII
MERCURIUS
In Sole visus Gedani,
Anno Christiano M DC LXI, d. III Maji, St. n.
Cum aliis quibusdam rerum Cœlestium observationibus, rarisq; phænomenis.
Cui annexa est,
VENUS
In Sole pariter visa, Anno 1639, d. 24 Nov. St. V.
LIVERPOLIÆ, A JEREMIA HORROXIO:
NUNC PRIMUM EDITA, NOTISQUE ILLUSTRATA.
Quibus accedit succincta
HISTORIOLA,
Novæ illius, ac miræ Stellæ in collo Ceti, certis anni temporibus clarè admodùm affulgentis, rursùs omninò evanescentis.
Nec non
GENUINA DELINEATIO,
Paraselenarum, & Pareliorum quorundam rarissimorum.

Cum Privilegio Sac. Cæsareæ, & Regiæ P. & S. Majestatum
GEDANI.
AUTORIS TYPIS, ET SUMPTIBUS,
imprimebat SIMON REINIGER.
ANNO M DC LXII.

Figure 1 — The title page of Hevelius's Mercurius In Sole visus Gedani *published in 1662. By permission of the Institute for Astronomy, Vienna University.*

book *Mercurius In Sole visus Gedani* [7] and published both in Gdansk in 1662 (Figure 1).

Two centuries later, William Robert Whatton, a fellow of the Society of Antiquaries and the Royal Society[8], started writing a translation of the *Venus* as part of a biography of Horrocks that he was preparing; sadly he died before completing the work. However, his son, the Rev. Arundell Blount Whatton, at the behest of a newspaper columnist, in 1859 finally published the *Venus* in English as an appendix to his *Memoir of the Life and Labors [sic] of the Rev. Jeremiah Horrox, Curate of Hoole, near Preston*[9].

How many of us, as we watched the transit of Venus in 2004, remembered Jeremiah Horrocks's evocative account[10]:

> When the time of the observation approached, I retired to my apartment, and having closed the windows against the light, I directed my telescope, previously adjusted to a focus, through the aperture towards the sun and received his rays at right angles upon the paper already mentioned. The sun's image exactly filled the circle, and I watched carefully and unceasingly for any dark body that might enter upon the disc of light.
>
> … I watched carefully on the 24th from sunrise to nine o'clock, and from a little before ten until noon, and at one in the afternoon, being called away in the intervals by business of the highest importance which, for these ornamental pursuits, I could not with propriety neglect.

But during all this time I saw nothing in the sun except a small and common spot, consisting as it were of three points at a distance from the centre towards the left, which I noticed on the preceding and following days. This evidently had nothing to do with Venus. About fifteen minutes past three in the afternoon, when I was again at liberty to continue my labours [sic], the clouds, as if by divine interposition, were entirely dispersed, and I was once more invited to the grateful task of repeating my observations. I then beheld a most agreeable spectacle, the object of my sanguine wishes, a spot of unusual magnitude and of a perfectly circular shape, which had already fully entered upon the sun's disc on the left, so that the limbs of the Sun and Venus precisely coincided, forming an angle of contact. Not doubting that this was really the shadow of the planet, I immediately applied myself sedulously to observe it.

…This observation was made in an obscure village where I have long been in the habit of observing, about fifteen miles to the north of Liverpool, the latitude of which I believe to be 53° 20´, although by the common maps it is stated at 54° 12´…

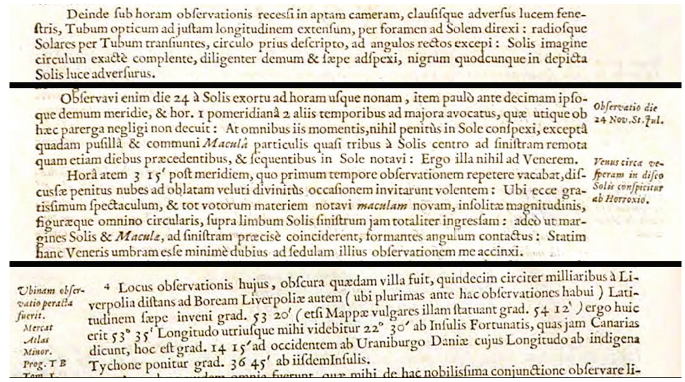
However, this popular and oft quoted account is, I believe, a poor translation by Whatton from the original Latin text[11]:

Deinde sub horam observationis recessi in aptam cameram, clausisque adversus lucem fenestris, Tubum opticum ad justam longitudinem extensum, per foramen ad Solem direxi: radiosque Solares per Tubum transiuntes, circulo prius descripto, ad angulos rectos excepi: Solis imagine circulum exactè complente, diligenter demum & sæpe adspexi, nigrum quodcunque in depicta Solis luce adversurus.

…Observavi enim die 24 à Solis exortu ad horam usque nonam, item paulò ante decimam ipsoque demum meridie, &hor. 1 pomeridianâ 2 aliis temporibus ad majora avocatus, quæ utique ob hæc parerga negligi non decuit: At omnibus iis momentis, nihil penitùs in Sole conspexi, exceptâ quadam pusillâ & communi Maculâ particulis quasi tribus à Solis centro ad sinistram remota quam etiam diebus præcedentibus, & sequentibus in Sole notavi: Ergo illa nihil ad Venerem.

Horâ atem 3 15´ post meridiem, quo primum tempore observationem repetere vacabat, discusæ penitus nubes ad oblatam veluti divinitùs occasionem invitarunt volentem: Ubi ecce gratissimum spectaculum, & tot votorum materiem notavi maculam novam, insolitæ magnitudinis, figuræque omnino circularis, supra limbum Solis sinistrum jam totaliter ingresam: adeò ut margines Solis & Maculæ, ad sinistram præcisè coinciderent, formantes angulum contactus: Statim hanc Veneris umbram esse minimè dubius ad sedulam illius observationem me accinxi.

… Locus observationis hujus, obscura quædam villa fuit, quindecim circiter milliaribus à Liverpolia distans ad Boream Liverpoliæ autem (ubi plurimas ante hac observationes habui) Latitudinem sæpe inveni grad. 53 20´ (etsi Mappæ vulgares illam statuant grad. 54 12´)



Deinde ſub horam obſervationis receſſi in aptam cameram, clauſiſque adverſus lucem feneſtris, Tubum opticum ad juſtam longitudinem extenſum, per foramen ad Solem direxi : radioſque Solares per Tubum tranſiuntes, circulo prius deſcripto, ad angulos rectos excepi : Solis imagine circulum exactè complente, diligenter demum & ſæpe adſpexi, nigrum quodcunque in depicta Solis luce adverſurus.

Obſervavi enim die 24 à Solis exortu ad horam uſque nonam, item paulò ante decimam ipſoque demum meridie, & hor. 1 pomeridianâ 2 aliis temporibus ad majora avocatus, quæ utique ob hæc parerga negligi non decuit : At omnibus iis momentis, nihil penitùs in Sole conſpexi, exceptâ quadam puſillâ & communi *Maculâ* particulis quaſi tribus à Solis centro ad ſiniſtram remota quam etiam diebus præcedentibus, & ſequentibus in Sole notavi : Ergo illa nihil ad Venerem. *Obſervatio die 24 Nov. St. Jul.*

Horâ atem 3 15′ poſt meridiem, quo primum tempore obſervationem repetere vacabat, diſcuſſæ penitus nubes ad oblatam veluti divinitùs occaſionem invitarunt volentem : Ubi ecce gratiſſimum ſpectaculum, & tot votorum materiem notavi *maculam* novam, inſolitæ magnitudinis, figuræque omnino circularis, ſupra limbum Solis ſiniſtrum jam totaliter ingreſſam : adeò ut margines Solis & *Maculæ*, ad ſiniſtram præcisè coinciderent, formantes angulum contactus : Statim hanc Veneris umbram eſſe minimè dubius ad ſedulam illius obſervationem me accinxi. *Venus circa veſperam in diſco Solis conſpicitur ab Horroxio.*

Ubinam obſervatio peracta fuerit. 4 Locus obſervationis hujus, obſcura quædam villa fuit, quindecim circiter milliaribus à Liverpolia diſtans ad Boream Liverpoliæ autem (ubi plurimas ante hac obſervationes habui) Latitudinem ſæpe inveni grad. 53 20′ (etſi Mappæ vulgares illam ſtatuant grad. 54 12′) ergo huic erit 53° 35′ Longitudo utriuſque mihi videbitur 22° 30′ ab Inſulis Fortunatis, quas jam Canarias dicunt, hoc eſt grad. 14 15′ad occidentem ab Uraniburgo Daniæ cujus Longitudo ab indigena Tychone ponitur grad. 36 45′ ab iiſdemInſulis. *Mercat Atlas Minor. Prog. T B*

Figure 2 — Horrocks's account of the Transit of Venus. By permission of the Institute for Astronomy, Vienna University.

and at times obscures its true meaning. For some reason it seems not to have been superseded by later more accurate translations.

In the preface to his book, Whatton says that the work on a biography of Horrocks was begun by his father, who had "gathered together much interesting detail connected with his personal history; and he also set about preparing a translation of his celebrated Treatise upon the transit of Venus over the Sun. But he did not live to complete his work"[12]. This brings to mind the question as to whether the translation was solely his father's work.

However he goes on to say that "In the translation of the *Venus*, I have endeavoured to adhere closely to the original, and have taken the text of Hevelius as a basis, merely correcting the punctuation from the Greenwich manuscript where it was necessary to do so, and altering the arrangement of the sentences where the difference of language required it," implying that the translation was all his own work and not that of his father.

I accept that the differences between the English and Latin languages require a certain amount of changes of word order, but his claim that he had adhered closely to Hevelius's Latin text and had only corrected its punctuation is, as I will show, being slightly economical with the truth.

The "Greenwich manuscript" to which Whatton refers is also mentioned in Prof. Rigaud's book *Correspondence of Scientific Men of the Seventeenth Century* published in 1841. In a footnote to a letter from Flamsteed to Collins dated 1670 March 20, Rigaud says:

"The *Venus in Sole Visa* was not inserted in the collection of Horrox's posthumous works. Hevelius had published it from a manuscript which was lent him by Huygens, among whose books there appears to be a tract answering the description of it; but Prof. Uylenbroek, with his accustomed care, was kind enough to examine this question for me completely, and could find no traces of the papers having been returned after the publication. This is much to be regretted, since the text, as printed by Hevelius, wants correction, especially in the punctuation. There is a manuscript at the Greenwich Observatory, which belonged to Flamsteed, (though not written by him) which varies much from the printed text, and may suggest some probable corrections; but it is no further authority" [13].

Rigaud goes on to quote directly from the Greenwich manuscript, which turns out to be very useful as it allows it to be identified as being the same later version that was sent to Mercator. A copy of this handwritten manuscript is held at the Cambridge University Library and comes from the papers of John Flamsteed[14]. Although Rigaud said that after publication the *Venus* had not been returned, the Library holds copies of two handwritten manuscripts that appear to match the printed version, at least in the sections being discussed[15].

Interestingly, the footnote also contains the following lines: "the late W.R. Whatton Esq. of Manchester, had made considerable collections for a life of Horrox, which he intended to have prefixed to a new edition of the *Venus in Sole Visa*, and he had the whole nearly ready for the press," which would seem to imply that indeed the translation had been completed by Whatton senior by the time that his son continued his work.

Not being a Latin scholar, I have not attempted a full translation of the *Venus*. Instead, in the following sections, I shall concentrate on highlighting some important differences between Whatton's translation and Hevelius's Latin text (and indeed an inconsistency in that text) when describing the circumstances of Horrocks's observations of the transit of Venus.

The Location

Whatton's translation tells us something of Horrocks's location when he observed the transit of Venus:

> This observation was made in an **obscure village** where I have **long been in the habit of observing**, about fifteen miles to the north of Liverpool, the latitude of which I believe to be 53° 20´.

However, if we look at what the *Venus* actually says:

> *Locus observationis hujus, **obscura quædam villa** fuit, quindecim circiter milliaribus à Liverpolia distans ad Boream Liverpoliæ autem (**ubi plurimas ante hac observationes habui**) Latitudinem sæpe inveni grad. 53[°] 20´ (etsi Mappæ vulgares illam statuant grad. 54[°] 12´.)*

The location is given as an *obscura quædam villa*, which could be translated as a "certain humble country house." To me this looks like a "false friend" as *villa* is not the usual Latin word for village; that is *pagus* or *vicus*. *Villa* is a villa or country house, which would seem to describe Carr House in Much Hoole, the generally accepted location for Horrocks's observations[16]. The word *obscura* though, is more difficult to translate as it has many further meanings such as dark, shady, hidden, obscure, indistinct, unknown, ignoble or reserved.

Now Whatton's translation would have us believe that Horrocks had "long been in the habit of observing" there. This seems to be based on linking the phrase in parentheses: (*ubi plurimas ante hac observationes habui*) (or, where I have made most observations before this) with his "obscure village," whereas I believe that it should be linked with Liverpool.

The problem is that Whatton has associated *Liverpoliæ* with the preceding word *Boream* to make "north of Liverpool" rather than with the following word *Latitudinem* to make "the latitude of Liverpool." In the process he has also ignored the first *Liverpolia*, which is contained in the phrase *quindecim circiter milliaribus à Liverpolia distans ad Boream* (about fifteen miles distant from Liverpool to the north). That *Liverpoliæ* should be the start of a separate clause is made clear by the use of the conjunction *autem* (but or moreover) in its usual second position. As a check, if we now remove the parentheses, the Latin of this second clause becomes *Liverpoliæ autem Latitudinem sæpe inveni grad. 53 20´*, which makes perfect sense as "however the latitude of Liverpool frequently I have found [to be] 53° 20´."

Combining all of the above changes gives the translation: "The place of this observation was a certain humble country house, about fifteen miles distant from Liverpool to the north, however the latitude of Liverpool (where I have made most observations before this) frequently I have found [to be] 53° 20´ (though the common maps may place that 54° 12´)."

This would seem more reasonable as Horrocks came from Toxteth Park in Liverpool and made many observations from there. It is interesting to note that on 1640 September 12, Horrocks, in a letter to Crabtree, said that he had made a new determination of the latitude of Toxteth to be 53° 25´ [17]. This new value also appears in the Greenwich manuscript, helping to date it as post-Hevelius's version.

The Whatton translation goes on to give the geographic co-ordinates of the villa: "therefore the latitude of the village will be 53° 35´, and the longitude of both 22° 30´ from the Fortunate Islands, now called the Canaries. This is 14° 15´ to the west of Uraniburg in Denmark, the longitude of which is stated by Brahé, a native of the place, to be 36° 45´ from these Islands."

Here Whatton has made another change from the Latin text: "*ergo huic erit 53° 35´ Longitudo utriusque mihi videbitur 22° 30´ ab Insulis Fortunatis, quas jam Canarias dicunt, hoc est grad. 14 15´ ad occidentem ab Uraniburgo Daniæ cujus Longitudo ab indigena Tychone ponitur grad. 36 45´ ab iisdem Insulis,*" but only in that he has replaced Tycho with his surname Brahé.

The value given for the latitude (53° 35´) is quite close to the modern value for Hoole[18], but the longitudes differ greatly. Toxteth is 15° 40´ west of the site of Tycho Brahe's observatory at Uraniburg not 14° 15´ and Uraniburg is 30° 51´ east of the Canaries not 36° 45´. Given the difficulties at the time of measuring longitude accurately, these errors are not surprising; however it is interesting to note that the latter value is more consistent with a prime meridian passing through the Cape Verde islands not the Canaries[19].

The Room

Whatton's translation is very specific about the room used for Horrocks's observations: "When the time of the observation approached, I retired to **my apartment**, and having closed the windows against the light."

If we compare this with the *Venus: "Deinde sub horam observationis recessi in* ***aptam cameram****, clausisque adversus lucem fenestris,"* which could be translated as "Then just before the time of observation, I retired to a suitable room, and with the windows having been shut against the light."

Here we see that that the *Venus* did not specify whose room it was. Whatton has assumed that it was Horrocks's room and added that interpretation into his translation. The adjective that is used to describe the room is *aptam*, from *aptus*, which can be translated as "fitted with" or "suitable," but not "my" (the Latin for "my" is *meus*). In fact, if we look through the whole translation of the *Venus*, Whatton has used "apartment" a further five times to translate the following phrases:

> *Loci angustia* - smallness of my apartment[20] (Literally: "narrowness of the room")
>
> *Loci angustia* - narrowness of the apartment[21] ("narrowness of the room")
>
> *Obscurâ camerâ* - dark apartment[22] ("dark room")
>
> *Opaco conclavi* - the apartment[23] ("dark room")
>
> *Sub opaco* - darkened apartment[24] ("under dark")

Only two of these ("narrowness of the apartment" and "dark apartment") would appear to be reasonable translations of the original.

