

June / juin 2007 Volume/volume 101 Number/numéro 3 [724]

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# Journal

The Journal of the Royal Astronomical Society of Canada    Le Journal de la Société royale d'astronomie du Canada



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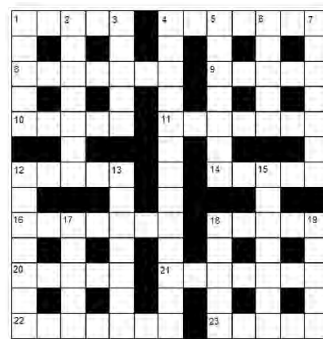
by Ray Khan



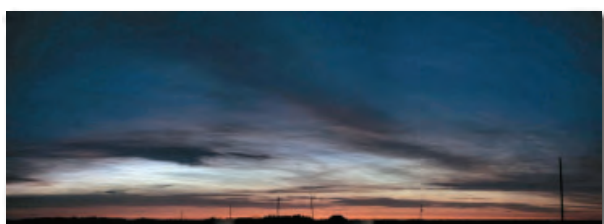
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*by Curt Nason*



On the Cover:

Forest fire smoke helped colour the Moon on the evening of September 6, 2006. This series by Alister Ling was taken from St. George's Crescent, overlooking the river valley to the south side of Edmonton. Canon 10D, 300-mm, f/13, ISO 100, 1/15th sec. Composited in Photoshop.

As Alister notes, "It really helps to know exactly at what azimuth the Moon is going to rise from a particular location!"

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by Bruce McCurdy, Edmonton Centre (bmccurdy@telusplanet.net)

*Rising like lightspill from this sleeping town*

*Like the light in a lover's eyes*

*Rising from the hearts of the sleepers all around*

*All those dreamers trying to light the sky*

*Burning - all night long*

*Burning - at the gates of dawn*

*Singing - near and far*

*Singing - to raise the morning star*

— BRUCE COCKBURN

Environmental issues dominate the news these days. One such issue of particular concern to astronomers is light pollution. Urbanites have become so accustomed to artificial lights as a necessary and benign contributor to modern society that the problem of wasted light is largely “hidden in plain view.” While nobody is seriously opposed to “smart lighting” where and when it is needed, a substantial portion of generated light is wasted for no better reasons than poor planning and ill-conceived lighting fixtures.

We naturalists of the night have an obligation to educate and inform all sectors of society. Not only is the night sky our own particular passion, it is *everybody's* birthright, and a timeless source of wonder and inspiration for our future scientists, artists, and poets.

The issue is much larger than “just” astronomical. My approach is not to hide my special interest — as an astronomer, I mourn the gradual degradation of the night sky, one of humanity's greatest natural treasures. But then I expand on that — as a concerned citizen, I am opposed to the needless burning of fossil fuels and creation of greenhouse gases; as a taxpayer, I resent the cost of sending light up into the sky; as a driver, I fear the glare in my eyes that may cost me a moment of reaction time at the worst possible split-second; and so on.

Given the “win-win-win” solutions to this problem, it is important to form partnerships with other potential winners. In Edmonton Centre, we have formed a solid relationship with national and provincial parks. An early result was the recent declaration of Beaver Hills Dark Sky Preserve (BHDSP), which formally protects in perpetuity 300 square kilometres surrounding and including our observing site. Our goal as astronomers was not merely to create a “Sky Zoo”; we are using our new status as stakeholders in the area to connect with surrounding communities and promote smart lighting initiatives.

Within the city, our objectives are similar. We are developing relationships with municipal parks, the zoo, the botanic gardens, and the science centre — institutions whose own mandate is

# 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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The *Journal of The Royal Astronomical Society of Canada* is published at an annual subscription rate of \$80.00 by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Annual fees for 2007: Youth, \$34.25; Ordinary, \$55.00; Life Membership, \$2,100. Applications for subscriptions to the *Journal* or membership in the RASC, and information on how to acquire back issues of the *Journal* can be obtained from:

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Canadian Publications Mail Registration No. 09818

Canada Post: Send address changes to 136 Dupont St, Toronto ON M5R 1V2

Canada Post Publication Agreement No. 40069313

We acknowledge the financial support of the Government of Canada, through the Publications Assistance Program (PAP), toward our mailing costs.

U.S. POSTMASTER: Send address changes to IMS of NY, PO Box 1518, Champlain NY 12919.

U.S. Periodicals Registration Number 010-751.

Periodicals postage paid at Champlain NY and additional mailing offices.

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environmental leadership and public education. We will try to convince town planners and private developers that smart lighting will be “The Look” of environmentally sensitive communities of the future — and who doesn’t want to live in one of those?

Prospective partners include the influential arts and cultural community. Birders are natural allies, especially groups like the Fatal Light Awareness Program (FLAP). So are other environmental non-government organizations, such as those who support protection of wildlife corridors and migration routes through responsible land-use guidelines. In Edmonton we have set up a long-term light-pollution display at Mountain Equipment Co-op, whose clients/members are the outdoors-oriented demographic particularly sensitive to environmental issues. The response has been tremendous, and we have constantly had to restock the display with brochures promoting responsible lighting (courtesy of our friends in Calgary Centre, the International Dark-Sky Association, and BHDSP).

In the process of publicizing the issue, we are also raising awareness in astronomy. Since the declaration of BHDSP, our co-signatories, Parks Canada and Alberta Parks & Protected

Areas, have both taken significant steps to include astronomy in their interpretive programming, and have involved us in the planning and delivery process.

We also need to nourish partnerships within the astronomical community, with other Centres and other astronomy clubs. RASC is a national organization with members and resources from coast to coast. As the flurry of activity on the national LPA discussion list has shown, we have much to learn from each other. Let’s share our planning mechanisms and success stories, as Mark Coody of Belleville Centre has done on page 108 of this *Journal*. The imperative remains to “think global, act local.”

Now is an ideal time to take action, when public awareness of environmental issues is high. Recent surveys show a significant majority of urban Canadians care deeply about these issues, and there is increasing pressure on politicians to pay more than lip service to the matter. We must ensure that light pollution is recognized for the wastrel it is, and that it is included in the public discussion. ●

*Bruce McCurdy is chair of the RASC Edmonton Centre’s Light-Pollution Abatement Committee and is a Contributing Editor of the Journal.*

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# Correspondence

## Correspondance

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### Elvis appears along with the Lunar X!