There have been suggestions that the most suitable room in Carr House for the observation of the transit was of too high a status to be Horrocks's, but as the *Venus* does not say that the room was Horrocks's, it could be that he was just allowed to use it on that day for his important work.

The Telescope

When describing the arrangement of Horrocks's telescope, here again Whatton introduces his assumptions and interpretations into the translation: "I directed **my telescope, previously adjusted to a focus,** through the aperture towards the sun." However, again the *Venus* is not so specific: *"****Tubum opticum ad justam longitudinem extensum****, per foramen ad Solem direxi."* This could be translated as: "I directed the telescope, extended to the right length, through a hole towards the Sun."

One thing to note here is that in other places the *Venus* also uses the word *telescopii* for telescope rather than *tubum opticum*, but I do not think that is of much consequence. Needless to say the *Venus* in this case does not say that it was Horrocks's own telescope!

The Latin phrase contains another "false friend" in that *ad justam* does not mean adjusted, instead I believe that it means "to the right or to the proper." There is also no mention of focus, instead just the descriptive *extensum*, from *extendo* (to extend, stretch out or enlarge). There can be no doubt that Horrocks did adjust his telescope to focus the image of the Sun, but that is an interpretation, not a translation. If we look at the literal translation "extended to the right length" it could be reflecting the fact that Horrocks would have had to pull out the eyepiece of the telescope a little from its normal position to form a real image of the Sun on a piece of paper.

The Time

Trying to understand the times used in the *Venus* was what first led me to examine the Latin text in more detail. One problem I have with the Whatton translation is that it does not differentiate between the casual references to time and the precise recording of observations that are in the *Venus*.

At the beginning of the translation we have: "I watched carefully on the 24th from sunrise to nine o'clock, and from a little before ten **until noon**, and at one in the afternoon," but this ignores an important qualification in the *Venus* when it describes noon: *"Observavi enim die 24 à Solis exortu ad horam usque nonam, item paulò ante decimam* ***ipsoque demum meridie****, &hor. 1 pomeridianâ"* or: "For on the 24th I observed from sunrise right up to nine o'clock, also a little before ten and then at noon precisely, and at one in the afternoon."

The *Venus* qualifies *meridie*, from *meridies* (midday, noon, or south), by both *ipso* (precisely) and *demum* (just or precisely), turning a casual reference into a precise observation. This could have been important to Horrocks for calibrating the clock that he would use later to record his observations of Venus. Clocks in 1639 were still very inaccurate, as the pendulum clock was not introduced until a few years later, so a check against the Sun at local noon would have been very useful. It is interesting to note that in the three handwritten manuscripts of the *Venus, & hor. 1 pomeridiana* is written in full as *et hora prima pomeridiana, i.e.* the figure "1" was introduced by Hevelius making the time appear more exact than it really was.

When the Whatton translation describes the time of Horrocks's first sighting of Venus, it says it was: "**About** fifteen minutes past three in the **afternoon**…."

This seems strange, as surely Horrocks would have wanted to make a precise record of the time for use in his calculations of the position of the node of Venus's orbit. In fact, those later calculations do not treat this time as being any more imprecise than other ones taken during the transit. However, if we look at what the *Venus* actually says: *"Horâ **a[u]tem** 3 15´ **post meridiem**"* or "but 3h 15m after noon." The Latin word for "about" *(circa)* does not appear. Is it possible that Whatton could have been confused by the misprinted *autem* (but) appearing as *atem*?

Also, the translation does not distinguish between the casual single word for afternoon (*pomeridianâ*) that was used in the previous phrase "one in the afternoon" and the more precise scientific term *post meridiem*. This latter phrase I believe is being used in its more literal sense, *i.e.* after noon or after the Sun had crossed the meridian at noon, making it clear that the noted time (3 15´) was a precise observation made in local apparent time and linked directly to the motion of the Sun[25].

The Diversion

During the above description of the times of Horrocks's observations, the Whatton translation contains the phrase: "and at one in the afternoon, being called away in the intervals by business of the **highest importance** which, for these **ornamental pursuits**, I could not with propriety neglect."

This phrase must be one of the most famous and researched in the whole of the *Venus*, with much speculation on what the "business of the highest importance" might be. Unfortunately, in this case examining the *Venus* does not offer any further clues. All it says is: *"&hor. 1 pomeridianâ 2 aliis temporibus ad majora avocatus, quæ utique ob hæc parerga negligi non decuit"* where *ad majora* (to greater things) is not elaborated any further. Note that the strange figure "2" at the start of this phrase has nothing to do with the text and is purely a reference number to a footnote that Hevelius added to his version and is not present in all three handwritten manuscripts.

One point of interest though, is that in the Greenwich manuscript, the word *parerga* is written in the Greek alphabet so making a direct reference to its origin. In Greek mythology the parerga were the incidental deeds that Hercules performed whilst carrying out his twelve labours. To my mind the sense is of doing something while you should really be doing something else, *i.e.* Horrocks is doing astronomy rather than his job.

Whatton calls these "ornamental pursuits," which I believe obscures the meaning (I certainly did not understand it). Although, according to my English dictionary, parerga is an English word, I would propose the following translation instead: "I was distracted at the other times to greater things, which it was not proper I neglected, at least for the sake of these minor diversions."

The Appearance of Venus

The Whatton translation describes Horrocks's reaction to seeing Venus for the first time: "I then beheld a most agreeable spectacle, the object of my **sanguine wishes**." Here again a word has been introduced that does not appear in the original *Venus*: *"Ubi ecce gratissimum spectaculum, & tot votorum materiem"* or, "When lo and behold a most agreeable spectacle, and the subject of so many wishes!"

Whatton appears to have introduced the word "sanguine." The Latin for "sanguine" is *laetus*, so is it possible that he might have misread the ampersand in *& tot* (and so many) as *lae*, making it into *laetot*?

Curiously, at the time of the next transit in 1761 (thus, before the time of Whatton's translation), a book entitled *The Annual Register Of the Year 1761*[26] included a description of the 1639 transit taken from Hevelius's version of the *Venus*. Part of this description says "for then he beheld the most agreeable sight, a spot, which had been the object of his most sanguine wishes." So is it possible that I am doing a disservice to Whatton and he was just carrying on the tradition of this earlier work?

Whatton's translation continues by saying: "which had already fully entered upon the sun's disc on the left, so the limbs of the Sun and Venus **precisely** coincided." Here I believe we have another false friend, as the *Venus* says: *"supra limbum Solis sinistrum jam totaliter ingressam: adeò ut margines Solis & Maculæ, ad sinistram **præcisè** coinciderent."*

The word *præcisè* means briefly or absolutely, but not precisely, the Latin for precise is *demum*. Thus the description could be of something much more dynamic than Whatton's translation would suggest, namely "had already entirely entered upon the left limb of the Sun, to such an extent that the edges of the Sun and of the spot briefly coincided on the left." Bearing in mind that second contact for Horrocks would have occurred at 15:18 UT or 3:17 local apparent time, *i.e.* two minutes after he first saw Venus, this seems a wholly reasonable description of the event, as anyone who watched the 2004 transit would recognize. In addition, Whatton has omitted one vital piece of information (as we shall see in the next section) that the edges of the Sun and spot (not Venus as Whatton interprets it) were also touching on the left (*ad sinistram*).

The Measurements

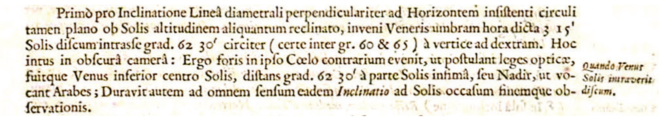
Whatton's translation contains Horrocks's description of his measurements of the position of Venus on the Sun's image[27]:

> In the first place, with respect to the inclination, the line of the diameter of the circle being perpendicular to the horizon, although its plane was somewhat inclined on account of the Sun's altitude, I found that the shadow of Venus at the aforesaid hour, namely fifteen minutes past three, had entered the Sun's disc about 62° 30´, certainly between 60° and 65°, from the top towards **the right**. This was the appearance in the dark apartment; therefore out-of-doors beneath the open sky, according to the law of optics, the contrary would be the case, and Venus would be below the centre of the sun, distant 62° 30´ from the lower limb, or the nadir, as the Arabians term it. The inclination remained to all appearance the same until sunset, when the observation was concluded.

Here there is an interesting puzzle. The *Venus*, as we have seen, says that when Horrocks first saw Venus it was *supra limbum Solis sinistrum* (upon the left limb of the Sun) and that the edges of the Sun and Venus *ad sinistram præcisè coinciderent* (briefly coincided on the left). However, now the translation says that Venus "had entered the Sun's disc about 62° 30´, certainly between 60° and 65°, from the top towards **the right**." Why the discrepancy? Has Whatton made another error in his translation?

In this case though, it would appear that Whatton is not the guilty party[28] (Figure 3):

> *"Primò pro Inclinatione Lineâ diametrali perpendiculariter ad Horizontem insistenti circuli tamen plano ob Solis altitudinem aliquantum reclinato, inveni Veneris umbram hora dicta 3 15´ Solis discum intrasse grad. 62 30´ circiter (certe inter gr. 60 & 65) à vertice* ***ad dextram****. Hoc intus in obscurâ camerâ: Ergo foris in ipso Coelo contrarium evenit, ut postulant leges opticæ, fuitque Venus inferior centro Solis, distans grad. 62 30˝ à parte Solis infimâ, seu Nadir, ut vocant Arabes; Duravit autem ad omnem sensum eadem Inclinatio ad Solis occasum finemque observationis."*


Primò pro Inclinatione Lineâ diametrali perpendiculariter ad Horizontem insistenti circuli tamen plano ob Solis altitudinem aliquantum reclinato, inveni Veneris umbram hora dicta 3 15' Solis discum intrasse grad. 62 30' circiter (certe inter gr. 60 & 65) à vertice ad dextram. Hoc intus in obscurâ camerâ: Ergo foris in ipso Cœlo contrarium evenit, ut postulant leges opticæ, fuitque Venus inferior centro Solis, distans grad. 62 30' à parte Solis infimâ, seu Nadir, ut vocant Arabes; Duravit autem ad omnem sensum eadem *Inclinatio* ad Solis occasum finemque observationis.

Quando Venus Solis intraverit discum.

Figure 3 — Horrocks's measurement of the position angle of Venus. By permission of the Institute for Astronomy, Vienna University.

The phrase above in the Venus, *à vertice ad dextram*, means "from the top towards the right," so in this case Whatton and the Venus agree, so why the change of position, and which one is correct?

If we assume that Horrocks was using a Galilean telescope, this telescope, when adjusted to project a real image of the Sun onto a piece of paper, would have (as the *Venus* says) introduced a single inversion about both vertical and horizontal axes. This would have moved the position of Venus from the bottom left quarter of the Sun (its true position seen without a telescope) to the top right. However, this is its position as though the observer were looking through a piece of transparent paper towards the Sun. When the observer turns his back on the Sun to look at the front of the paper, another reversal is introduced, this time only about a vertical axis, so the position of Venus shifts from the top right to top left.

Horrocks's first two descriptions match this exactly, so for some reason the third is out of step. This is where the handwritten manuscripts of the *Venus* are very interesting. All three write the phrase as "*a vertice* ***ad sinistram***" (from the top towards **the left**), with two of them underlining the phrase and placing a cross in the margin[29]. It would seem that somewhere along the way confusion has occurred, and Hevelius has changed the direction, possibly to agree with his own experience with Keplerian (inverting) telescopes.

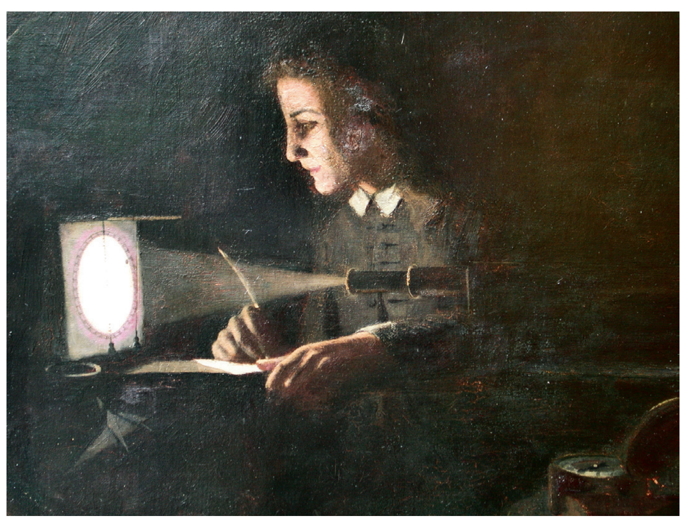


Figure 4 — J.W. Lavender's representation of Horrocks observing the transit. By permission of Astley Hall Museum & Art Gallery, Astley Park, Chorley.

It is interesting to note that Venus is depicted in the incorrect top right hand corner in W.R. Lavender's portrait of Horrocks (Figure 4) and in Ford Madox Brown's painting "Crabtree Watching the Transit of Venus." Curiously chapter three of the *Venus* also claims that William Crabtree saw it in this position. However the handwritten manuscripts of this section of the book show that this is another of Hevelius's changes.

That Hevelius made some changes there can be no doubt, for the famous diagram of the observation that he inserted into the published version of the *Venus* does not match Horrocks's description either of what he saw on his paper, or how he projected it back onto the heavens (Figure 5).

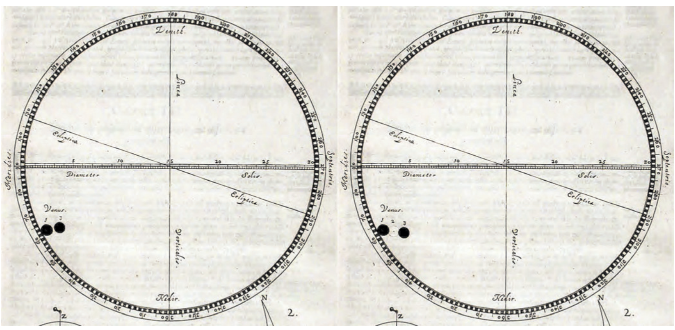


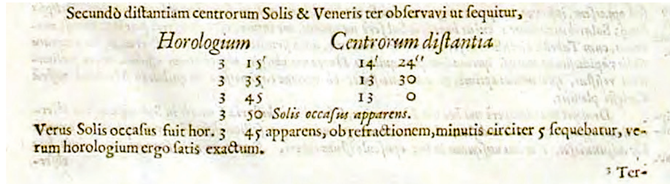
Figure 5 — Hevelius's diagram of the transit (right) compared with the true appearance (left). By permission of the Institute for Astronomy, Vienna University.

In Figure 5, I show on the right Hevelius's drawing[30] and on the left how the transit would have appeared on the sky, based on a prediction by HM Nautical Almanac Office. The prediction matches Horrocks's description that: "The inclination remained to all appearance the same until sunset," whereas Hevelius's diagram would suggest that a change in inclination had been seen. Similarly, Hevelius's diagram shows the second observation of Venus to be mid-way between the other two observations, whereas Horrocks made three observations separated by 20 minutes and 10 minutes as described in the Venus[27] (Figure 6):

"Secundò distantiam centrorum Solis & Veneris ter observavi ut sequitur,

Horologium	Centrorum distantia
3 15´	14´ 24″
3 35	13 30
3 45	13 0
3 50	*Solis occasus apparens.*

Verus Solis occasus fuit hor. 3 45 apparens, ob refractionem, minutis circiter 5 sequebatur, verum horologium ergo satis exactum."



Secundò diſtantiam centrorum Solis & Veneris ter obſervavi ut ſequitur,

Horologium	*Centrorum diſtantia*
3 15′	14′ 24″
3 35	13 30
3 45	13 0
3 50	*Solis occaſus apparens.*

Verus Solis occaſus fuit hor. 3 45 apparens, ob refractionem, minutis circiter 5 ſequebatur, verum horologium ergo ſatis exactum.

³ Ter-

Figure 6 — Horrocks's measurements of the motion of Venus relative to the Sun. By permission of the Institute for Astronomy, Vienna University.

Or from Whatton's translation:

" In the second place, the distance between the centres of Venus and the Sun I found, by three observations, to be as follows:

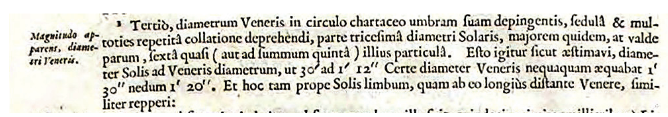
The Hour.		Distance of the Centres.
At 3 . 15	by the clock.	14″ 24´
At 3 35	by the clock.	13 30
At 3 45	by the clock.	13 0
At 3 50	by the clock.	*the apparent sunset.*

The true setting being 3.45 and the apparent about 5 minutes later, the difference being caused by refraction. The clock therefore was sufficiently correct."

giving an unequal spacing.

It seems that Hevelius was well-known for "reconstructing" observations for inclusion in his books, as the diagram of his own observations of the 1661 transit of Mercury (contained in the same volume as the *Venus*) was questioned at the time by Flamsteed and others[31].

Curiously, Horrocks might also have been guilty of reverse engineering his results. On the subject of the apparent diameter of Venus, the *Venus* says[32] (Figure 7):



Magnitudo apparens, diametri Veneris.

³ Tertiò, diametrum Veneris in circulo chartaceo umbram ſuam depingentis, ſedulâ & multoties repetitâ collatione deprehendi, parte triceſimâ diametri Solaris, majorem quidem, at valde parum, ſextâ quaſi (aut ad ſummum quintâ) illius particulâ. Eſto igitur ſicut æſtimavi, diameter Solis ad Veneris diametrum, ut 30′ ad 1′ 12″ Certe diameter Veneris nequaquam æquabat 1′ 30″ nedum 1′ 20″. Et hoc tam prope Solis limbum, quam ab eo longiùs diſtante Venere, ſimiliter repperi:

Figure 7 — Horrocks's measurement of the diameter of Venus. By permission of the Institute for Astronomy, Vienna University.

"In the third place, I found after careful and repeated observation, that the diameter of Venus, as her shadow was depicted on the paper, was larger indeed than the thirtieth part of the solar diameter, though not more so than the sixth, or at the utmost the fifth, of such a part. Therefore let the diameter of the Sun be to the diameter of Venus as 30´ to 1´ 12´ , and this was evident as well when the planet was near the Sun's limb, as when far distant from it."

This value for the diameter of Venus (1´ 12˝)[33] is consistent with Horrocks having seen second contact at the time of his first observation at 3:15 p.m., as a Venus radius of 36˝ added to the distance of the centres of 14´ 24˝ gives an apparent radius of the Sun of 15´, or a diameter of 30´.

Now, in the Greenwich manuscript of the Venus, the distance of the centres for 3:15 is given as 14´ 25˝[34], whereas the distances for the other two times remain the same. Why the change? It would appear that Horrocks in the later version of the manuscript had a change of heart over the size of Venus, giving it as 1´ 10˝ (his lower estimate), whether this was because Crabtree (the only other person to see the transit) had measured a smaller value of 1´ 3˝ we can but speculate. However, the change, for whatever reason, meant that using the original distance of the centres would leave a gap of 1˝ between Venus and the limb of the Sun. To close that gap and hence maintain second contact Horrocks was forced to move it away from the centre of the Sun also by 1˝.

The Translation

In conclusion, I present here my translation of the most interesting and famous parts of the *Venus*, which incorporates all of the points mentioned in the previous sections, in the hope that it might provoke someone to create a replacement for the Whatton translation in time for the next transit in 2012:

> Then just before the time of observation, I retired to a suitable room, and with the windows having been shut against the light, I directed the telescope, extended to the right length, through a hole towards the Sun, and I intercepted at right angles the solar rays passed through the tube, with the circle previously having been described. With a picture of the Sun exactly filling the circle, I looked painstakingly at length and often, to notice whatever black spot might be in the described light of the Sun.
>
> …For on the 24th, I observed from sunrise right up to nine o'clock, also a little before ten and then at noon precisely, and at one in the afternoon. I was distracted at the other times to greater things, which it was not proper I neglected, at least for the sake of these minor diversions: but, at all these moments I observed nothing inside on the Sun, except a certain very little and common spot with about three small parts, remote from the centre of the Sun towards the left, which I also noted on the preceding and following days on the Sun: therefore this had nothing to do with Venus.
>
> But 3h15m after noon, which was the first time to be free to go back to observing, the clouds having been completely scattered just as if offered by divine influence, invited a favourable opportunity: When lo and behold, a most agreeable spectacle, and the subject of so many wishes! I saw a new spot of unusual size, and of altogether circular shape, had already entirely entered upon the left limb of the Sun, to such an extent that the edges of the Sun and of the spot briefly coincided on the left, forming an angle of contact. Immediately there was very little doubt that this was the shadow of Venus, I prepared myself to observe it with diligence.
>
> …The place of this observation was a certain humble country house, about fifteen miles distant from Liverpool to the north, however the latitude of Liverpool (where I have made most observations before this) frequently I have found [to be] 53° 20´ (though the common maps may place that 54° 12´) therefore 53° 35´ will be for this. The longitude of both I think will be 22° 30´ from the Fortunate Islands, which now are called the Canaries, that is 14° 15´ to the west from Danish Uraniburg whose longitude is placed by the native Tycho 36° 45´ from the same islands.

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Astley Hall Museum & Art Gallery, Astley Park, Chorley. ✶

Notes and References

Mark Edwards, B.Sc., Dip. Adv. Stud. Sci., FRAS, was born in Coventry and studied radio astronomy in the 1970s under Dr. Henry Palmer and Sir Bernard Lovell at the Jodrell Bank Observatory. Now semi-retired after working for thirty years in the telecommunications industry he now follows his interest in astronomy as an amateur from home and as a member of the committee of the Coventry and Warwickshire Astronomical Society. It was while researching the times of the 1639 transit for Coventry that he was led to examine Horrocks's account more closely. In addition to trying to understand Horrocks's observations, his research interests include dating and locating old paintings from the astronomical events they contain.

1 This account is taken from Aughton, Peter. *The Transit of Venus*. London: Phoenix, 2005. 16, 30, 31, 50. The actual date of Horrocks' birth is uncertain, Allan Chapman argues for his birth year being 1619, see Chapman, Allan (1990). Jeremiah Horrocks, the transit of Venus, and the 'New Astronomy' in early seventeenth-century England. *The Quarterly Journal of the Royal Astronomical Society, 31(3),* 334.

2 Wallis, John. *Jeremiae Horroccii Liverpoliensis Angli, ex Palatinatu Lancastriae, Opera Posthuma*. London: D. Pauli, 1678, 323, 333. This is referred to hereafter as *Opera Posthuma*. In a letter from Horrocks to Crabtree dated 1639 June 1, he says that he is travelling to Hoole on the following 7th of the month, and in another letter to Crabtree dated 1640 July 18, he says that he has just returned to Toxteth.

3 This is the date according to the Julian calendar still in use in England in the 17th century, although by then most other European countries had changed to the present-day Gregorian calendar. This resulted in the confusing use of both styles of date on the title page of Hevelius's "*Mercurius in Sole visus Gedani,*" where the date for his observations of the transit of Mercury is given as 1661 May 3 in the Gregorian calendar, whereas the date for Horrocks' observations of the transit of Venus is given as 1639 November 24 in the Julian calendar. To be consistent, the latter should read 1639 December 4 in the Gregorian calendar.

4 Wallis. *Opera Posthuma*. Reference 2. 338. The date of Horrocks's death was written by William Crabtree on the reverse of the last letter he received from Horrocks on 1640 December 19.

5 Aughton, Peter. *The Transit of Venus*. London: Phoenix, 2005. 4.

6 Applebaum, Wilbur and Hatch, Robert A. (1983). Boulliau, Mercator, and Horrocks's "Venus in Sole Visa": Three Unpublished Letters. *Journal for the History of Astronomy, 14(3),* 171. In a footnote (no. 20) Applebaum and Hatch mention that this route for the *Venus* comes from Huygens's own letters, whereas Aughton states that it was Samuel Hartlib who showed the *Venus* to Christian Huygens, but gives no reasons for that assertion.

7 Hevelius, Johannis. *Mercurius In Sole visus Gedani Cui annexa est, Venus in Sole partier visa*. Gdansk: Simon Reiniger, 1662. This is referred to hereafter as *Venus*.

8 W.R. Whatton was also a surgeon at the Manchester Royal Infirmary and had the dubious honour of operating on the first victim of a railway accident, William Huskisson, on 1830 September 15.

9 Whatton , Arundell Blount (1859). *Memoir of the Life and Labors of the Rev. Jeremiah Horrox, Curate of Hoole, near Preston; to which is appended A Translation of His Celebrated Discourse upon the Transit of Venus across the Sun*. London: Wertheim, Macintosh and Hunt, pp 123-126. This is referred to hereafter as: *Memoir.*

10 Whatton. *Memoir*. Reference 9. 123-126.

11 Hevelius. *Venus*. Reference 9. 115-116.

12 Whatton. *Memoir*. Reference 9. vii-viii.

13 Rigaud, Stephen Jordan (1841). *Correspondence of Scientific Men of the Seventeenth Century, including letters of Barrow, Flamsteed, Wallis and Newton, printed from the originals, in the Collection of the Right Honourable the Earl of Macclesfield Vol II.* Oxford: University Press, pp 110-111.

14 Horrocks, Jeremiah. *Venus in Sole Visa*. 14. Cambridge University Library, West Road, Cambridge, CB3 9DR, England. RGO 1/68/C. The passage referred to: "*Die autem 23 admodum nebulosa, ne Sol quidem visus. Sequente 24 paulo clariore, observationem institui a Solis exortu ad horam usque nonam*" replaces the rather less descriptive "*Observavi enim die 24 à Solis exortu ad horam usque nonam*" of the Hevelius version.

15 Horrocks, Jeremiah. *Venus in Sole Visa*. Cambridge University Library, West Road, Cambridge, CB3 9DR, England. RGO 1/76 and Add. 9320.

16 In a letter (translated into Latin by Wallis) from Horrocks to Crabtree dated 1639 June 1 (Wallis. *Opera Posthuma*. Reference 2. 323), he refers directly to Hoole using the word "villa" to describe it, but sadly without any further elaboration.

17 Wallis. *Opera Posthuma*. Reference 2. 334.

18 Using the later latitude of 53° 25´ for Toxteth gives a latitude of 53° 40´ for Hoole, which is even closer to the modern value of 53° 42´.

19 A note in the margin (which appears not to have been added by Hevelius as it is present in the handwritten manuscripts) says "Prog. T.B. Tom.1. pag. 13." This seems to be a reference to Tycho Brahe's *Progymnasmata* which does indeed give the value of 36° 45´, but does not give the prime meridian on which it was based. However, in his *Astronomiæ Instauratæ Mechanica* he gives the same value with the explanation that it had been estimated from the calculations of Copernicus and by considering the differences between the meridians used by Ptolemy and Copernicus.

20 Hevelius. *Venus*. Reference 7. 114 and Whatton. *Memoir*. Reference 9. 118.

21 Hevelius. *Venus*. Reference 7. 115 and Whatton. *Memoir.* Reference 9. 121.

22 Hevelius. *Venus*. Reference 7. 115 and Whatton. *Memoir*. Reference 9. 125.

23 Hevelius. *Venus*. Reference 7. 117 and Whatton. *Memoir*. Reference 9. 129.

24 Hevelius. *Venus*. Reference 7. 120 and Whatton. *Memoir*. Reference 9. 140.

25 On 1639 May 22, Horrocks observed an eclipse of the Sun from Toxteth during which he made several measurements of the Sun's altitude to calibrate his clock (Wallis. *Opera Posthuma*. Reference 2.327-328). He also did this for the transit, but only by checking the time of sunset. Presumably he was too occupied in measuring the size and position of Venus beforehand.

26 Burke, Edmund (1762). *The Annual Register, or a View of the History, Politicks, and Literature, Of the Year 1761*. London: R. and J. Dodsley, 194.

27 Whatton. *Memoir*. Reference 9. 125-126.

28 Hevelius. *Venus*. Reference 7. 115.

29 Horrocks, Jeremiah. *Venus in Sole Visa*. 15. Cambridge University Library, West Road, Cambridge, CB3 9DR, England. RGO 1/68/C and RGO 1/76. Applebaum and Hatch note the same discrepancy. In a footnote (no. 31) to a letter to Hartlib attributed to Mercator, they also point out that the same mistake was made by John Wallis when he edited Horrocks' Opera Posthuma. On page 393 when he gave Horrocks' observations of the transit, he added the note "lege dextram" – read right, after "sinistram."

30 Hevelius. *Venus*. Reference 7. Figure G. (between pages 116 and 117).

31 Flamsteed, John. Letter from Flamsteed to Sir Jonas Moore. 45-49. Cambridge University Library, West Road, Cambridge, CB3 9DR, England. RGO 1/43.

32 Hevelius. *Venus*. Reference 7. 116.

33 Note that the diameter of Venus (1´ 12˝) given here is not a true angular diameter. It is based on making the Sun's image fill a circle whose diameter was divided into a scale of 30 equal parts, so it should be read as 1 graduation and a fifth on that scale. In Chapter 16 of the *Venus*, Horrocks (Hevelius, *Venus*, 137) uses an angular diameter of the Sun of 31´ 30˝ to derive an angular diameter for Venus of 1´ 16˝.

34 The changed values of 14´ 25˝ and 1´ 10˝ are also quoted in Wallis. *Opera Posthuma*. Reference 2. 393.

Pen & Pixel

Figure 1 – Charles Banville from the Victoria Centre captured two perfect moments in time on December 10—the emergence of the Moon from the Earth's shadow and the onset of fog in Victoria Harbour. This image was taken from Gonzales Observatory using a Canon D7 with an 85-mm lens. Exposure was ½ second at f/2.8 and ISO 800.

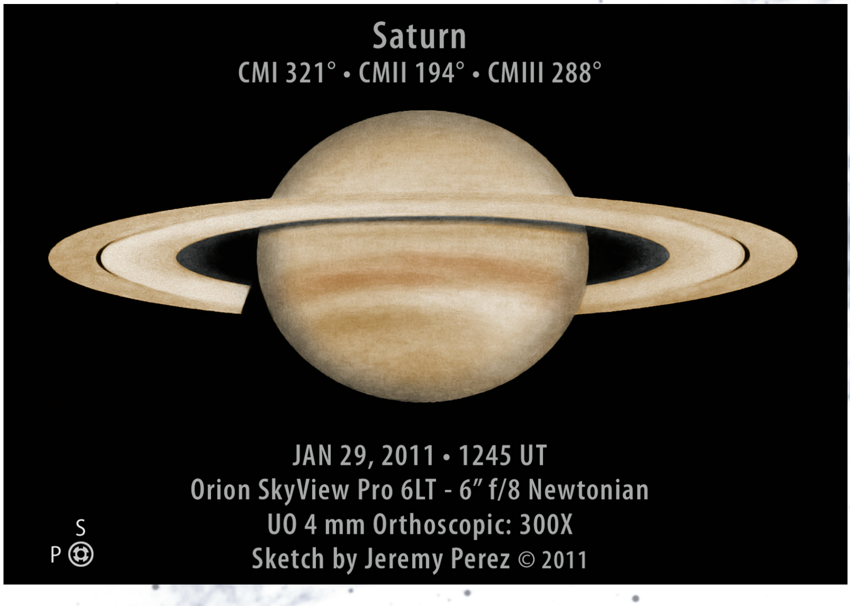

Figure 2 – Now that Saturn's rings are opening, visual observers are being presented with a much finer view of the rings than in the past two years. Jeremy Perez of Flagstaff, Arizona, took advantage of January skies and his artistic abilities to portray the planet.

Figure 3 – Kerry-Ann Lecky-Hepburn brings us IC 342, a nearby spiral galaxy in Camelopardalis that usually doesn't attract much attention. Though large—bigger than the full Moon—it is partly obscured by dust in the Milky Way, giving it a visual magnitude of 9.1. Kerry-Ann used an Astro-Tech AT8RC telescope and a QHY-8 camera to collect 58 10-minute sub-exposures (totalling 9 hours 40 minutes) of this impressive galaxy.

Figure 4 – Sometimes a familiar object becomes unfamiliar when an exposure enhances details that the eye often overlooks. This nearly full Moon by Steve McIntyre is an integration of 120 frames taken with a Canon XS (with filter removed) on an AT106 refractor (4-inch APO) with a field flattener. Steve picked an ISO of 100 with four different exposure times: 1/500; 1/320; 1/200; and 1/160 second to compose the image.