It was a pleasure to read David Chapman's article about Werner X in the 2007 April *JRASC*. A couple of weeks before, on March 26 at roughly 05:45 UT, several observers in the Edmonton RASC found the feature to be quite obvious and prominent. To paraphrase Mr. Chapman, when the time is right, you can't miss it!

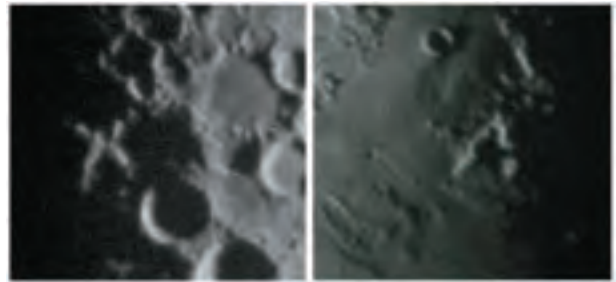
An additional parameter that could affect the X's visibility is solar latitude on the Moon, which varies slowly from +1.5 to -1.5 degrees. It's not much, but it would have its greatest impact at low Sun angles. At the same colongitude, or altitude of the Sun, parts of the X may be in shadow at one solar latitude but not another.

Attached is a cropped still image (north up) that I took from my backyard with my 32-cm Newtonian at 05:49 UTC March 26, 2007, when the colongitude was 358.8 and solar latitude +0.5.

By a remarkable coincidence, this is exactly the same colongitude for "Elvis" to appear, at least to my eyes! A few years ago, I noted that when the shadows were just right, Ukert N and the surrounding terrain produced an outline of a figure in black, with the aforementioned crater as his head.

I've included two images, one of the "X" and the other of "Elvis." It is important to note that south is up — with north up the illusion disappears somewhat.

*Alister Ling*  
*Edmonton Centre*



Left — Lunar X at colongitude 358.8°, imaged by the author at 2007/03/26 at 05:49 UT.

Right — "Elvis" imaged at the same time. The "head" is Ukert N. Equipment: 32cm f/5.6 Newtonian, "Barlowed" to f/11.2, Canon 10D, 1/250th sec, ISO 800

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# The Antikythera Mechanism: Still a Mystery

by Martin Beech, *Campion College, the University of Regina* (beechm@uregina.ca)

**W**onder piled upon wonder; I can think of no better way to describe the Antikythera Mechanism.

It is an absolute gem. Plucked from a long-lost shipwreck lying beneath the eastern Mediterranean Sea<sup>1</sup> by sponge divers in 1900, the mechanism is, to paraphrase Winston Churchill, a mystery contained within an enigma. For those who haven't encountered the Antikythera Mechanism before, it is (though perhaps more correct to say "was") a mechanically geared device constructed with the clear intent of "describing" a number of solar-lunar astronomical cycles. While it is incredible that any fragments of the mechanism survived the watery shipwreck (see Figure 1), the additional fact that it was constructed *circa*



Figure 1 — The 82 fragments that constitute the Antikythera Mechanism. For further details and images see: [www.xtekxray.com/antikythera\\_images.htm](http://www.xtekxray.com/antikythera_images.htm). See also the Web page for the Antikythera Mechanism Research Project at: [www.xtekxray.com/antikythera\\_images.htm](http://www.xtekxray.com/antikythera_images.htm).

100 BC is even more remarkable. The mechanism is unique, having no surviving prototypes, no surviving copies, and no surviving provenance. Indeed, geared mechanisms of similar sophistication were not to be made in Europe until the first half of the 14th century. All in all, the origins of the Antikythera Mechanism are a mystery; we do not know who built it, or who designed it, and to some extent, we have no clear idea of its

intended use. This latter point, however, is a topic of great debate, and as with all good mysteries, there is much to tease the imagination and just enough solid evidence to hint at various design possibilities. The latest salvo in the problem-fraught world of explaining the Antikythera Mechanism was published by Tony Freeth and co-workers in the journal *Nature* last November (444, 587 - 591, 2006).

There has been a long history of explaining the Antikythera Mechanism, and the new study by Freeth and collaborators is, no doubt, not going to be the last word on the topic. The basic problem, as illustrated in Figure 1, is that the mechanism is largely in fragments and it is clear that many pieces are missing. There are, however, 30 recognized gears (most of which reside in the single fragment seen in the upper left-hand corner of Figure 1). The late Yale University historian of science Derek de Solla Price published the first comprehensive description<sup>2</sup> of the Antikythera Mechanism in 1974, and in a remarkably detailed study, suggested a reconstruction of the machine using a total of 31 gears. The more recent reconstruction by Freeth and co-workers (see Figure 2) uses 36 gears, of which 7 are hypothetical<sup>3</sup>

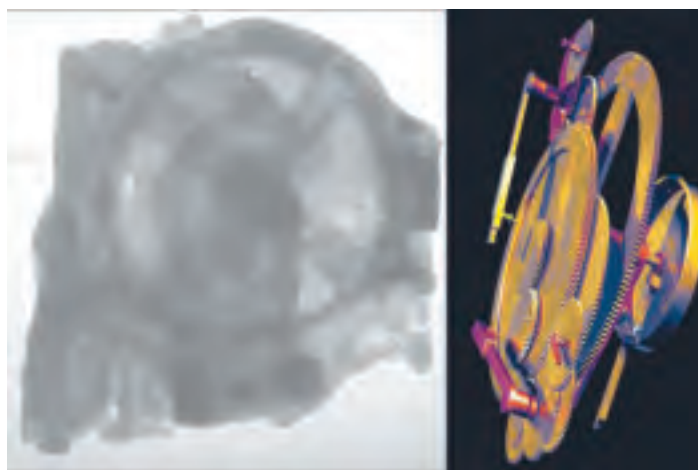


Figure 2 — On the left is an X-ray image of the largest gear-containing fragment of the Antikythera Mechanism, while on the right is a computer-generated image of the recent gearing arrangement proposed by Freeth *et al.* Further images can be seen at [http://content.techrepublic.com/2346-10877\\_11-38336-1.html](http://content.techrepublic.com/2346-10877_11-38336-1.html). Animations of the mechanism in action can be downloaded from [www.etl.uom.gr/mr/index.php?mypage=antikythera\\_ani](http://www.etl.uom.gr/mr/index.php?mypage=antikythera_ani).