Cosmic Contemplations

Hocus Pocus, There's No Need to Focus!

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

When I read some of the first online stories about the new Lytro camera early last year, I thought it was an elaborate hoax. It claimed to be able to refocus those blurry out-of-focus images—after they were mistakenly taken. The examples shown were remarkable. Too remarkable, reminding me of the advanced features of the Pomegranate cell phone that included a single-serving coffee brewer, shaver, and harmonica. That turned out to be a slick and viral marketing campaign from the government of Nova Scotia (http://pomegranatephone.com/), and I still wish they had built it, perhaps at Malcolm Bricklin's defunct car factory. However, the Lytro camera is reality. As I write, just past New Year's Day, the first customers have received this $500 device and posted images. The future of digital imaging has arrived.

Figure 1 — the Lytro camera.

Looking at this minimalistic, rectangular *über*-gadget, you might find my words too bold. In fact, techno pundits have deplored it as a toy, because it takes low-resolution images, has no wireless interface, and cannot do video. Sadly and not surprisingly, they completely miss the point. Lytro has upended and reconceptualized image taking, because *images are no longer taken but computed*. The Ford Model T automobile was a terrible vehicle to operate (you had to hand crank the engine to start and manually advance or retard the ignition timing on the fly), but it profoundly changed and continues to change all of our lives. The image-processing algorithms and CCD sensor modifications developed by Lytro hold the promise to do the same for imagers everywhere.

Lytro company founder and CEO, Dr. Ren Ng has made his 2006 Stanford University doctoral thesis available on the Lytro Web site and I read it, several times. Unfortunately I still do not understand the mathematics behind his digital light-field camera but I think I can summarize how it works and what it means for astro imaging. A digital light-field camera records all the light rays within the camera as pixel data and by reverse ray tracing this data with proprietary algorithms, can correct the light-ray paths so that they converge at the correct focal plane. Images that are out of focus are the result of light rays not converging at a common focal plane, namely the CCD sensor. Since light-ray paths can be corrected *ex post facto*, out-of-focus problems can be remedied. Since each pixel of the resultant image can now be focused independently of each other, depth-of-field problems can be eliminated in portrait photography. For example, a wedding portrait often situates the groom behind his loving bride and in order to emphasize the couple, a large aperture (or small f-stop) is chosen that will result in a shallow depth of focus and allow the distracting background to vanish in a blur of unfocus or bokeh.

However, if the depth of focus is too shallow, it becomes difficult to keep both partners in focus, since they are not standing within the same plane. Digital light-field imaging allows you to ensure that both figures remain in focus, deepening the depth of field while keeping the large aperture, which improves image quality through a high signal-to-noise ratio. Since the path of light rays can be corrected, this naturally leads to the correction of lens aberrations that also manifest as focus problems, in this case light rays not converging to a common point.

Figure 2 — Examples of refocusing and extended depth of field.

For amateur astro-imagers, fast imaging platforms like the Hyperstar (f/2) or camera lenses can be difficult to accurately focus because the range of optimum focus positions is very narrow. In the case of camera lenses, the act of focusing itself is very difficult to attenuate. Off-axis optical aberrations such as coma in reflectors and astigmatism in refractors become difficult to ignore with the availability of larger and larger imaging sensors. Spherical aberrations are also becoming more commonplace with the trend to larger diameter refractors, in which light rays passing through the periphery of the lens refract too strongly. The fundamental issue of good focus can be addressed with light-field imaging, and the addition of extra optical elements such as coma correctors or field flatteners may be avoided. Depth of field is not an issue with astro imaging, since all subjects are focused at infinity. Although this technique was demonstrated in Dr. Ng's prototype, consumer cameras and software are currently unable to perform this correction.

Mathematically mapping all the light rays inside the camera seems improbable despite several assumptions designed to simplify the system. Instead of a 5-dimensional representation of each light wave (a 3-D Cartesian coordinate for position and a 2-D one for direction), the lack of internal camera obstructions or scatter allowed Ng to express each ray as a pair of two coordinate values, one signifying the two dimensional position of the ray as it enters the optical plane and the second as it intersects the imaging plane. The radiance of any spot would be an integral expression of all light rays converging at that spot. The limited resolution of light-ray direction data collection also reduced the number of light rays processed to a finite quantity.

A microlens array (with an f-value matching the main camera lens) is placed a focal length over the CCD sensor, such that each lens covers a square array of pixels that will record the directional data of all light rays emerging from the optical plane and converging onto one pixel of the final image. The total resolution of the sensor is reduced by a factor equivalent to the size of each microlens pixel array. A full frame sensor (24 × 36 mm) with 2-µm pixels (a common size found in compact point-and-shoot cameras) yields an image of over 200 megapixels. If each microlens covered a 10 × 10 pixel array, then the final image would have a 2 MP size. There is an assumption that in the very near future even more pixel-dense sensors will be available, so that the final image will be of a respectable size.

Each microlens pixel array creates a subaperture image—a facsimile of the final image but reduced in scale and field of view. The directional data of each light ray are recorded as small parallax shifts; each subaperture image is similar to the ones beside it but with minute shifts. Those parts of the final image that are not in focus exhibit these small positional shifts, so that when the subaperture images are summed together, those areas become blurred. Areas that are in focus do not shift and when summed, exhibit sharpness and clarity. So instead of representing each light ray as a vector quantity and performing complex and repetitive calculations to reposition errant vectors, Ng developed a refocus algorithm that merely shifts these subaperture images the appropriate amount and direction before summing them all to create a final in-focus image. Even this algorithm proved very processor intensive, and so he developed another using a Fourier slice transformation that proved to be an order of magnitude quicker.

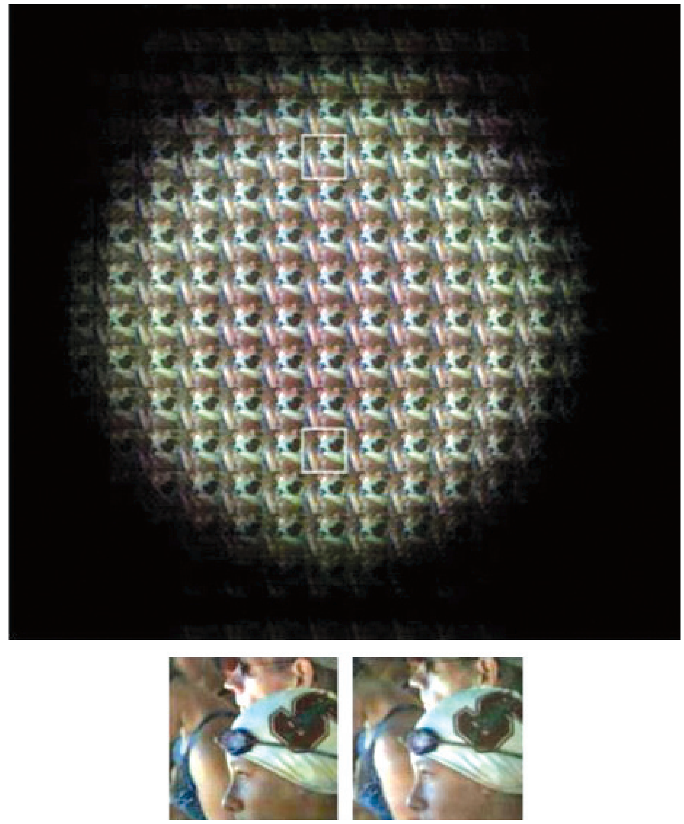

Figure 3 — Sub-aperture images of the light field in Figure 2. The bottom images are close-ups of the outlined regions in the top and bottom of the array.

The new Lytro camera is clearly intended as a proof-of-concept exercise, as the many engineering compromises required to lower the price point to the consumer level make it unattractive to the serious amateur. The real revenue for the company lies in licencing the technology to established camera manufacturers, which I predict will radically change the way we perform astro-imaging in the next decade.

Now for a less esoteric retro look back to the 1960s. We're all familiar with the T-thread (M42 × 0.75mm) attachment found on all manner of telescopes and accessories. The T does not refer to telescope but to the Japanese camera lens manufacturer Tamron, who introduced it in 1957 as a means to simplify their manufacturing process and inventory control. Dealers need theoretically stock only a handful of lenses, which could fit a multitude of camera bodies using an inexpensive T-ring adaptor. Like many good ideas, it did not catch on and disappeared in the 1970s. This means that there are plenty of good quality orphaned lenses available at lost cost for widefield imaging, and most astro-imaging cameras come with a T-thread attachment. Pentax camera lenses also use a 42-mm diameter flange but have a coarser 1-mm thread pitch, which will prevent secure seating. The T-thread mount also has an unusually long flange-to-sensor distance specification (to ensure working with all known 35-mm camera bodies) of 55 mm, allowing the potential placement of a thin-profile off-axis guider between camera and lens. This is certainly the case with the QSI line of astro-imaging cameras.

One of the more prolific T-mount lens manufacturers of that time period was Vivitar. Like Kodak, the Vivitar company of today is a pale shadow of its former self. It was then known for designing advanced and exceptional lenses such as the 800-mm solid catadioptric lens that still commands eBay prices in the thousands. Actual manufacturing was farmed out to a variety of companies, and the first two digits of the serial number denote this identity. I was pleased to find this lens (Figure 4-1) on eBay, because this 300-mm f/5.6 was made by Olympus, who probably had some excess capacity prior to launching their OM series of cameras in the early 1970s.

Figure 4 — The 300-mm f/5.6 Vivitar lens and its modifications.

A problem arose when I discovered that the flange-to-sensor distance of my KAF6303e-chipped camera exceeded 55 mm by a few millimetres. This meant that the lens would not be able to focus at infinity and be unusable. Dismantling the lens (Figure 4-2) revealed a brass screw head (Figure 4-3) that prevented the helical focusing mechanism from turning further clockwise and shortening the lens barrel. I couldn't remove the screw but did grind it flush, resulting in enough further focus in travel to allow the lens to come to infinity focus (Figure 4-4). ✶

Jim Chung has degrees in biochemistry and dentistry and has developed a particular interest for astro-imaging over the past four years. He is also an avid rider and restorer of vintage motorcycles, which conveniently parlayed into ATM projects, such as giving his Skywatcher collapsible Dobsonian the Meade Autostar GOTO capability. His dream is to spend a month imaging in New Mexico away from the demands of work and family.

On Another Wavelength

Deep-Sky Objects in Canes Venatici

by David Garner, Kitchener-Waterloo Centre
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Canes Venatici is a small, obscure constellation surrounded by Ursa Major, Bootes, and Coma Berenices (Figure 1). It is home to several galaxies and a globular cluster. Four of the galaxies found in this constellation: M51, M63, M94, M106, and the globular cluster M3, can all be easily viewed with a small telescope.

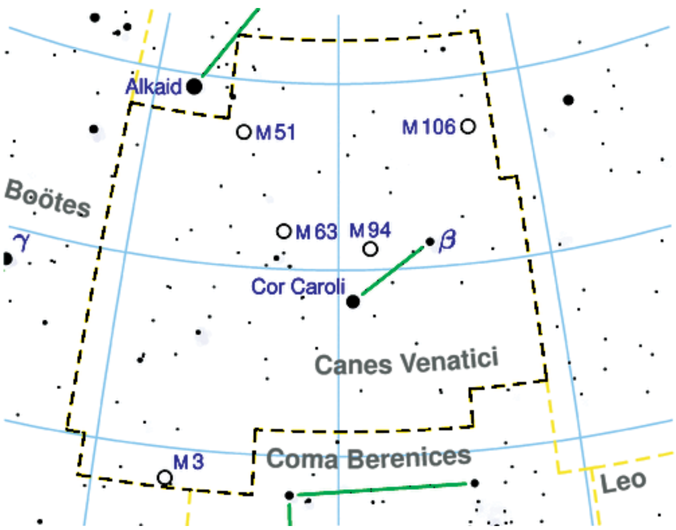

Figure 1 – A map of the constellation Canes Venatici.

Canes Venatici has only two stars brighter than fifth magnitude (α CVn and β CVn), both of which were originally placed by Ptolemy in the constellation Ursa Major. This constellation's brightest star, Cor Caroli (α CVn) is actually a double star. The brighter star of the double (α^2 CVn) is slightly east of its fainter companion α^1 CVn. The two are 19.6 arcseconds apart, have a combined apparent magnitude of 2.81, and can be easily resolved with a small telescope. Interestingly α^2 CVn has a very strong magnetic field that is believed to produce enormous starspots. Because of these starspots, the brightness of the star varies between 2.84 and 2.98 with a period of 5.47 days. This star is the prototype of a class of variable stars with magnetic fields and starspots known as α^2 Canum Venaticorum stars.

The second brightest star in the constellation, β CVn, is a G-type main-sequence star that was thought to be a strong candidate for having a planet in the habitable zone. So far no planet has been found.

Figure 2 – The galaxy M51 and its companion. Courtesy of Stephen Holmes, KW Centre. The image is 250 minutes (25x10 minutes) exposure on a QHY9 through an 8-inch GSO Ritchey-Chrétien 1600-mm focal length at f/8 on an EQ6 mount autoguided with KWIQGuide.

The best known deep-sky object in Canes Venatici is the Whirlpool Galaxy, also known as M51 (and NGC 5194). Most observers agree this is one of the best examples of a face-on spiral galaxy in the northern hemisphere (Figure 2). At magnitude 8.4, the galaxy is visible even in small telescopes. It has a bright centre, prominent spiral arms, separated by a few arcminutes from its companion galaxy, NGC 5195.

In the last 40 years, with the advent of radio astronomy and subsequent radio images, M51 has been confirmed to be interacting with NGC 5195. Computer simulations show that M51's spiral structure was originally caused by NGC 5195 when it passed through the main disk of M51 approximately 500 to 600 million years ago. The two galaxies are still interacting, though now NGC 5195 lies slightly behind its larger companion.

Occasionally, you may notice that M51 is used to refer to the pair of galaxies, where NGC 5194 is M51a and NGC 5195 is M51b. Charles Messier is credited with discovering M51 on 1773 October 13, but it was Pierre Mechain later in 1781 who discovered the companion. The spiral structure of M51 was not detected until 1845 when Lord Rosse examined the area through his immense 72-inch telescope, The Leviathan.

Nearby M63—also known as the Sunflower Galaxy—is part of the M51 Group of galaxies. It was discovered in 1779 by Pierre Mechain and then added to Charles Messier's list. M63 is similar in brightness to M51, at magnitude 8.6. The central portion of the galaxy is bright with the spiral arms fanning out from it in a circle. The image in Figure 3, taken in infrared light by NASA's *Spitzer Space Telescope*, reveals complex dust lanes that trace the galaxy's spiral arms all the way to the nucleus. These dusty patches are the cradles of new stars.

Figure 3 – Messier 63 viewed in infra red light. Image Credit: NASA/JPL-Caltec.

Figure 4 – The galaxy M106. Composite of IR, x-ray, radio and, visible light. Image credit: NASA/CXC/University of Maryland)

Messier 94 (NGC 4736), another spiral galaxy in Canes Venatici, was also discovered by Pierre Méchain, this time in 1781; it was catalogued shortly thereafter by Charles Messier. M94 appears to have a central oval-shaped, bar-like structure surrounded by two rings. The inner ring has an approximate diameter of 70 arcseconds; the outer ring, hosting a complex spiral-arm structure, is approximately 10 arcminutes across. It is currently believed that the central oval distortion may be responsible for creating the galaxy's peripheral disk.

In the same year, Méchain also found M106 (NGC 4258). For several decades now, M106 has been known to have a much larger extent in radio radiation than in visible light. In 1946, M106 was classified as a Seyfert galaxy due to its x-rays and strong emission lines. Figure 4 shows a composite image of M106 in IR, x-ray, radio, and visible light. The centre of a Seyfert galaxy such as M106 is thought to contain a supermassive black hole that causes its suite of unusual emissions.

For something a little different in Canes Venatici, take a look at the globular cluster M3 (NGC 5272), discovered by Messier in 1764. Today, it has become one of the best-studied examples of its type, in part because of its large population of variable stars—274 are known so far. This cluster is one of the largest and brightest (apparent magnitude 6.2) globulars, made up of approximately a half-million stars. ✶

Dave Garner teaches astronomy at Conestoga College in Kitchener, Ontario and is a Past President of the K-W Centre of the RASC. He enjoys observing both deep-sky and Solar System objects and especially trying to understand their inner workings.

Further Light on Mungo Turnbull and the 1882 Transit of Venus Reflected in Press Reports from Toronto and Environs

R.A. Rosenfeld, RASC Archivist (randall.rosenfeld@utoronto.ca), and Tom Luton, Librarian of the Toronto Centre's F.L. Troyer Library (CAO) (tluton@rogers.com)

Abstract

This paper is a sequel to the study and edition in the last *Journal* of a transit of Venus (ToV) letter from an original founder of the Society, Mungo Turnbull, to Sir John A. Macdonald. We present new information about Turnbull's claims, career, and circumstances, as well as a document providing both a rare visual image of Turnbull, and the probable reason he was not viewing the ToV from *inside* the Toronto Magnetic and Meteorological Observatory. We close by setting Turnbull's ToV experience in the context of media coverage of the ToV from Toronto and environs.

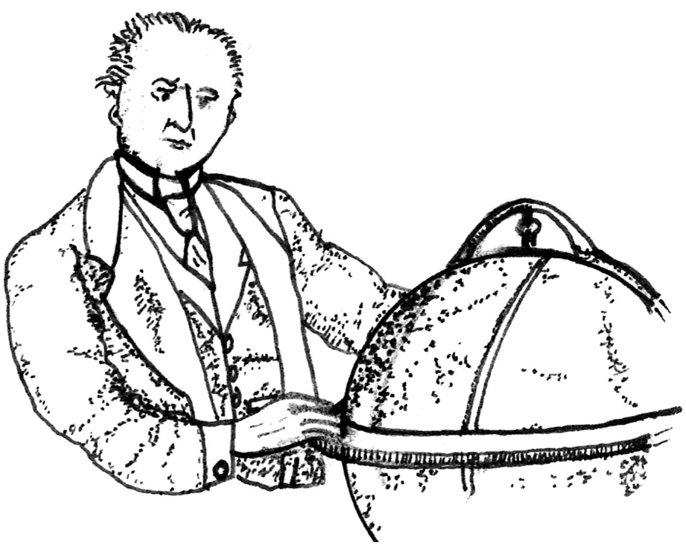

Figure 1 – Portrait of Mungo Turnbull from The Toronto Mail *1890 July 12, 2, col. 2, redrawn by R.A. Rosenfeld. The errors in Turnbull's anatomy and that of his globe in the original have not been corrected*

Readers will recall from the previous issue of the *Journal* the intriguing case of Mungo Turnbull, one of the original group of eight whose Confederation-era Toronto Astronomical Club (TAC)—or its quintessence at least—weathered near-death to became the RASC of today. Some curious aspects of that transmutation remain occult, as, for example, how Turnbull maladroitly caused his status to fall from that of luminary on Toronto's amateur astronomical scene to a minor body orbiting its outer limits. The documentary record of his role in the Society of 1868-1869, press reports of his telescope-making prowess in 1870, his 1882 letter seeking Transit of Venus (ToV) patronage from the Prime Minister, his limited press campaign around the ToV, the poverty of his scientific inventions of the 1880s and 1890s, and the record of his greatly reduced role in the resurrected Society of the 1890s furnished data to determine the ephemeral course of his astronomical downward mobility (Rosenfeld 2012). Another document now affords us an elusive likeness of Turnbull (Figure 1), and a telling insight into his character, further revealing why his request for ToV patronage was not as well received as he doubtless desired.

The neglected genius kept out of the observatory

In the very year of the Society's revival, *The Toronto Mail* (Anon., 1890) carried a profile of Mungo Turnbull. It reads:

> **"WATCHER OF THE HEAVENS**
>
> **Mr. Mungo Turnbull, a Devoted Astronomer, of this city—A Remarkable Telescope—The New Spot on Jupiter's Disc.**
>
> Great and memorable results in all the arts and sciences have been achieved by persevering, solitary workers, who have often been cramped and confined by narrow circumstances, but who have nevertheless made their lives a patient devotion to the pursuit of their choice. It is by the life-work of these men that human knowledge is advanced and the highest results of civilization won, more than any other individual influences in the history of mankind. These bearers of the torch of enlightenment often live and die unhonoured and unnoticed, and their tardy praises are spoken only after they are long dead.
>
> In the person of Mr. Mungo Turnbull, who resides at 48 Bellevue avenue, Toronto possesses a man whose work in the construction of astronomical instruments and whose achievements in observational astronomy should claim for him general attention as a really remarkable man. Mr. Turnbull has been devoted to astronomy and the higher mathematics since his boyhood. "Before I was twenty-three years old," he said recently, "I believe I could calculate eclipses and occultations on my own account more accurately than I can now with the aid of the

astronomical tables." Mr. Turnbull is now in his sixty-sixth year. His place of birth was Jedburgh, in Roxburghshire, one of the border counties in the south of Scotland.

> He studied for a time in London, and made himself master of the optician's art. He is especially adept at grinding lenses for astronomical instruments. Of late years he has devoted himself to the making of instruments, the designs being original with him, and the adjustments wonderfully fine and delicate. A large celestial globe and a powerful telescope, mounted on an instrument of his own device and construction, are among the most notable of the instruments he now has at his house. The telescope has lenses almost as powerful as those of the Observatory instrument, and its mounting give it an unique character. Mr. Turnbull is at present deeply interested in the study of a spot which has lately appeared on the disc of Jupiter, and which is being intently watched by all astronomers who can point their telescopes at that bright planet on unclouded nights."

The article is valuable for it informs us of the Scottish locale of his birth, and enriches our already lavish choice of when that happened, adding 1824 to the dates previously reported, —all of which originated with Turnbull (Rosenfeld 2012, 28)[1]! Its author comes close to claiming Turnbull is a London-trained master optician, and states outright that he is an inventor and manufacturer of precision scientific equipment, a genius in celestial mechanics in early adulthood, able to achieve greater accuracy without access to the nautical almanac tables than with their use, a man deserving of fame for his triumphs in observational astronomy and telescope manufacture, whose telescope is a close rival to the 15.2-cm O.G. (object glass) Thomas Cooke & Sons ToV refractor in the Toronto Magnetic and Meteorological Observatory, a veritable "bearer of the torch of enlightenment" selflessly advancing human knowledge and achieving great things for civilization beyond other human actors in the "history of mankind." For all that, he is yet a prophet without honour in his own country, a martyr to narrow circumstances stoically enduring the want of material success.

One could be excused for thinking this a Romantic period description of a latter-day Galileo facing persecution, an impoverished Kepler, or an unheralded Horrox. The tone of the panegyric does nothing to allay suspicions that author and subject may have been one and the same—although in fairness the lack of a byline proves nothing, as many if not most newspaper articles of the time were unsigned. If Turnbull approved of the Mungo Turnbull purveyed by *The Toronto Mail*, he may not have been aware of how revealing it was in ways unintended. The effect of the profile's flattery is paradoxically as unflattering now as it would have been some twelve decades ago, regardless of whether the image was entirely self-fashioned, or not. Much like an optical defect, hyperbole does nothing for one's clarity of vision. And the profile raises as many questions as it settles.

Early reports of the reflectors Turnbull built as an amateur in the Toronto of the 1870s are positive (Rosenfeld 2012, 28). The fullest printed account of his instruments and their maker makes no mention of any experience gained in London through informal or formal training (apprenticeship), and no one who has given the 1870 article a cursory glance will leave with the impression that Turnbull is a London-trained master optician. *The Toronto Mail* profile is frustratingly deficient in the circumstantial details that would allow a reader in the 1890s or now to verify its statements; exactly when did his London education take place, what was its duration, who was his teacher, and where did he practice as an optician? *The Toronto Mail*'s statements may be true in whole or part, or they may not be. On balance Turnbull's life circumstances do not particularly lend them credence. If he was a London-trained optician, why did he emigrate to Canada as a carpenter, and only set himself up as a "cabinet maker – optician," then "optician" but not "cabinet maker" in subsequent years (Table 1)? A trained optician would have faced some competition in mid-Victorian Toronto, but nonetheless might have done quite handsomely out of servicing the surveying and engineering trade, as did Turnbull's colleague among the original Society founders, Charles Potter (1831-1899)—who incidentally had received training under the famous Dollond firm in London, and didn't hide the fact in his advertising (Smith 1993).[2]

It is hard to assess the precision of Turnbull's scientific instruments, but to judge by the manuals he issued to accompany them, they were flawed inventions, regardless of their level of workmanship (Rosenfeld 2012, 28-29). Judgement as to their "fine and delicate" adjustments should be suspended until actual examples are located for evaluation. The comparison to the Magnetic and Meteorological Observatory's ToV Cooke achromat is interesting. It could be read to suggest that Turnbull had constructed a refractor with a nearly comparable O.G. to the ToV Cooke achromat, but sources are thus far lacking to suggest he essayed anything other than reflectors. It may be a comparison of his 0.3-m-class silver-on-glass reflector from *ca.* 1870 with the 15.2-cm O.G. ToV Cooke achromat. If so, it reflects a common doctrine of the time, which equated the effectiveness of a reflector of a given aperture with a refractor of half its size (Webb 1859, pp. 1-2, note †—this was taken for Gospel truth in many amateur circles as recently as 40 years ago).

Aside from the report of the publicly presented results of calculations of the local circumstances of an eclipse, we have little on which to judge his abilities as a celestial mechanician. There is no evidence of precocious mathematical virtuosity, but the proof in that pudding may lie in some as yet undiscovered archival larder.

Date	Address	Occupation	notes
1870	25 Nassau Street	Cabinetmaker	
1871-1873	25 Nassau Street	Cabinetmaker	
1873-1874	23 Nassau Street	Cabinetmaker	(houses on street renumbered)
1874-1876	23 Nassau Street	Cabinetmaker, Optician	
1878	23 Nassau Street	Scientific Apparatus Manufacturer	
1880	23 Nassau Street	Globe manufacturer	
1883	75 Arthur Street	Globe manufacturer	
1885	212 Bathurst Street	Optician	
1886	54 Sheridan Avenue	Instrument maker, Selby & Co.	
1888	54 Sheridan Avenue	instrument maker	
1890	Bellevue Avenue		
1892	57 Nassau Street		
1895	91 Brunswick Street		
1896	23 Westmoreland Avenue		
1897	23 Westmoreland Avenue		
Information drawn from Census of Canada, and other sources			

Table 1 – Mungo Turnbull's Toronto addresses and stated occupations 1870-1897

If this reflects Turnbull's attitude towards himself, and is a measure of the respect to which he thought he was entitled, then it fully accounts for why he was not part of Carpmael's scientific team for the Dominion's official ToV campaign. Combined with the poor level of literate and scientific ability witnessed by his ToV patronage letter to Macdonald, his exclusion from the observatory on the day of the ToV seems fully justified.

Nor do we have extant proof of his distinction as an observer, either in our earliest published records, reminiscences, or in manuscript materials in our archives, such as the *Astronomical & Physical Society Album*. The one object of his observational interest reported in *The Toronto Mail*, the Great Red Spot (GRS), was widely reported in the astronomical world *ca.* 1878, and was of burning topical interest in the amateur periodical literature of the time, such as *The English Mechanic & World of Science*, and the *Astronomical Register*. Turnbull could not but be aware of it. Unfortunately, his observations, whatever may have been their worth, made no impact on the Jovian science of his day, and his name is entirely absent from the standard modern accounts of 19th-century GRS observations, such as Peek (1958), Rogers (1995), or Hockey (1999).

The comments regarding his lack of material success, "cramped and confined by narrow circumstances," seem indeed borne out by the comments of A.F. Miller (Chant 1919, 126), one of the most respected members of the revived Society and an amateur with an acknowledged international reputation. Turnbull's frequent changes of address in his later years may be a symptom of his lacklustre career as an inventor and manufacturer of scientific instruments (Table 1, and Figure 2). This may or may not have been a result of their quality, although a host of other factors could have been responsible.

The most disturbing features of the profile are not the claims to competence and achievement, which appear doubtful, but the pretensions to the status of a great man ignored, whose "great and memorable results" allow "human knowledge" to be "advanced and the highest results of civilization won, more than any other individual influences in the history of mankind," placing Turnbull in the rank of the "bearers of the torch of enlightenment." It isn't even remotely true.

The date of *The Toronto Mail*'s profile of Turnbull may also be significant. It may not be coincidence that it appeared the year the Society woke up from hibernation. The paper's characterization of Turnbull as a "persevering, solitary worker," and the lack of mention of the Society in the piece may be significant. One would not know that he had had a previous and apparently amicable association with some of the men who revived the RASC. It was four years from the Society's reawakening before he rejoined it in 1894. That interval from 1890 to 1894 was also the period of Charles Carpmael's presidency of the Society. Nor may it be a coincidence that Turnbull did not join the revived Society till after Carpmael's term of office and death. His reluctance to sign up may have been due to lingering resentment over having been denied a role within the

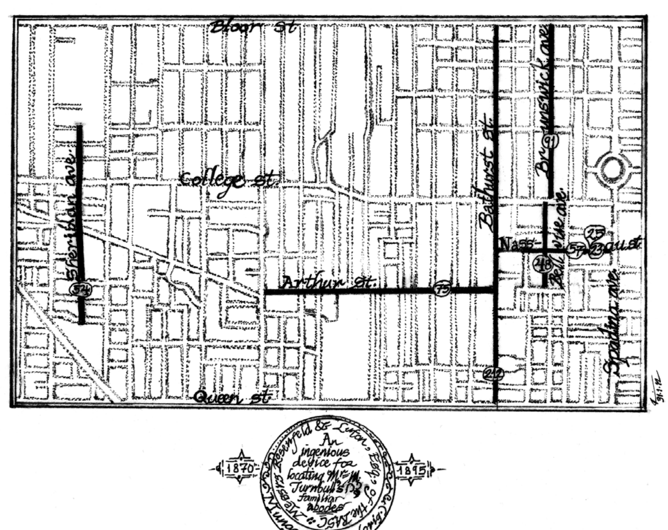

Figure 2 – Map showing Turnbull's Toronto residences 1870-1895 (his 1896-1897 residence at 23 Westmoreland Ave. is north of this map). Drawn by R.A. Rosenfeld

observatory under Carpmael as part of the Dominion's ToV campaign. Perhaps one day we will have the full story. RASC "politics," it would seem, is nothing new.

Other aspects of Turnbull's career

Thanks to suggestions by readers of the earlier article, we can also flesh out the picture of Mungo Turnbull a little. Louise Herzberg reports that in addition to his being a founding member of the Toronto Astronomical Club/Society in 1868-1869, and joining the American Association for the Advancement of Science in 1889, Turnbull was almost certainly also a member of the Recreative Science Association, probably during the late 1870s and into the 1880s.[3]

Eric Briggs raised the possibility that confessional differences may have contributed to tensions between Society members and Turnbull, observing that some notable early members were Orangemen.[4] The suggestion is worth entertaining. The documentary trail has not led in that direction thus far, although new evidence may change that. Turnbull's religious affiliation in the 1891 census is given as Presbyterian (*Census of Canada*, 1891, 41), seemingly not a problem for members of a protestant fraternal organization. There are, however, shades of Protestantism, and the Orange Order was as much a political sectarian organization as a charitable one. If Turnbull harboured Scottish secessionist views, republican sympathies, or liberal views towards Catholic rights, he might have run afoul of the Orange machine said to dominate Toronto's civic life, which could have had some effect on his business prospects. The Society, however, seems to have gone out of its way to be an ecumenically welcoming body from its inception. While Orangemen were in its ranks, the outrageous perpetual curate of Tow Law, the Rev. T.E. Espin was a Corresponding Member (a class of honorary membership), and the Rev. Charles H. Shortt, who had Oxford movement associations as Vicar of Smoky Tom's, chaired RASC meetings and was a member of Council in the 1890s. If Anglo-Catholic Church of England clergymen weren't anathema enough for any indurate Orangeman, a decade later the Rev. I.J. Kavanagh, sj, had a seat on Council. Fortunately, shared astronomical interests seemed able to overcome confessional dividing lines. There is always the possibility that religious-political differences could have been joined to other, apparently more compelling reasons to marginalize Turnbull.