(one of the surviving gear fragments isn't actually used in the new reconstruction, its purpose presently being unclear).

While the precise details of its construction may never be known, the existence of the Antikythera Mechanism clearly tells us one thing that was hitherto unknown: there must have been a vibrant community of skilled metal workers, engravers, and artisans in the ancient world over 2000 years ago, of which at least a few must have been capable of making remarkably complex machines. The existence of this sub-culture, however, was not generally suspected until the discovery of the Antikythera Mechanism was made, and its recovery has forced historians to re-evaluate their assumptions about ancient Greek technology. There are a few vague hints within the surviving literature to suggest the existence of "magnificent" astronomical "machines," but no useful details or descriptions are ever provided by the ancient authors. In their recent work, Freeth and co-workers have upped the ante somewhat and suggest that the renowned philosopher Hipparchus may have been involved in the design of the Antikythera Mechanism; a suggestion based upon their conjecture that his lunar theory is incorporated within the surviving gearing. We, of course, will probably never know if this is true or not<sup>4</sup>.

Many suggestions have been made concerning the intended user, or users, of the Antikythera Mechanism, but the issue continues to remain unclear. Why was it built? In spite of its sophistication, it seems reasonably clear that it was not intended to make precise predictions of astronomical phenomena. First, the gearing ratios and hand-crank operation of the mechanism, while good, would have provided at best only approximated times at which, for example, eclipses would occur, and at what approximate times various planetary alignments might take place. At best the machine would have only followed what "astronomers" already knew was likely to be happening in the sky — there is no apparent means, for example, of "setting" the device to some specific date into the future or the past<sup>5</sup>. Second, one could argue, the prediction of eclipse times and other astronomical phenomena was achieved well enough through hand- and table-based calculations by scribes distributed throughout the ancient world, who had no apparent access to similar machines. Such information was not actually deemed to have any great value in ancient Greek society. Third, the complex construction and intricate workings of the Antikythera Mechanism rule out its use as a "visual" demonstration piece — showing, as it were, the "clockwork" of the heavens. This all suggests that the Antikythera Mechanism was actually an exhibition device, probably (one might conjecture) built for a rich patron, who never actually used it, by a singularly gifted craftsman. The Antikythera Mechanism is a treasure for sure,

but mostly likely not a calculator built for real astronomical (or astrological) use by a practising astronomer (or astrologer — though there was no ancient distinction between the two occupations). ●

## Notes and references

1. The story behind the Antikythera Mechanism's discovery is given by J. Marchant (2006, *Nature*, **444**, 534 — 538). It is generally agreed that the shipwreck from which the mechanism was recovered was a treasure-ship returning to Rome with looted plunder from Asia Minor circa 85 – 60 BC. Details concerning some of the recovered cargo are given in G.D. Weinberg *et al.* (1965, The Antikythera shipwreck reconsidered. *Trans. Am. Phil. Soc.* **55**, 3 – 48). Additional background details can be found at [http://en.wikipedia.org/wiki/Antikythera\\_mechanism](http://en.wikipedia.org/wiki/Antikythera_mechanism).
2. Price, D. de S. 1975. Gears from the Greeks. *Trans. Am. Phil. Soc.* **64**, 1 – 70. An "expanded" reconstruction of the Antikythera Mechanism is given by M.T. Wright (2002, A planetarium display for the Antikythera Mechanism. *Horological Journal*, **144**, 169 – 173). The general consensus among present-day commentators is that Price's reconstruction of the Antikythera Mechanism is no longer valid.
3. The fact that a number of the surviving gears are only partially preserved means that there is an unavoidable uncertainty in the measurement of their physical size and teeth counts. Freeth *et al.* provide a summary of teeth count determinations in a supplement to their paper — see: [www.nature.com/nature/journal/v444/n7119/supinfo/nature05357.html](http://www.nature.com/nature/journal/v444/n7119/supinfo/nature05357.html). A detailed description of each surviving gear fragment is provided by M.T. Wright (2005, The Antikythera Mechanism: a new gearing scheme. *Bull. Sci. Inst. Soc.* No. **85**, 2 – 7).
4. I should point out that the details presented by Freeth and co-workers do indicate that the Antikythera Mechanism had a gear and pinion system that allowed for a lunar anomaly correction of about the size advocated by Hipparchos. To argue that Hipparchos was actually involved in the design of the mechanism, however, stretches very thin data too far. This being said, it certainly appears that the machine incorporated within its design the very latest in astronomical thinking.
5. It is true that the various dial fragments do show zodiacal and calendric scales, but to access data concerning, say, potential eclipse events many months or years into the future, or events that occurred in the distant past, would not have been possible — short of excessive amounts of winding upon the machine.



# Determining the Orbital Periods of Jupiter's Galilean Satellites Using Simple Devices

by Raymond Auclair, *Unattached Life Member* (auclair@cyberus.ca)

### ABSTRACT

In this project, I sought to analyze the motion of Jupiter's moons and to determine the orbital periods of the four Galilean satellites using small telescopes, simple timing techniques, and basic analytical tools similar to those that might have been used by Galileo himself. Satellite positions were observed from March 8 to May 11, 2006. Timings were done using a metronome, following the objects' drift out of the field of view because of the Earth's rotation.

I discuss the methods used in observing, timing, and analysis. Emphasis is given to identification of errors and to corrections applied to the raw data. Computations used simple sine-curve fitting and optimizing parameters (period, amplitude, elongation) to minimize the sum of the squares of the errors. Additional corrections were applied to offset the rotation of the synodic frame of reference at Jupiter relative to the Earth.

Synodic periods calculated from two months of observations are 1.7698 days for Io, 3.5528 days for Europa, 7.1524 days for Ganymede, and 16.687 days for Callisto, in very good agreement with published values. Orbital distances and date and time of elongations were also determined.