Finally, Peter Broughton noted that the earlier paper did not make use of Dr. Albert D. Watson's Presidential Address to the RASC (1917).[5] It ought to have. In the course of a selective anecdotal review of the history of the Society, Watson states:

> *Mungo Turnbull, a well-educated Scotch cabinet-maker, had accompanied a polar expedition as a carpenter some years before the Toronto Astronomical Club was founded. His chief interest in Astronomy was dependent upon his remarkable skill as a maker of optical instruments...the author held a very lofty conception of the aims and achievements of Science...I very well remember a visit to Mr. Turnbull in later years and how much conversation with him and his wife impressed me with the deep resentment of both at the unpardonable neglect by the public of the science of star-law, which, as they claimed, would have served to ennoble the public mind had it been given right of way with its beneficent influence. Mr. Turnbull's active interest in astronomical matters was maintained for many years, and all the older members still alive will remember his constant interest in the Science. He died before the incorporation of the Society under its present royal charter.* (Watson 1917, 51-52).

Thanks to Watson, we now have an approximate date of death for Turnbull, pre-1903—which accords with the date on Turnbull's death certificate, 1902 November 16 uncovered by one of us (TL). And the information that he served as a carpenter on a polar expedition. Which polar expedition, when? He was in fact awarded the Arctic Medal for service on HMS Phoenix in 1853 as a "stoker," not as a carpenter (TL). It is curious that Watson's account is characterized by the same lack of circumstantial detail as in *The Toronto Mail* profile, detail that would permit independent verification of Turnbull's statements. This holds for the statement regarding his education. Watson's account is also notable for its silence about any optical training Turnbull may have received in London, his abilities as an observer, and his qualities as a celestial mechanician. Watson's reticence on these matters is interesting, given that he is clearly favourably disposed towards the memory of Turnbull. From what Watson writes, one would not know that there was any break with the Society. Implicit confidence cannot be placed in Watson's statements, for in places where they can be checked, he is not always to be relied upon, *e.g.* the "incorporation of the Society under its present royal charter" is a fiction, for no royal charter had been issued to the RASC, which Watson ought to have known for he was a member when royal *permission* was granted to affix the regal adjective to our corporate name!

A.F. Miller's remembrance of Turnbull is pithier, but possibly more in accord with the picture of Turnbull's life that has emerged than Watson's roseate memory. Recounting the fortunes of the TAC during the poorly documented period of the 1870s, Miller remembers that: "Sometimes old Mr. Turnbull would come; poor man, he had a wretched life!" (Chant 1919, 126).

The ToV and the Toronto press

The RASC arguably enjoyed a much higher press profile in the later years of Victoria's reign and that of Edward VII than at any time since. Regular Society meetings were reported on at some length in Toronto newspapers (including the questions after papers), special events received coverage, and even Society social occasions were not neglected. It is no surprise then, that eight years prior to the formal reawakening of the Society, the 1882 ToV received ample coverage in many of the Toronto dailies. In this respect, Toronto was no different than other major cities in North America and Europe.

On the day preceding the ToV, *The Globe* carried an extensive article (placed closer to the back than to the front of the broadsheet), which gave in two and a half columns a sober account of why the ToV was being observed, the history of previous ToVs (even quoting from Jeremiah Horrox's appalling poetry), a very basic explanation of the geometry of ToVs (illustrated with a barely adequate diagram), and a brief account of the official Canadian ToV preparations. Numbers were not shunned in the presentation, although formulae and calculations did not appear. There are several attempts in the article to place the ToV in various perspectives of human history:

> *The importance of the transit of Venus which occurs to-morrow may be conceived when it is known that it is the last opportunity that any one now living will have of viewing a recurrence of the phenomenon. One hundred and twenty one years will have passed into the record of the past before another transit occurs. What momentous political and social changes will have taken place before then we cannot conceive, or what amazing advances will be made in the regions of scientific discovery or philosophical investigation, is a subject for the wildest conjecture.* (Anon. 1882, Transit of Venus, col. 3)

On the day after the Transit of Venus, *The Globe* reported on the results in two columns on the second page—the disappointing results from overcast Toronto, as well as the more successful results from the more fortunate transit stations. Names are named, and a surprising quantity of circumstantial detail is provided. And Toronto's disappointment is recounted:

> *The grave apprehensions entertained by Mr. Carpmael that the unfavourable state of the weather today would interfere with the observation of the transit of Venus at the Toronto Observatory were unfortunately not unfounded. At an early hour this morning the dull, leaden aspect of the sky was far from reassuring, and as the hour for the first contact of the planet with the sun approached, the heavens were overcast with heavy cumulous masses of clouds, pervious indeed to his light, but too dense, however, to admit of his disc being visible. It was no ordinary disappointment to the observers when the time of the first contact passed without a glimpse of the sun being obtained.*
> (Anon. 1882. The Transit of Venus)

Sometimes understatement is the most effective way to convey the depths of disappointment.

The Globe was one of the better quality newspapers available in the city. *The Mail*, a rival with which it eventually merged, was several notches below, and it showed in the tenor of its headlines, and content:

> SIC(K) TRANSIT.
> -----------------------
> Opinion Expressed by the Toronto Observers.
> -----------------------
> Successful Results Elsewhere.
> -----------------------
> Effect of the Transit on Hamilton's Coloured Astronomer
> -----------------------
>
> ...Early yesterday morning the gentlemen who had obtained permission to view the transit from the tower of THE MAIL placed their telescopes in position, and hoping against hope, awaited the result. Outside of the Observatory, THE MAIL offered the best position anywhere near the business part of the town for observing the phenomenon, as it towers far above every other building in the neighbourhood. About 6 a.m. the sky was cloudless, but an hour later heavy banks of clouds made their appearance above the horizon, and soon overspread the whole sky... Cold and miserable, the amateur astronomers stuck to the roof of THE MAIL until the transit was over. Then as they packed their instruments, a gentleman remarked that he hoped they would have better luck on the next occasion, a hope which another of the party said was very problematical unless they mended their ways.
>
> AT THE OBSERVATORY
> ...Besides the regular staff, two or three gentlemen brought their own instruments to the Observatory, so as to get the correct time should a chance present itself of viewing the transit. One of these, Mr. Roberts, used an eight-inch reflector of his own manufacture, and which by the way is an excellent instrument. Mr. Miller, secretary to the hospital, was there also with a four-inch refractor, whilst Mr. Menzies was prepared to do his part with an alto-azimuth [*sic*] transit. All these gentlemen waited patiently until the hour of last contact had passed. They were rewarded early in the day by a glimpse of the planet on the sun, but only for a few seconds...HAMILTON, Dec. 6—Mr. Ebenezer Hutton, the aged coloured man who in a recent lecture proclaimed that the sun do move, was prostrated from overwork to-day while observing the transit of Venus. He was taken to the city hospital this afternoon in a handsome sleigh, and escorted by several friends. While Mr. Hutton is recuperating he will not rest from his astronomical labours, but will prepare some further startling propositions in astronomy." (Anon. 1882. Sic(k) Transit)

The Mail's coverage managed to be both informative, and unedifying. While it was public spirited to make the top of their building available to amateurs for observing the ToV, it was also clearly self-serving, given that it would generate publicity for the paper. And the patronizing attitude of the newspaper towards Mr. Hutton was wholly gratuitous, whatever the quality of his astronomy. Why mention that he was black? But then, for the *The Mail*'s story to have its intended effect, it apparently was a necessary ingredient, alas.[6] The casual racism does serve to remind us that the past is a different country, and that one needn't travel to an "exotic" locale to send back accounts of the ToV tinged by colonialism, for to paraphrase Oscar Wilde, such things begin at home. On the more positive side, it might be worth while looking for unbiased accounts of what Ebenezer Hutton was about. He is certainly one of the earliest Afro-Canadian amateur astronomers who can be known by name. Perhaps "race" can be made to count in a positive way.

The Toronto World gave the ToV front-page coverage, and opted for a tone mid-way between that of *The Globe* and its rival *The Mail*. Its headline belonged to the world of the latter, "THE TRANSIT TELESCOPED," but its content would not, on the whole have sullied the former (Anon. 1882, The Transit Telescoped). All three papers did a fair turn at reporting the results obtained by professional astronomers, not just locally, regionally, and nationally, but also worldwide, certainly a commendable policy.

Where was Mungo Turnbull in all of this? It's hard to say. He did not occupy a place front to centre, not even locally. Julian Smith thought the newspapers noted him in the company of the other leading amateurs on the grounds outside the Toronto Magnetic and Meteorological Observatory, yet his name figures in none of the reports cited *supra* (Smith 1993, 25).[7] His fugitive presence or absence on that day may be an apposite comment on his troubled standing within the Canadian astronomical scene of the late 19th century. ✶

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Endnotes

1 The census search in the original article was incomplete. The correct historical record of Turnbull's stated age is: 1871 census, 54 yrs. (born 1817); 1881 census, 60 yrs. (1821); 1890 article, 66 yrs. (1824); 1891 census, 66 yrs. (1825); 1901 census, 75 yrs. (1825); 1902 death certificate, 83 yrs. (1819). The suggestion that the George Turnbull of the 1871/1881 Census is Mungo Turnbull can now be discarded (Rosenfeld 2012, 28).

2 "The early 1870s saw two more 'opticians' establish themselves in Toronto....The other was less troublesome; this was Mungo Turnbull, Potter's friend from the Astronomical Society. Turnbull added a small optical shop to his Nassau street home around 1873, but it was no threat to Potter. Potter and Turnbull were close friends, and Turnbull, an accomplished telescope maker, would often show his latest models to Potter and the other Society members" (Smith 1993, 22). We have thus far not been able to find documents attesting to any close friendship between Potter and Turnbull, nor that Turnbull displayed his "latest instruments" to Society members more than a few times.

3 Email communication of L. Herzberg to R.P. Broughton 2012 January 17, forwarded to R.A. Rosenfeld 2012 January 18. We thank Louise Herzberg and Peter Broughton for bringing this to our attention. Also see Broughton 1993, 23, on the Recreative Science Association and the Toronto Astronomical Society/Astronomical & Physical Society of Toronto/RASC.

4 Email communication of E. Briggs to R.A. Rosenfeld 2012 January 24. We thank E. Briggs for raising the issue.

5 Email communication of R.P. Broughton to R.A. Rosenfeld 2012 January 13. We thank Peter Broughton for bringing Watson's address to our attention. Watson is the source of the statement that Turnbull had received "a good Scottish education" (Broughton 1994, 21).

6 It should be recalled that at the 1769 ToV, David Rittenhouse fainted at first contact, and no one made a point of his being "white"; Hindle 1964, 55-57. In fact, the phenomenon of feeling faint or being otherwise emotionally "overcome" at events such as total solar eclipses is not unknown, and says nothing about the quality of the observer. It is certainly not a "racially" based trait, as *The Mail* attempts to insinuate.

7 It is conceivable that Turnbull is mentioned in the ToV account in the *Evening Telegram* of 1882 December 7, 1, but we were unable to consult it, as that particular issue is not held in the research libraries of the University of Toronto, nor the Toronto Public Library, nor does it appear readily accessible online.

Obituary

An Extraordinary Magician with Optics—Eric Harvey Richardson (1927–2011)

by Gordon Walker

In November 2011, Canada and the world of astronomy lost a brilliant optical designer when Harvey Richardson succumbed to cancer at the age of 84. He earned a BA in Physics (1949) and an MA in Nuclear Physics (1952) from UBC and completed his Ph.D. in Molecular Physics from the University of Toronto in 1960 while on the staff at the Dominion Astrophysical Observatory (DAO) in Victoria. He spent his whole scientific career in Victoria, writing his first astronomical papers in the late 1950s in collaboration with Andrew McKellar. McKellar was a distinguished molecular spectroscopist who had deduced a 2.3 K universal background radiation from optical spectra as early as 1941. He pressed successfully for a coudé spectrograph (bearing his name) to be attached to the 1.2-m DAO telescope that was erected in 1961. While, sadly, McKellar did not live long enough to use them, the spectrograph and telescope gave Harvey the perfect opportunity to exploit new ideas and, with the skills of the optical team assembled under Roy Dancey, to elevate the 1.2-m to a gold standard in optical spectroscopic performance. From there he never looked back and blossomed to provide designs for both space and giant ground-based telescopes.

The launch of *Sputnik* in 1957 and the remarkable improvement in electronic technology and computing power in the 1960s galvanized an unprecedented surge of interest in, and funding of, astronomy and its instruments world wide. Harvey, with his creative penchant for innovation, was perfectly placed to exploit the opportunity.

While optical design is both a science and an art, it always carries a certain air of magic when clear, sharp images reappear through a complex system of lenses and mirrors. This air of magician was greatly enhanced in Harvey's case by his exotic sartorial choices in hats and coats. With the advent of digital computers and ray-tracing programs in the late 1960s, Harvey, in collaboration with Chris Morbey, worked hard to improve existing programs and to use them innovatively. According to Chris "with his uncanny knowledge, Harvey somehow knew what should be possible, and I did my best to implement them in the program. He sensed just what a particular glass should be able to do. Like a sculptor or musician it was a matter of getting the clay or notes to cooperate towards something already detailed in the mind." Chris and Harvey were too successful on one occasion, when they produced a camera with such good resolution that the Americans would not allow the paper to be presented for general distribution!

Figure 1 – Harvey peers through one of his "Richardson" image slicers

In optical astronomy, information is conveyed by photons, and nowadays heroic efforts are made not only to collect as many as possible by building larger and larger telescopes, but to lose as few as possible on the way to the detector. On reaching the detector, the image must be the best that atmospheric conditions will permit. But it was not always so. In the 1960s, astronomers were still content to waste more than 99% of the light entering the telescope and sit up all night in a cold dome watching it happen. Mirror coatings were often of doubtful quality; in spectroscopy (especially at high resolution), much of the starlight was lost at the spectrograph entrance slit and photographic detectors were at best ~1% efficient.

For the 1.2-m, Harvey, closely helped by Murray Fletcher, moved to speed things up (Richardson 1968). His all-reflecting spectrograph design had an unorthodox hyperbolic collimator with a spherical camera mirror that dispensed with a Schmidt plate corrector, since the inherent spherical aberration of the camera was balanced by one of opposite sign from the collimator. By doubling the diameter of the collimator beam with a four-grating mosaic, the spectrograph throughput was automatically doubled.

Harvey introduced multilayer coated mirrors in the coudé train that gave them superb reflectivity (Richardson 1968) . Because it was only possible to make such mirrors in a small size, he reduced the coudé beam from the secondary to a small, nearly parallel beam that was converted back to f/30 before the focus. To improve transmission at the spectrograph slit, he came up with one of his most brilliant devices— the Richardson image slicer. This device had the effect of successively reflecting starlight in a quasi-spherical cavity in such a way that most of the light ended up going through the slit without altering the f/ratio of the incoming beam. There were other image slicer designs around at the time, but they had limitations. In the Richardson device, a one-dimensional image of the telescope pupil is projected onto the detector. (Returning on a flight from London sometime in the 1970s when one could still wander into the cockpit, I was startled when the co-pilot asked me what an image slicer was! Turned out he had shares in Scott Plastics, the company in Victoria with the license to build them.) Before he died, Harvey had already designed an image slicer for the *James Webb Space Telescope*—a fitting tribute once the telescope is built and launched.

The throughput improvements to the DAO 1.2-m telescope left only the inefficiency of the photographic plate to be eliminated. Elaborating on a technique pioneered by Roger Griffin at Cambridge, Jim Stillburn and Murray introduced a high contrast, negative stellar spectrum template at the camera focus, and Harvey devised an elaborate multi-mirror system to squeeze the transmitted light onto a single photomultiplier—in one stroke gaining the ~20% efficiency of a photocathode and the high signal from combining all of the transmitted photons. A radial velocity could then be measured by mechanically stepping the template and estimating the position of minimum transmission. With all of these improvements, one could now measure quality radial velocities for stars thousands of time fainter than before.

During my time at DAO in the 1960s, Harvey was in the next office. He and I often discussed my developing preoccupation with multi-channel, signal-generating detectors (now known as video cameras!). In the 1970s when my lab at UBC built a series of such systems of increasing complexity, the McKellar spectrograph with all of Harvey's innovations was a perfect place to try them out, culminating with the solid-state detectors with which everyone is familiar today. Harvey was a key player in providing designs to incorporate our devices into the spectrograph.

A saga played out in the background to these efforts in the 1960s and 70s—the demise of the Queen Elizabeth II 4-m telescope and the forging of a collaboration with France to build the 3.6-m Canada-France-Hawaii-Telescope (CFHT), completed atop Mauna Kea in 1979. Harvey, conspicuous by his leather top hat, played no small part in the many international design and planning meetings about the telescope optics and auxiliary instruments. The small, high-reflectance-mirror coudé train and his spectrograph design plus image slicer were incorporated lock, stock, and barrel into the new telescope. The international impact of the DAO improvements was such that not just one, but two, large coudé rooms were included on successive floors of the CFHT building. The coudé spectrograph, complete with a solid-state detector (Reticon) from UBC, became an immediate favorite with both French and Canadian astronomers, produced a flood of important papers, and was the foundation for the search, by Bruce Campbell, Stephenson Yang and me, for extra-solar planets.

Harvey played a much wider role than just the coudé in the CFHT design (Richardson 1979). There had been a heated debate about whether the CFHT should be a classical parabolic-hyperbolic system or a Ritchey-Chrétien (RC) in which the figure of each mirror is relaxed radially by a few nm to give a wide, in-focus field at the Cassegrain focus. The RC would have allowed several instruments to share the Cassegrain focal plane simultaneously, but images at the prime and coudé would have had to be corrected, although, as RC proponents were quick to point out, wide-field correction at prime focus required a simpler corrector than for a classical system. The ultimate choice was a classical configuration for which Charles Wynne designed an immense, three-element prime-focus corrector. Harvey modified this design to give a flat final surface on the top lens allowing a grism to be introduced for low-resolution slitless spectroscopy. A grism is a zero-deviation disperser combining a shallow prism and coarse transmission grating.

Harvey's greatest contributions to CFHT were in innovative designs for instruments. He designed a medium-resolution spectrograph with high throughput for the prime focus that was capable of taking spectra from the atmospheric ultra violet limit to the red limit of then-available detectors. The spectrograph was named the "Herzberg" in honor of the Nobel Prize winner.

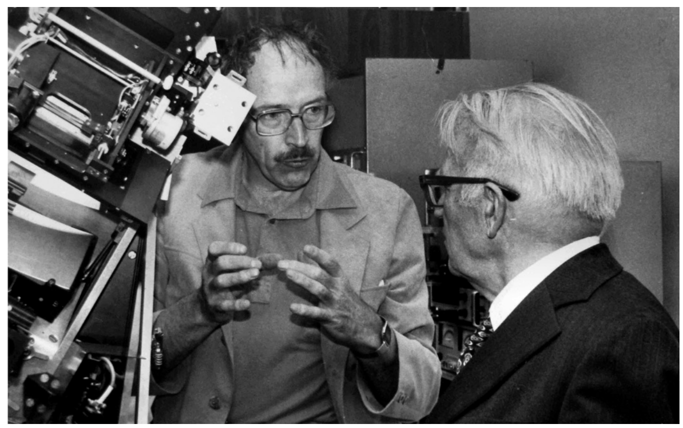

Figure 2 - Harvey explains details of his CFHT prime focus spectrograph to Gerhard Herzberg for whom the spectrograph was named.

From early on, in the search for quality sites for large telescopes, Harvey understood and appreciated the importance of atmospheric thermal turbulence and its impact on image quality (seeing)—something now taken for granted. The largest effect is rapid image motion. Mauna Kea had proved an excellent choice for CFHT, and pains had been taken to put the telescope high enough to avoid ground-layer turbulence. René Racine made great efforts to remove seeing generated within the dome. Robert McClure had Harvey design a highly compact rapid guider system to remove the atmospheric image motion—the high-resolution camera or HRCam (McClure 1989). The camera was highly successful and paved the way for the correction of higher-order distortions with the adaptive optics bonnette—AOB (Rigaut *et al.* 1998). The latter required rapid sensing of wave-front distortions introduced by the atmosphere and the application of their reflex to a deformable mirror at a pupil in the optical train to recover a seeing-corrected image. Magic indeed!

Many people contributed to the success of AOB but, in the words of Derrick Salmon then Optical Engineer at CFHT, "Harvey designed the AO bonnette optics and wave-front sensor and, after several outlandishly huge (MANY metre-long) initial suggestions, came up with a delightfully compact system. He rather daringly incorporated many millimetre-scale toroids in the wave-front sensor that drove fear into the hearts of those who actually had to either fabricate or align them, but in the end it worked really very well. The AOB is a surprisingly compact instrument, and the optics and working components only occupy about 1/2 its volume. Compared to other systems it is almost dainty." The testament to its success is in the many exciting discoveries, such as those on the presence of a black hole at the centre of our Milky Way Galaxy. AOB was just the first of several, increasingly powerful adaptive optical systems in which Harvey was involved, not only for CFHT but Gemini and the Star Fire Range.

The astronauts on the historic Moon landing of *Apollo 11* in July 1969 deployed an array of 100 corner-cube reflectors designed to exactly retro-reflect laser beams directed from observatories on Earth, thereby allowing astronomers to regularly measure the lunar distance to better than 3 cm (Alley *et al.* 1970). The *Apollo* missions 14 and 15 also left reflectors with the latter being the largest. These are the only *Apollo* experiments still in regular operation and Harvey was part of the Lunar Ranging Team involved with the careful design of the corner-cube reflectors and, at the MacDonald Observatory in Texas, with the laser-launch optics and the detection system for the return signal on the then new 2.7-m telescope. The experiment has been a huge success (not least in proving that the moon landings actually happened!). Although some 10^{17} photons are fired in each laser pulse, the laser beam spreads to some 7 km at the Moon while diffraction at the small 3.8-cm aperture of the individual corner-cube reflectors spreads the return beam to some 20 km at the Earth, resulting in only about 1 reflected photon being detected each second.

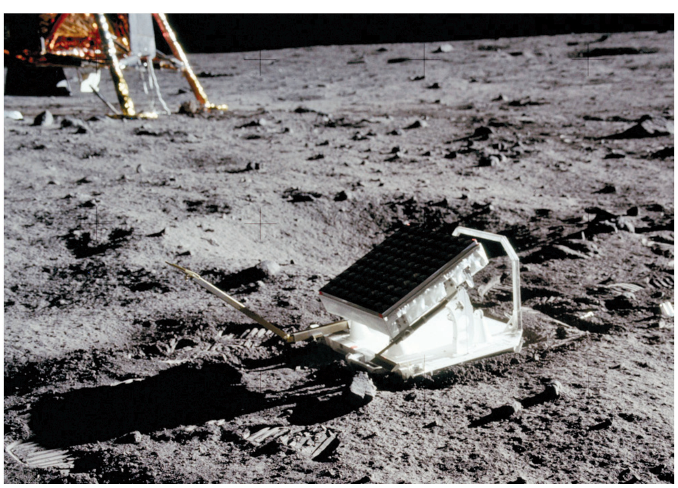

Figure 3 – The array of 100, 3.8-cm-diameter corner-cube reflectors deployed by the astronauts of Apollo 11 *in 1969 for the lunar-laser-ranging experiment.*

The Northern Lights are very much a Canadian phenomenon. The Earth's magnetic field is similar to that of a bar magnet and results in the north polar field lines crowding into an oval annulus some 6000 kilometres in diameter centered to the north of Hudson Bay. This crowding focuses charged particles into the upper atmosphere, causing oxygen and nitrogen to fluoresce in characteristic green and red colors. While the Auroral Oval is easy to see at night, could it be seen by day, and what was the impact of ultra violet sunlight? The Swedish *Viking* satellite was launched into a polar orbit in 1986 with the Canadian Ultraviolet Imager (UVI) on board (Anger *et al.* 1987). Rayleigh-scattered sunlight is low in the vacuum UV, and absorption by atmospheric ozone cuts out reflection from the ground, allowing any day-side aurora to be seen at high contrast. There were two cameras, one each for the strong oxygen and nitrogen UV emissions. Harvey carried out a detailed telescope design based on a concept by Alister Vallence Jones.

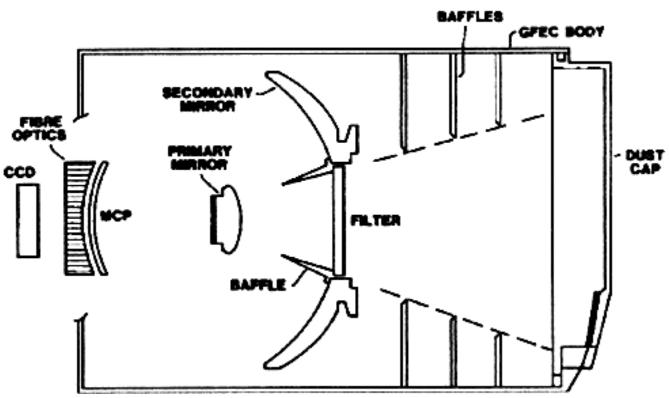

Figure 4 – Optics of one of the two cameras in the Canadian Ultraviolet Imager.

The cameras were very fast, f/1, reversed Cassegrains as shown in Figure 4 where the primary is smaller than the secondary, and both mirrors are spherical. The field of view was 25 degrees and the baffles allowed observations to within 45 degrees of the Sun. The UV image was focused onto a curved photocathode. Electrons from the photocathode were multiplied in a channel plate to make a flash of visible light in a phosphor that was eventually registered on a CCD with an image building up from the accumulation of flashes. The curved phosphor was matched to the plane surface of the CCD and corrected for distortions using a tapered fiber-optic bundle. The experiment was highly successful, giving unprecedented high time and complete spatial coverage of auroral sub-storms and other activity.

These few examples give some idea of the breadth of Harvey's achievements. Following his retirement in 1991 from the DAO (by then part of the Herzberg Institute of Astrophysics—HIA), he continued as an Adjunct Professor at the University of Victoria in the Department of Mechanical Engineering, where he continued to contribute to the field of

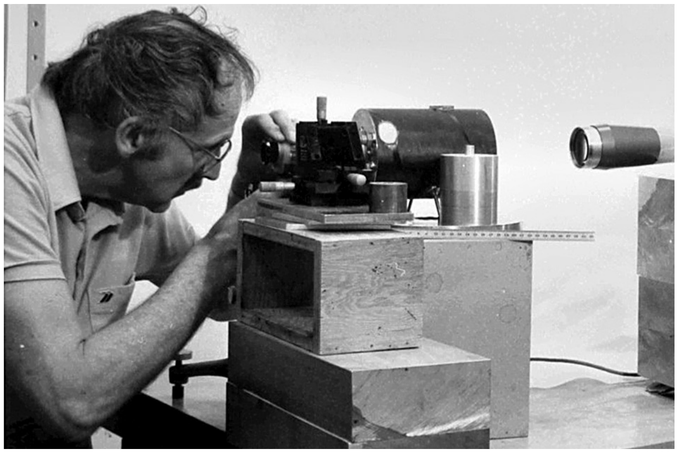

Figure 5 – Harvey making critical adjustments to a Viking Ultra Violet Imager for the mapping of dayside aurora from Earth orbit.

adaptive optics with the optical design of the Altair system for Gemini, and future systems (CFHT IMAKA and the Thirty-Metre Telescope NFIRAOS). His work contributed to the formation of the Adaptive Optics research lab. One of his students, John Pazder, who has assumed his mantle as optical designer at HIA, recalls how inspirational Harvey was: "Harvey had a child-like curiosity not just in astronomical optics, but the world around him. He would infect you with this curiosity, and leave you striving to learn and understand more each day." Harvey continued to work, inspire and be consulted up to the end. His many instruments and ideas remain a most fitting tribute. ✶

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Imager's Corner

Layered Mask Stretching

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

This edition continues a group of Imager's Corner articles that will focus on a few techniques that are useful in processing astrophotos. Over the next several editions, I'll attempt to give a guide to image stretching, background correction, SMI processing, and any other technique that I happen to find useful. All the techniques discussed will be useable with nothing more than a standard image processor that supports layers and masks. No special astroimage processor is required.

This edition will deal with layered mask stretching (LMS). The LMS technique builds on the masking concept shown in the column on SMI processing (see JRASC December 2011, p. 268); a version of it has been used in daylight photography for some time. The main tweak from the technique used for daytime work is to use a mask made from the image itself. This also works well for daytime work, so experiment a bit.

Let's start with the rather bland image of the Orion Nebula shown in Figure 1.

If we apply a simple curve stretch as covered in an earlier column, the outer detail shows through, but at the expense of the bright core as shown in Figure 2.

The solution to this is to do a layered blend of both images. Using a mask to blend the images allows the faint detail of the stretched version to come through without the core being blown out and showing no detail. Start by duplicating the un-stretched image on another layer. Call the bottom layer *stretched* and the top layer *core*. Next hide the *core* layer and make the *stretched* layer active. Apply several passes of a curves adjustment to this layer to bring out the faint detail as shown in the stretched image Figure 2.

Now for the mask magic: place a mask made from the luminance channel of the stretched image on top of the core image to let some of the core detail show through. The layer stack should look something like the sample in Figure 3 (it is a *Paint Shop Pro* stack)

The problem with this approach is that it leaves a very washed-out image, as all of the bright areas of the stretched layer are replaced by the dim areas of the core layer. See Figure 4.

To correct this apply a Gaussian blur to the mask layer. Experiment a bit with the blur radius to get the effect you want. To produce the final figure I used a 50-pixel radius. See Figure 5.

Figure 1 – The initial image, unstretched.

Figure 2 – The curve-stretched image.

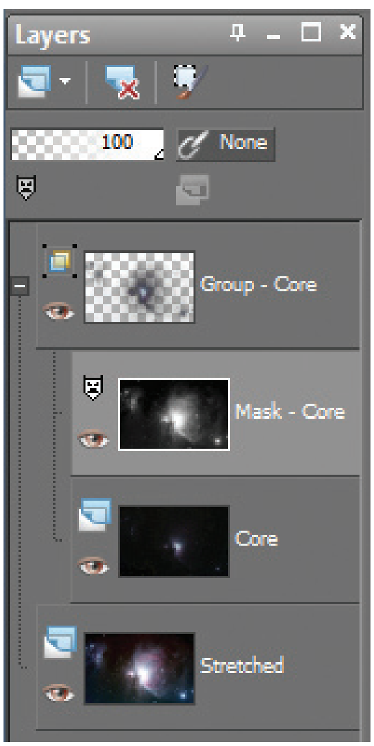


Figure 3 – The layer stack.

The technique essentially provides spatial control over where the stretch is applied. Where the stretched layer is very bright and washed out, the core image is allowed to show through to blend the best of both images. It is very useful on objects that have a wide dynamic range, such as galaxies and bright nebulae.

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

Figure 4 – Nearly there: the washed-out image.

Figure 5 – The final LMS-processed image.

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

Second Light

More Planets from the *Kepler* Mission

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

The *Kepler* mission was launched on 2009 March 6 to explore the diversity of planets with a particular emphasis on looking for Earth-sized planets in Earth-like orbits around Sun-like stars. This is the "holy grail" of the mission, along with determining how common they are. We still do not have an Earth analogue, but there recently have been several very interesting results, including finding two Earth-sized planets orbiting Kepler-20 by François Fressin of Harvard University and his colleagues (published online on 2011 December 20, and in print in the 2012 February 9 issue of *Nature*), the discovery of three Mars-sized planets orbiting KOI-961, and the identification a planet in the habitable zone of Kepler-22.

There are now (27 January) 755 exoplanets listed in the iPhone exoplanet app. Kepler-22b is the smallest known in the "habitable zone," that orbital region around a star where the planet's estimated temperature would allow for the existence of liquid water on the surface. There is considerable uncertainty in determining a habitable zone, though, because it depends upon the composition of the planet's atmosphere. For example, without any greenhouse gases in Earth's atmosphere, its average surface temperature would be below freezing. Venus is just inside the nominal habitable zone in the Solar System, but is far too hot for liquid water because of an overabundance of carbon dioxide.

Kepler-22b has a radius ~2.4 times the Earth's radius—there is no information yet about the planet's composition. Its parent star is slightly smaller and cooler than the Sun, but at 290 days the orbit is close to Earth's in length. The system lies at a distance of ~600 light-years. Its discovery was announced by Bill Cochran and Michael Endl of the University of Texas, together with the *Kepler* science team, at a meeting in early December. The few planets around this size for which we have masses seem to be gaseous (based upon their average densities), so it seems likely that Kepler-22b is not a habitable rocky planet.

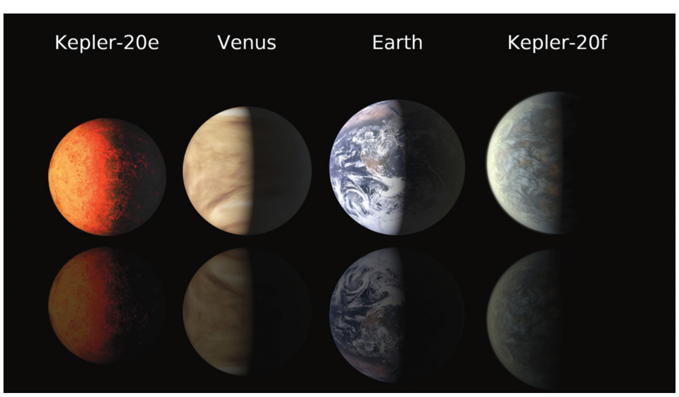


Figure 1 – An artist's impression of Kepler-20e and f, compared to Venus and Earth. Image courtesy of François Fressin, Harvard University, and Nature.