### RÉSUMÉ

Le but du projet était d'analyser le mouvement des satellites de Jupiter et d'en déterminer les périodes orbitales à l'aide d'un petit télescope, en utilisant un chronomètre simple et en suivant des méthodes d'analyse qui auraient pu être utilisées par Galilée lui-même. Les positions des satellites ont été relevées du 8 mars au 11 mai 2006. Les intervalles ont été déterminés à l'aide d'un métronome, en laissant dériver les lunes hors du champ de vision, au rythme de la rotation terrestre.

Je décris les méthodes d'observation, de mesure de temps et d'analyse. Je m'attarde à l'identification des erreurs et aux corrections apportées aux données brutes. À partir d'une sinusoïdale, je minimise la somme des carrés des erreurs afin d'optimiser les paramètres (période, amplitude, élongation). Je corrige aussi la rotation du référentiel synodique Jovien, par rapport à l'observateur terrestre.

Après deux mois d'observations, j'ai calculé des périodes synodiques de 1,7698 jours pour Io, 3,5528 j pour Europa, 7,1524 j pour Ganymède, et 16,687 j pour Callisto, ce qui est près des valeurs publiées. J'ai aussi estimé des rayons orbitaux et les moments des élongations maximales.

### Introduction

*Superest ut, quod maximum in praesenti negotio existimandum videtur, quatuor planetas a primo mundi exordio ad nostra usque tempora numquam conspectos, occasionem reperiendi atque observandi, necnon ipsorum loca, atque per duos proxime menses ...Die itaque septima Ianuarii, instantis anni millesimi sexcentissimi decimi... (Galileo)*

Galileo discovered the moons of Jupiter on January 7, 1610, and observed their positions relative to Jupiter for the following two months (to March 2, 1610). Two years later he published periods for his new "planets." "They were virtually the same as the modern values." (Van Helden, in Galilei, 1989).

### The Spirit of the Project

My goal was to use two months' worth of observations taken with simple devices to determine how periods calculated using such a method compare with modern values. I did not wish to recreate Galileo's observations, nor did I aim to recreate the exact conditions that existed at some specific time in history. Instead, I tried to keep things as simple as possible so that each element of the project could represent the way things were done at some time in the 17th century.

Like Galileo's, my first observations of Jupiter's moons were casual and, unfortunately, not very accurate. After a few weeks, it became clear that I needed to keep a better "account of the changes in their positions, accurately determined from then

on.” (Galileo, after his 11th day of observation).

In order to maintain a Galilean spirit, I didn’t consult ephemerides, star charts, or virtual planetaria. Only once did I observe a shadow cast by a satellite on Jupiter’s disk. On another occasion, I observed a satellite reappear from Jupiter’s shadow. Thus there are only two satellites for which I have evidence for prograde motion. I never saw a moon in front of Jupiter’s disk.

### History Repeats Itself?

Galileo had designed a special device — a series of holes in a plate designed to be fitted over the objective lens — to estimate angular distances separating objects. However, as Albert Van Helden notes in his translation of Galileo’s *Sidereus Nuncius* (Starry Messenger), “all efforts to turn this form of telescope into a measuring instrument failed.”

I could have constructed a reticulated eyepiece using a hair and some glue. However, the metal holder of my main eyepiece (7 mm) is physically too long and I would have had to drill hair-sized holes at exactly 7 mm from the central plane of the lens in order to pass the hair inside the tube. I did not have the proper tools (and even if I did, I am manually inept).

On a few occasions, I drew star fields around Jupiter. The idea was to be able to distinguish the satellites from the fixed stars. However, as was the case for Galileo in 1610, Jupiter spent most of the two months in an area devoid of stars visible in the 80-mm telescope.

In describing the working of his telescope and his project, Galileo states that he used sine tables. That gave me the idea to try to fit sine curves through the data I obtained. Eventually I ended up using a cosine curve, which is simply a sine curve offset by a quarter rotation: I began my cycles at greatest elongations rather than at conjunctions, the latter being impossible to observe in my telescopes.

Galileo did not slip on ice and break a few ribs while setting up his telescope. I did.

### Basic Concepts

The fact that orbits are generally ellipses was known by Galileo (from Kepler’s work). Astronomers already knew how to modify circular models to approximate the shape of ellipses; using epicycles was one way of doing this. However, proper equations for ellipses were also well known. Because of the low eccentricity of the Jovian moons’ orbits, I decided to model circular orbits, making the analysis easier. In any event, a first approximation (using circular orbits) would have been used before applying corrections towards a more-refined, elliptical model.

In correcting for the rotating frame of reference (Jupiter’s solar longitude changes less rapidly than Earth’s), I used the equatorial system (Right Ascension and Declination). I compared my results with the ecliptic system (longitude) and found one just as acceptable as the other. Both systems would have been known to Galileo. I modelled the rotation of the frame as a

changing angle in a plane triangle, allowing the use of formulae that were known well before Galileo’s time.

### Methods and Instruments

#### The Accident

On February 28, while I began to set up my 10-inch Meade Newtonian in the backyard to be ready for the projects, I fell on the ice and cracked a few ribs. Fortunately, there were no complications, and the cracks healed well. However, I was unable to lift anything for a month and therefore unable to use my big telescope. The tripod (20 kg) spent the rest of winter on top of snow and ice, out of use until after April 20, when the snow was gone and the ground dry.

In early March, I borrowed my wife’s telescope, a 2-inch zoom refractor purchased for the transit of Venus in June 2004. No part weighs more than 1.5 kg (the tripod).

I tried using a digital video camera mounted on the same tripod with maximum zoom, but this proved unsuccessful. From tens of minutes of film, I got only a few frames showing one or two moons.

A new telescope was acquired in late March. It was possible to leave this new telescope completely mounted in the garage. With a total mounted weight of less than five kg, I could lift it easily, carry it five metres to a location in the driveway, and put it down so that my ribs barely noticed. This became the telescope of choice for this project (Figure 1).



Figure 1— The author (and observer), the three telescopes, the video camera (on the nearer table), and other equipment used for the project.

Because of the accident, and because the month of April is usually mediocre for astronomy in Ottawa, I asked my brother Michel Auclair to help make observations. He lives near Québec City, and I hoped that he could fill gaps when I’d be clouded out. As it turned out, I had an exceptionally clear period from April through to mid-May, while he was consistently clouded out.

However, Michel sent me eight observations; only one was taken on a night when I was not able to observe (April 7). This observation was used in the analysis.

## Timings

The original plan was to estimate the distance from each moon to Jupiter in terms of “Jupiter diameters.” When satellites were close to Jupiter, this was easy to do. However, it proved very imprecise at distances greater than five diameters. Luckily, I had also experimented with several kinds of timing techniques right from the start.

### Methods of Timing

Use of a stop watch or a digital watch did not work out well. I cannot observe with reading glasses, and I cannot read my watch without reading glasses. Because observations were done at night, there was not enough illumination to read the watch despite a generous amount of light pollution in my neighbourhood. As a result, my early observations were less accurate than those later on.

It was reported that Galileo used his pulse to time events<sup>1</sup>. I was unable to use my pulse because of medication, so I borrowed another of my wife’s instruments — a metronome. After setting the metronome at 120 beats per minute, I was able to count elapsed time and estimate intervals to the nearest half-second. The time count began at zero when the westernmost object disappeared from the field of view of the unguided telescope. Each limb of Jupiter and each of the moons were counted as distinct objects. Multiple runs were done, with several times measured for runs having large intervals.

### Data Records

The exact time of an observation was recorded to the nearest ten minutes in most cases. I suspect this was similar to the time accuracy available to Galileo. Times in my logbook are often in local time: Eastern Standard Time (UT -5) until April 2, then Eastern Daylight Saving Time (UT -4). Appendices show dates and times in UT. Spreadsheets show Julian Dates, with the number truncated to show only time elapsed since 12h UT on March 5, 2006 (Julian Date 2,453,800.0).

All observations were noted on small pieces of paper, usually with a drawing showing the relative positions of moons and planet. Except for the last observations in May (where entries were posted directly to the logbook), the scraps of paper were taped in the logbook. Some early entries show “converted” data (in planet diameters); later entries, however, are consistently done in time units. Earlier entries were converted back to time equivalents for the analysis. In summary, distances from Jupiter to the satellites are in seconds of time: the time interval respectively

of the disappearance from the field of view of the moons and the planet.

Jupiter’s equatorial diameter of 142,980 km subtended a little over 43 arc-seconds at its largest, and its declination was approximately  $-15^\circ$ . The equatorial diameter of Jupiter spanned three seconds in RA at that declination. Thus, it took three seconds for Jupiter to traverse a fixed point in the scope. A total of 82 timings were collected (including 8 from Michel) on 40 distinct nights.

## The Instruments

### Telescopes

- 1) Refractor: 50-mm aperture, built-in image erector, and zoom (15× to 45×).
- 2) Sky-Watcher SK 80/400 EQ/TA refractor: 80-mm aperture, 400-mm focal length; PLÖSSL 25-mm (16×) and 7.5-mm (53×) eyepieces; on an equatorial mount manually driven by worm gears. By itself, this telescope would have been quite sufficient for this project.
- 3) Meade 10<sup>1</sup>/<sub>4</sub>-inch Newtonian reflector: 260-mm aperture, 1000-mm focal length; PLÖSSL 25-mm (40×) and 7.5-mm (133×) eyepieces; on an equatorial mount with direct electrical drive on hour circle; no fine correction for tracking.
- 4) Dobson Newtonian: 150-mm aperture, 1200-mm focal length; eyepieces unknown (Michel’s telescope).

### Camera

Canon Elura 70 digital video camcorder: 25-mm aperture; nominal focal length 45-mm with 18× optical zoom and “360× digital zoom,” used on manual-focus setting at infinity and aimed through the eyepiece with the telescope’s focus set for my right eye. The video was then analyzed for best frames, which were then captured on the photo card and transferred to a computer file. This setup provided only a few shaky frames of Jupiter (Figure 2).



Figure 2 — Photos of Jupiter through the Meade telescope. These proved largely unsuitable for accurate measurements of the positions of the moons.

<sup>1</sup> <http://scienceworld.wolfram.com/biography/Galileo.html>

## Other Equipment

The metronome is a Taktell-Piccolo “Wittner Prazision” made in Germany. It has a slide that can be adjusted for the desired number of beats per minute, from 40 to 208. There is a key to rewind the spring and, when “fully loaded,” it can beat at 120 b/s for almost 19 minutes.

A red light (7.5 W) was mounted on an extension chord; it was only necessary when observing in the backyard (with the large Meade). At the usual location for the other scopes, street lights provided more than sufficient illumination.

## Calculations

### Transforming the Data

As the original purpose was to measure orbital periods and distances from Jupiter to each moon, the values collected at the eyepiece needed to be translated and expanded before they could be used in a spreadsheet.

### Translation and Reflection

To begin, I used the timings of the planetary limbs to determine the value for the centre of the planet (half-way between the limbs), and subtracted this value from all data. This effectively moved the origin (0) to the centre of the planet. I also changed all the signs of the observations, a procedure that reverses the direction of the timing.

TABLE 1: A SAMPLE ENTRY FOR ONE RAW (UNCORRECTED) OBSERVATION.

2006-03-12 06:00 R1	0	4	10/13	22	32		
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For example consider the entry “0, 4, 10/13, 22, 32” shown in Table 1. The numbers represent the timing of two moons, Jupiter’s leading and trailing limbs, and the remaining two moons. The zero value is moved to the centre of the planet (subtract  $11\frac{1}{2}$ ) and the signs inverted to give “ $11\frac{1}{2}$ ,  $7\frac{1}{2}$ , 0,  $-10\frac{1}{2}$ ,  $-20\frac{1}{2}$ ” (the

TABLE 2: THE RELATIVE POSITIONS OF EARTH, SUN, AND JUPITER (AT OH UT) USING DATA FROM [www-lep.gsfc.nasa.gov/code693/TYPE/sun2.html](http://www-lep.gsfc.nasa.gov/code693/TYPE/sun2.html)