There are 47 other candidate planets in their star's habitable zone—astronomers are working to confirm that the planets are truly there and not just artifacts in the data.

The three planets orbiting KOI-961 are the smallest overall, with sizes comparable to Mars. They were announced during the recent meeting of the American Astronomical Society in Austin Texas, on January 11, by John Johnson and Philip Muirhead of Caltech. They are nowhere near the parent star's habitable zone, with orbital periods ranging from 0.45 days to 1.87 days. However, finding small planets around an M star, which is the most abundant kind in the Galaxy, gives hope for seeing many more planets. The problem with M dwarfs is that their habitable zones are very narrow, though that is compensated by several factors. Because the habitable zone is close to the star, the chances of catching a planet as it transits the star are better than for solar-type stars. Also, the dip in the light curve is larger, and the radial-velocity signature of the planet would be greater because the star's mass is lower. But the uncertainty in the size of the star—which feeds directly into the uncertainty in the planet's size—is quite large. And as M stars are quite "active" (lots of flares, *etc*), it is unclear that the planets would be habitable—radiation from the flares may sterilize the surface of any planet.

Kepler-20e and f are, respectively, sized like Venus and Earth. There are five planets overall in the Kepler-20 system, and an analysis of the orbital interactions allows some constraints to be placed on the masses (assuming they are rocky with iron cores); Kepler-20e lies in the range from ~0.4 to ~1.7 Earth masses and Kepler-20f in the range from ~0.7 to ~3 Earth masses. They are nowhere near the habitable zone, though, with orbital periods of 6 and 20 days. The equilibrium temperatures are 1040 and 705 K respectively.

It might seem to some readers that assuming that a small planet is mostly rocky with an iron core would be a dangerous and perhaps a circular assumption. The main consideration, however, is the cosmic abundance of materials. Carbon, oxygen, silicon, and magnesium are all very abundant. They are created inside stars and then ejected in winds and "core-collapse" supernovae (where a massive star explodes, leaving a neutron star or black hole behind). Iron is quite abundant also; type Ia supernovae are the main source. These are the supernovae used in the cosmic distance scale and are believed to be detonating white dwarfs that have accreted mass up to about the Chandrasekhar stability limit (and about which I wrote in my last column). Finally, the planets are sufficiently close to the star that, at their sizes, it is unlikely they are able to retain any significant atmosphere.

Kepler has now found Earth-sized planets, and separately, planets in the habitable zone. Soon we should have an Earth analogue and an estimate of how numerous they are. All of a sudden, what was once science fiction and speculation will soon be hard fact. ✶

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.*

Through My Eyepiece

Venus Revealed

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

While there's great anticipation about the upcoming transit of Venus, I'd like to write instead about the pleasures of observing the planet on an ongoing basis.

Venus is a striking object with the naked eye, blazing brightly in the twilight sky, but it's something of a disappointment when viewed with a telescope. It looks rather like a bland version of the Moon, going through similar phases, but without the craters. Part of the problem with Venus is that it is so bright. Its glare against a dark sky makes its subtle shadings hard to detect.

The solution, I discovered many years ago, is to observe Venus in broad daylight. Finding it used to be a challenge, one of the few times that setting circles were really useful. Back in the '60s, George Wedge and I used to observe Venus often with the 165-mm refractor at the Montreal Centre's observatory behind Molson Stadium, using its accurate setting circles to offset the refractor from the Sun. By calculating the difference in right ascension and declination between Venus and the Sun, we neatly dodged the problem of calculating sidereal time. Venus was a lovely sight floating in a clear blue sky through the big refractor.

I was so impressed, I made setting circles for my Cave 200-mm Newtonian. On a memorable day in 1961, I managed to locate Venus when only 27 hours from inferior conjunction, less than eight degrees from the Sun. Only a 20-year-old would dare to point a telescope so close to the Sun! Notice how the atmosphere forms a complete ring in my drawing, the cusps being extended beyond 180° to a full 360°. Jim Low, across the river in St. Lambert, also observed the full circle of Venus that day.

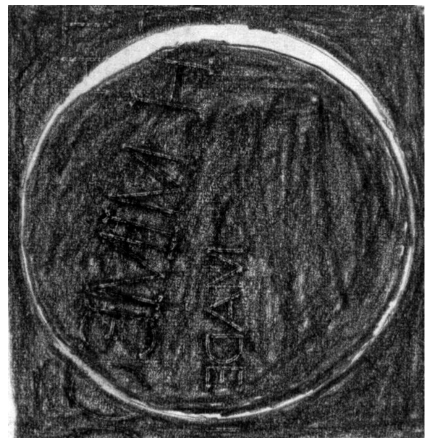


Figure 1 – Venus sketched by the author on 1961 April 9 at 16:05 UT using a 200-mm reflector at 90x. A watermark in the paper made shading difficult!

At that time, there was a lot of interest among planetary observers in trying to detect the dusky shadings that were sometimes seen on Venus's otherwise bland disk. Klaus Brasch and I spent a lot of time experimenting with various filters and attempting to confirm each others' observations. The one filter we found to enhance these markings was a Wratten 47—deep blue, almost violet.

Now that we know, from radar observations, what lies beneath Venus's clouds, there is renewed interest in observing the subtle shadings on Venus's disk. The advent of computerized telescopes has made finding Venus in daytime an easy task.

Even without a computerized telescope, there's a straightforward trick to help to spot Venus in daytime. Look for Venus on the day when it is in conjunction with the Moon. The Moon gives you a location and a target to focus on. Upcoming conjunctions will be on March 26, April 25, and May 22. And don't forget to look for Venus in transit on June 5! ✶

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, particularly of Jupiter and variable stars. Besides this column, he contributes regularly to the* Starry Night Times *and writes a weekly article on the* Space.com *web site.*

Edmonton welcomes you!

53rd General Assembly of the Royal Astronomical Society of Canada
2012, June 28 – July 1

Enjoy Canada's festival city this summer while attending the 2012 General Assembly (GA) of the RASC. It's an excellent opportunity to mix and mingle with fellow astronomers. We've put together an amazing program of exciting speakers for you together with some outstanding social events. We have lined up some great tours for you and your family, including an opportunity to meet a dinosaur face-to-face and a chance to hunt for a meteorite.

The GA will take place at the **University of Alberta** main campus, located in the heart of Edmonton next to the North Saskatchewan River valley—the largest urban greenbelt in North America.

The principal venue will be the **Centennial Centre for Interdisciplinary Science** (CCIS)—the newest building on campus and a vibrant environment for learning and discovery.

Lodging

Lodging will be available at the Lister Centre, which has easy access to campus and offers three styles of accommodation—hotel style, residence style with private washroom, and dormitory style with shared washrooms. We have block booked 80 rooms—some of each style.

The University of Alberta does **not** offer on-line bookings for these facilities, but a form is available on the Web site that can be faxed or emailed.

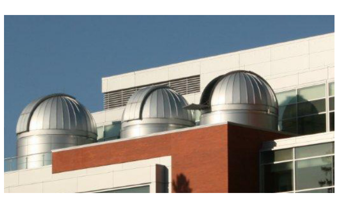
A **hospitality suite** has been reserved for the duration of the GA.

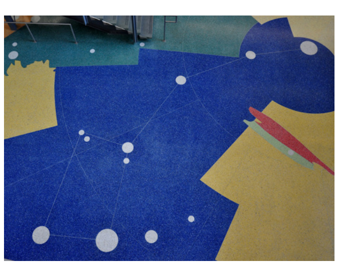
Featured Events

National Council BBQ

We are continuing the fine tradition started in Fredericton by hosting a BBQ for National Council delegates and their guests. The menu will consist of a choice of steak, chicken, or fish entrée* barbecued to your liking. Pre-registration is required. [Thu June 28]

Wine & Cheese Reception





This will be a great opportunity to relax and mingle in the astronomy-themed West Atrium of the CCIS. Admire the stellar terrazzo floor and the Solar System mobile, tour the observatories on the roof, participate in Murphy Night. This reception will be kicked off with an invited talk by **Dr. Martin Connors**. [Fri June 29]

Helen Sawyer Hogg Public Lecture

This public lecture will be presented by **Dame Jocelyn Bell Burnell**, best known as the discoverer of pulsars. A reception will follow. [Sat June 30]

Closing Banquet

The closing banquet in the Maple Leaf Room at Lister Centre will feature a choice of beef tenderloin, stuffed chicken, or glazed salmon for the entrée*. The featured speaker at the banquet will be **Dr. Chris Herd**. [Sun July 1]

Catered Meals

- National Council BBQ [Thu June 28]
- Wine & Cheese [Fri June 29]
- Catered Lunch [Sat June 30]
- BBQ before Hogg Lecture [Sat June 30]
- Closing Banquet [Sun July 1]

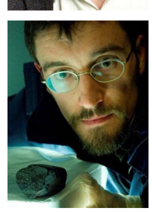
** Vegetarian options available upon request for all catered meals.*

Other Invited Speakers

Dr. Martin Connors
Athabasca University

Invited Talk

"Earth's Trojan Asteroid: A Space Odyssey to a Space Oddity"



Dr. Christopher Herd
University of Alberta

Banquet Speaker

"When the Sky Falls: Meteorites as Probes of Other Planetary Bodies"

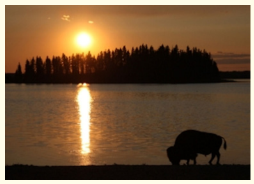
Tours

Our tours are designed to offer fun for the whole family. Choose among three full-day tours and four half-day tours. See the Web site http://edmontonrasc.com/2012ga/ga_registration.html for details.

Whitecourt Meteorite Crater

About 1,100 years ago, a space rock the size of a big tree stump slammed into western Canada. This is your chance to go on a guided tour of the impact crater. Hunt for your very own meteorite specimen!

Elk Island National Park & Beaver Hills Dark-Sky Preserve



Explore this beautiful oasis, home to herds of free-roaming plains bison, wood bison, moose, deer, and elk. Be it for wildlife viewing, hiking, golfing, picnicking, or camping, there is something for everyone at Elk Island National Park.

Fort Edmonton Park

At Canada's largest living history museum, explore Edmonton's progress from a fur-trade post in the vast Northwest to a booming metropolitan centre after the First World War.

Enjoy Centre

More than a garden centre, the Enjoy Centre is built on the central conviction that consumers want more than products and services. They want an experience. Always inspiring. Always evolving. Always inviting.

Jurassic Forest

A new interactive dinosaur park, featuring Tyrannosaurus rex, one of 40 life-sized, pre-historic robotic beasts. Take a guided tour or walk by yourself.

Muttart Conservatory

A year-round escape into the beauty of the world's plant life. Vibrant, colourful, tranquil and inspirational, the pyramids' display gardens are a welcome oasis for all.

TELUS World of Science—Edmonton

There's nothing quite like the TELUS World of Science. Kids love it. Adults think it's great. Experience science like never before. Explore an exhibit or two, catch the latest IMAX film, immerse yourself in cool Full-Dome shows in the Margaret Zeidler Star Theatre, or be dazzled by an array of Science Demonstrations.

Display Competition

We will have three display competitions, open as follows:

- Project displays (adult RASC members)
- Project displays (students—open)
- Photography and Visual Displays (open)

See the Web site http://edmontonrasc.com/2012ga/ga_registration.html for details.

Call for Papers

We will have two sessions of papers where delegates can share their astronomical experiences, data, and insights. Submissions are due by 2012 April 1. See the Web site http://edmontonrasc.com/2012ga/ga_papers.html for details.

Registration

Registration is now open! Registration fees are:

$110/person by March 31,
$135/person by May 31,
$150/person June 1, onwards

Online registration
http://edmontonrasc.com/2012ga/ga_registration.html
closes June 18.

Transportation

We are offering complimentary transportation between the Edmonton International Airport, VIA Rail Terminal, or bus terminals and Lister Centre *(or wherever you may be staying, if possible).*

See the Web site http://edmontonrasc.com/2012ga/ga_registration.html for details. Parking is available at Lister Centre for those who wish it.

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Society News

by James Edgar
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Have you checked out the revamped www.rasc.ca Web site? If you haven't, then it's time you did. Much work, effort, dollars, hours, and head scratching have gone into making a visit to our Web site a vibrant enjoyable experience. It's also meant to be an easy way to find things; with the new search engine and more user-friendly menus, finding stuff couldn't be easier. Thanks to the wide and varied team who worked so hard on improving this important aspect of our outreach. Believe it or not, a Web site is educational; our mandate is to educate, thus it forms a part of our charitable activities.

By the time you read this, National Council Meeting NC121 on March 10 may well be part of our history. Not only will it be historical, it will be a game-changer, as our governance model is reformed to match our actual way of doing business. More importantly, we will get our act in line with the precepts contained in the new Canada Not-for-profit Corporations Act (CNCA). I've been a RASC member since 2000, and there has been talk of changing governance since I joined!

Remember the Board Pilot Committee experiment of 2006 and 2007? We tried a 12-member board, as well as reporting to National Council. The problem was that there was still a small group who did the actual governing (decision making), while the larger committee met occasionally to discuss direction and policy. It added an extra layer of meetings, and accomplished nothing more than could be done "the old way." We may well end up with a board of directors of 8 to 12 people, different but the same. The difference will be key to a new way of operating—watch for more news as events unfold. ✶

Astrocryptic Answers

by Curt Nason

1 M	E	2 R	C	3 U	R	4 Y		5 H	A	6 D	A	7 R
U		E		R		E		I		E		I
8 S	E	D	N	A		9 R	E	G	U	L	U	S
C		D		N		K		G		O		I
10 A	P	A	T	I	T	E		11 S	U	S	A	N
		W		U		S						G
12 D	Y	N	A	M	O		13 C	14 O	S	15 M	O	S
O						16 A		C		I		
17 L	O	18 C	A	19 L		20 L	A	C	E	R	T	21 A
P		A		Y		U		U		A		S
22 H	Y	P	E	R	E	D		23 L	U	N	C	H
I		E		I		R		T		D		E
24 N	A	K	E	D		25 A	L	S	H	A	I	N

It's Not All Sirius—Cartoon

by Ted Dunphy

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

Executive committee and appointed officers for 2012/Comité exécutif et membres attitrés pour 2012

Honorary President	Jim Hesser, Ph.D., Victoria
President	Mary Lou Whitehorne, Halifax
1st Vice-President	Glenn Hawley, B.Sc., B.Ed., Calgary
2nd Vice-President	Colin Haig, B.Sc., M.Sc., Hamilton
Secretary/Recorder	James Edgar, Regina
Treasurer	Mayer Tchelebon, MBA, CMA, Toronto
Past Presidents	Dave Lane, Halifax and Scott Young, B.Sc., Winnipeg
Editor of Journal	Jay Anderson, B.Sc., MNRM, Winnipeg
Editor of Observer's Handbook	David M.F. Chapman, M.Sc., Halifax
Editor of The Beginner's Observing Guide	Mary Lou Whitehorne, Halifax
Editor of Observer's Calendar	Dave Lane, Halifax
Executive Director	Deborah Thompson, CAE, Toronto

Centre addresses/Adresses des centres

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

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Calgary Centre
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Calgary AB T2P 2M5

Charlottetown Centre
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Charlottetown PE C1A 3B5

Edmonton Centre
c/o Telus World of Science
11211 142 St
Edmonton AB T5M 4A1

Halifax Centre
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Oakville ON L6L 1G8

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Kitchener-Waterloo Centre
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London Centre
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Montréal Centre
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Pierrefonds QC H9K 1N6

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Victoria Centre
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Journal

Great Images

Lynn Hilborn surprises again with this exquisite 16-hour exposure of M78 (top) and NGC 2071 (bottom) taken on various nights between November and January. The two gas clouds, about 1600 light-years away, are cavities carved out of the Orion Molecular Cloud Complex, a group that also includes the Horsehead Nebula. Lynn used a TEC-140 refractor on a Takahashi NJP mount with an FLI ML8300 camera from his WhistleStop Observatory in Grafton, Ontario. For his 16 hours of work, Lynn accumulated 160 minutes in each of LRGB and 300 minutes in Hα.