Date 2006	RA Sun	Dec Sun	AU	RA Jup	Dec Jup S	Jup-Sun	Jup-Earth
March 2	22 50 50.7	7 20 33.1S	0.9910400	15 07 00.1	16 13 41.9	5.43173	
March 9	23 16 52.0	4 38 27.6S	0.9927695	15 06 57.1	16 12 16.5	5.430645	4.87
March 16	23 42 35.4	1 53 05.3S	0.9946200	15 06 18.1	16 08 28.0	5.42955	4.78
March 23	0 08 08.1	0 52 50.9N	0.9965985	15 05 02.5	16 02 14.5	5.42843	4.69
March 30	0 33 37.4	3 37 36.1N	0.9986160	15 03 13.5	15 53 48.4	5.42729	4.61
April 6	0 59 10.1	6 18 56.4N	1.0005910	15 00 53.0	15 43 16.2	5.42612	4.55
April 13	1 24 51.0	8 54 58.2N	1.0025570	14 58 06.6	15 30 59.9	5.42494	4.49
April 20	1 50 47.8	11 21 34.8	1.0045355	14 54 58.8	15 17 15.4	5.423725	4.45
April 27	2 17 05.4	13 43 16.4	1.0064580	14 51 36.4	15 02 29.7	5.42250	4.42
May 4	2 43 48.0	15 51 40.8	1.0082260	14 48 05.7	14 47 10.3	5.42125	4.41
May 11	3 10 56.3	17 47 23.5	1.0098620	14 44 34.4	14 31 50.4	5.41998	4.42

westernmost satellite exits the field of view 11.5 seconds before the centre of Jupiter). In retrospect, the sign inversion brings no advantage, and the entire analysis would have been done in exactly the same manner without it.

If a satellite was hidden from view, being behind or in front of the planet, it is given a value of 0, unless I had some indication of its true position, for example, if I saw it merge with the planet’s limb some minutes before.

Note that reflected values are positive when the satellite precedes Jupiter (to the west of the planet) and negative for moons on the east side.

### Expansion and Clean-Up

In order to get rid of the fractions, the entire scale was multiplied by 2. This expansion did not change the relative position and distances of the satellites; it merely changed my time units to “half-second” beats. The new second entry then became 23, 15, 0, -21, -41. In this new scale, the centre of the planet was always at 0, and so I could leave it out: my observations became “23, 13, -21, -41.”

Only one observation per night is retained, except where the observations span more than five hours, in which case there may be two. In one case (2006/05/10 07:30), two observations were “averaged” for the time when the transiting satellite should have value zero.

A complete listing of the observational data and the processing steps can be found in the supplemental material on the Web.

### Correcting for the Distance to Jupiter

There are three types of corrections for distance. Two deal with the finite speed of light, the other with the distance scale implied by the time count. Positions are recorded in “Earth time,” though all events take place around Jupiter and light takes time to reach us. Because the correction for the mean distance to Jupiter adds only a constant value to all of the timings, the delay was ignored.



However the changing distance to Jupiter over the dates of the observations imposed a small time compression on the data because of the varying light-travel time. Finally, as the Earth-Jupiter distance changed, the apparent amplitude of a moon's orbit varied, being wider at opposition (May 4) than in March or April.

### Calculating the Distance

Keeping with the spirit of the project, I tried to use techniques and information that were available in the 17th or 18th centuries. The relative distances of planets from the Sun were known. Setting the Sun-Earth mean distance at 1 gives distances in terms of the astronomical unit (AU). In Galileo's time, ephemerides existed that gave sufficiently accurate times of conjunction and opposition for planets.

Jupiter was at opposition on May 4, 2006. Taking this as the date of smallest distance between Jupiter and Earth, I found the celestial coordinates of Jupiter and the Sun for that date and for seven-day intervals (Table 2). As any three distinct points in a volume mark off a plane triangle (Figure 3), given any three elements (including at least one side), we can find the others (Table 3).

The distance from Earth to Jupiter (call it  $z$ ): to calculate this I took the distance from the Sun to Earth and from the Sun to Jupiter from the *Observer's Handbook 2006* (RASC 2006). I then calculated the apparent angle  $X$  (Figure 3) between the Sun and Jupiter (at the Earth), using spherical trigonometry's cosine formula, that likely predated the 14th century (according to [www.krysstal.com/sphertrig.html](http://www.krysstal.com/sphertrig.html)):

$$\cos(X) = \sin(\delta_s)\sin(\delta_j) + \cos(\delta_s)\cos(\delta_j)\cos(\Delta_{RA})$$

where  $\delta_s$  is the declination of the Sun,  $\delta_j$  is the declination of Jupiter, and  $\Delta_{RA}$  is the difference in Right Ascension between the two bodies.

Solving for the distance from Earth to Jupiter is a simple application of plane trigonometry:

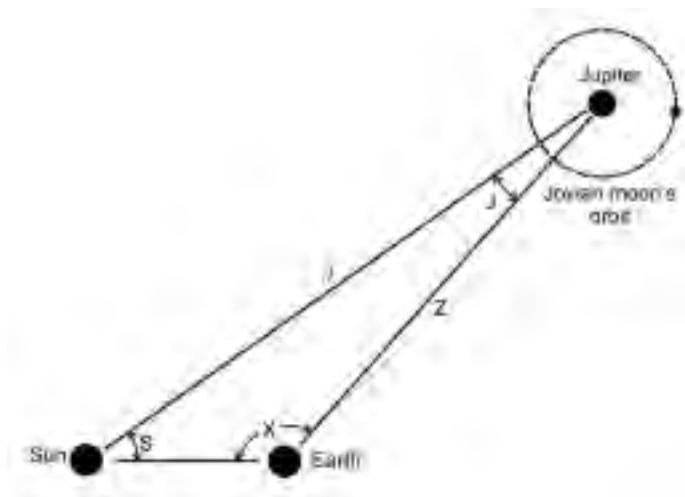


Figure 3 — Diagram showing the geometrical relationship between the Sun, Earth, and Jupiter used to solve for the elements in Table 4.

- 1) find the angle  $J$  at Jupiter using the sine formula:  $\sin J / \sin X = s / j$  where  $s$  is the distance from Earth to the Sun and  $j$  is the distance from the Sun to Jupiter
- 2) find the angle  $S$  at the Sun ( $180^\circ - X - J$ )
- 3) find the distance  $z$  with the plane cosine formula:

$$z^2 = s^2 + j^2 - 2sj\cos(S)$$

The calculation could be made more simply using ecliptic coordinates, as there are tables giving heliocentric positions of all planets including Earth. This would give us directly the angle at  $S$  using the spherical cosine formula, and we could jump directly to step 3.

Tables 3 and 4 give the results I obtained (rounded), along with the corrections that should be applied to bring all times and all relative moon distances to a uniform distance of 4.41 AU (at opposition).

The factor in Table 4 shows by how much larger the values would be if Jupiter had been at 4.41 AU throughout the period of observation. Given that observation times had an uncertainty

TABLE 3: THE ELEMENTS OF THE PLANE TRIANGLE EARTH-SUN-JUPITER

Date 2006	s	j	z	X	S	J
March 9	0.9927695	5.430645	4.87	119.43°	51.41°	9.16°
March 16	0.9946200	5.42955	4.78	126.58°	44.96°	8.46°
March 23	0.9965985	5.42843	4.69	133.86°	38.54°	7.61°
March 30	0.9986160	5.42729	4.61	141.24°	32.14°	6.61°
April 6	1.0005910	5.42612	4.55	148.73°	25.77°	5.49°
April 13	1.0025570	5.42494	4.49	156.30°	19.44°	4.26°
April 20	1.0045355	5.423725	4.45	163.91°	13.15°	2.94°
April 27	1.0064580	5.42250	4.42	171.54°	6.90°	1.57°
May 4	1.0082260	5.42125	4.41	178.51°	1.22°	0.28°
May 11	1.0098620	5.41998	4.42	187.12°	-5.80°	-1.32°

TABLE 4: TIME CORRECTIONS FOR THE CHANGING JUPITER-EARTH LIGHT-TRAVEL DISTANCE.

<i>Date</i>	<i>Distance</i>	<i>Time</i>	<i>factor</i>	<i>Date</i>	<i>Distance</i>	<i>Time</i>	<i>factor</i>
2006-03-09	4.87 AU	3m 50s	1.10	2006-04-13	4.49	0m 40s	1.02
2006-03-16	4.78 AU	3m 05s	1.08	2006-04-20	4.45	0m 20s	1.01
2006-03-23	4.69 AU	2m 20s	1.06	2006-04-27	4.42	0m 05s	1.00
2006-03-30	4.61 AU	1m 40s	1.05	2006-05-04	4.41	-	1
2006-04-06	4.55 AU	1m 10s	1.03	2006-05-11	4.42	0m 05s	1.00

of at least ten minutes, I decided to leave the times uncorrected. Instead, the cosine curve prediction was corrected using an equation that approximates the factor values (*i.e.* the predicted amplitude was made correspondingly smaller for calculations affecting early dates). The correction I use is not perfect but it should not affect the determination of the period.

### Calculating Parameters (Minimization Method)

I wanted to determine the most accurate orbital period that could be found using my observational data and some simple analytical tools from earlier centuries. For each satellite in turn, I estimated an orbital period, an amplitude (*i.e.* distance of maximum elongation), and an elongation date/time.

I began by supposing that each satellite’s orbit was circular and at different distances from Jupiter. If I knew precisely the orbital period, the apparent amplitude of the orbit, and the time of a greatest western elongation, I should be able to calculate the apparent distance between the moon and Jupiter’s centre for any date and time. This is what the cosine formula does.

A cosine curve begins with value 1 at time zero. As the angle increases, the value declines until it reaches zero at angle value  $\pi/2$  radians ( $90^\circ$ ), -1 at  $\pi$  radians, back to zero at  $3\pi/2$  radians, and +1 at  $2\pi$  radians where the cycle is completed ( $2\pi$  radians =  $360^\circ$ ).

At first, I estimated approximate values for these parameters (period, amplitude, elongation) and generated a “prediction” using the cosine curve. Then I sought the observation with the closest value at that time (to identify the satellite to which the prediction applied) and calculated an error value: the square of the difference between the cosine prediction and the closest observed value. This error value is never negative, and a greater difference is more severely punished than a smaller difference (*i.e.* errors can never cancel each other out, and very close observations are rewarded).

After applying this to every observation in the data set (45 observations), I then added the error values to get the sum of the squares. Then I perturbed (slightly altered) each of the three parameters in turn and watched what happened to the sum of squares. A move that diminished the sum was repeated, with smaller and smaller steps, to home in on the value that gives the least square. By perturbing each parameter in turn, I sought

to minimize the sum of squares (the error score).

I retained the parameter values that gave me the smallest possible sum of squares for a satellite. I then removed the timing that corresponds to the satellite that I had just identified and repeated the above process for the next satellite.

This can be done by hand, which would have taken months, working full time: Galileo did it in two years. Instead, I opted for the modern approach and made use of a spreadsheet (available online from the supplementary material). All the observational data were entered on four columns, one line per observation. Dates and times were transformed into Julian calendar dates, allowing direct calculations using dates. Thanks to the spreadsheet, I was able to perturb the orbital parameters and see the results immediately, considerably reducing the effort that Galileo had had to undertake.

### Conditions for Successful Minimization

This simple (if long) minimization process requires some conditions. Normally, in modern applications, partial derivatives are used to determine the direction of maximum slope (*i.e.* directly towards the minimum), and the perturbations are applied directly and simultaneously to each parameter in order to always proceed down the fastest slope towards the minimum (this is called a *gradient search*). In the 17th century, Galileo may not have had that luxury.

I used a simple *line search* method. For each “variable” parameter, I treated the other two parameters as fixed values. I kept refining the variable until I reached a one-dimension minimum. Then, I fixed that parameter and chose another parameter to be the new variable, repeating the one-dimension process. The process can work in data spaces that are smooth, but it can be long process. There is the possibility that perturbing only one parameter at a time will lead to a spiral path that does not converge to the true minimum in a finite number of steps (*Nocedal & Wright*<sup>2</sup>). However, the process can be stopped once it becomes clear that successive perturbation cycles lead to changes that are within the accuracy range that one seeks.

Another condition is that the data space must be convex: that is, there must be only one minimum; otherwise one risks ending up in a local minimum, other than the true minimum. I guarded against that by running some parameters (with coarse

<sup>2</sup>Most of the elements of this discussion are from a course I took in 2003 at Ottawa University : MAT4387 Optimization; Theory and Practice, for which *Nocedal & Wright* was the course manual.

steps) all over their possible range. My data space is not convex. I noted some local minima, and I investigated them to ensure that they did not hide deeper minima. This left me confident that I had picked the true minimum and stayed within its “neighbourhood”; in other words, I stayed within a region, around the lowest minimum, where the space is locally convex.

## Analysis and Results

I assumed that the orbits were circular and prograde. I have not observed anything that would let me think otherwise, but I recognize that this is not a proof.

I noted that all values were positive on date +2.7479 (all satellites are west of Jupiter), all values are negative on date +21.7500, then all positive again on +52.6042. All satellites were seen east of Jupiter again, briefly, on May 24 at 03h UT (date +79.6250), but no timings were taken as the clouds closed right back up. I conclude that no satellite has a period greater than 100 days.

By analyzing an all-night observation in May, it appeared that no satellite had a period less than one day. Over a six-hour period, a “same-day” satellite would have covered more than 90° of its orbit (I would have observed both an elongation and a conjunction for the same satellite).

### Outermost Satellite

I assumed that each satellite had its own distinct orbital distance; therefore, there must be one satellite whose orbital distance was greatest. If so, then the greatest maximum elongation values must belong to that satellite. In this section, I show calculations in more detail for the first satellite, then I proceed rapidly through the others.

### Selecting Seed Values

I had to select seed values to begin the calculation. The maximum absolute values were +86 (date +50.6354) and -84. There appears to be a return of similar values with a period of approximately 16.6 days. I set initial conditions as: period=16.6, amplitude=86,

elongation=50.6354. I perturbed the parameters and observed the effect on the error code (sum of squares).

Line 1a is the result of perturbing the value for amplitude, while leaving the other two fixed. At line 4p, the period was given an additional step of refinement because my main goal was to determine the period. The error code is the sum of the smallest of the squared differences for each observation line. If there are observational errors, regardless of how minor and random, then some squared values are positive non-zero, and the sum (the error code) cannot be brought to zero. Instead, I sought the minimum value.

The result (Table 5) was an observed period (in relation to the Earth-Jupiter line of sight) of 16.5487 days. This is the period to use when predicting satellite transits in front of (or behind) Jupiter.

I had to establish the rate at which the orientation of the Earth-Jupiter line changed in relation to the sidereal frame of reference. Here I used a two-step method (via the sidereal period). The RA of Jupiter changed by 21m 43.7s (or 5.43°) over a period of 56 days (March 16 to May 11), for an average rate of 0.097° per day.

Over 16.5487 days, the satellite covered 360° in relation to Earth, but only 358.3948° relative to the stars (it is missing 16.5487 times 0.097°). Its sidereal period, relative to fixed stars, was  $(360/358.3948) * 16.5487 = 16.62282$  days. For Earthlings, this period is not very useful (except to verify Kepler’s laws).

According to the *Observer’s Handbook* (RASC 2005), the heliocentric longitude of Jupiter changed by 5° in 60 days (1° in 12 days). In 16.62282 days, the satellite will be short by 1.385° in relation to the Sun. Its synodic period, relative to the Sun, is  $(360/358.615) * 16.62282$  days = 16.6870 days. The synodic period is used to predict shadow transits on Jupiter’s disk and eclipses of satellites by Jupiter’s shadow.

Time distances can be translated into angles, knowing that Earth’s rotation is 15° per hour. For example, if the observed “distance” from Jupiter’s centre to a moon is 40 seconds of telescopic drift, then the apparent angle, as seen from Earth, is 40 time-seconds \* 15”/time-second = 600” = 10’ (ten arc-minutes).

At the distance of 4.41 AU, an amplitude of 82.06120 “half-

TABLE 5: PERTURBATION OF THE ORBITAL PARAMETERS AND THE RESULTING SUM-OF-SQUARES ERROR CODE.

Perturbation	Period	Amplitude	Elongation	Error code
Seed	16.60000	86.00000	50.63540	1055.2591
1a	16.60000	<b>82.31155</b>	50.63540	765.7115
1p	<b>16.51700</b>	82.31155	50.63540	642.9080
1e	16.51700	82.31155	<b>50.70381</b>	568.8650
2a	16.51700	<b>81.90430</b>	50.70381	565.3129
2p	<b>16.54539</b>	81.90430	50.70381	555.6586
2e	16.54539	81.90430	<b>50.71036</b>	554.7398
3p	<b>16.54784</b>	81.90430	50.71036	554.5951
3a	16.54784	<b>82.06120</b>	50.71036	554.0691
3e	16.54784	82.06120	<b>50.71140</b>	554.0457
4p	<b>16.54870</b>	82.06120	50.71140	554.0278

seconds,” corresponding to an angle of 10.258 arc-minutes or 0.0029838 radian, represents an orbital radius of approximately 1,968,500 km (= 4.41 AU \* 0.0029838 radians). In comparison, the *Observer’s Handbook* (RASC 2006) gives the orbital period of Callisto as 16.689 days and the mean distance from Jupiter as 1,883,000 km.

### Second Farthest Satellite

The greatest elongation values, after the removal of Callisto’s values, are +47 and -47. Assuming that the high values belong to a single satellite, I found an apparent period near 7.12 days. There is a western elongation of +47 at date 54.6806. For seed values of 7.12, 47 and 54.6806, I began with an error code of 4830.

After a few iterations, I got values of 7.12515, 46.6619, and 54.25793.

Angle J (Figure 3) is the separation between Earth’s line of sight and the Sun’s. If we do not need the sidereal period, we can go directly from the observed period to the synodic period, using the fact that angle J decreases by  $0.1925^\circ/\text{day}$ . In 7.12515 days, the satellite will have covered  $360^\circ$  relative to Earth but only  $358.6284^\circ$  relative to the Sun. Its synodic period, calculated in this manner, is 7.1524 days.

The orientation in space of the plane triangle changes over time. Jupiter’s orbital plane is not the same as Earth’s, and neither matches Earth’s equatorial plane (used for the equatorial coordinate system). I did not correct for the change in orientation. However, I believe that this method is no less accurate than the two-step method used for Callisto.

At a distance of 4.41 AU, an amplitude of 46.6619 half-seconds (an angle of 5.833 arc-minutes or 0.0016967 radian) represents an orbital radius of approximately 1,119,300 km. In comparison, the *Observer’s Handbook* (RASC 2006) gives the orbital period of Ganymede as 7.155 days and the mean distance from Jupiter as 1,070,000 km.

### The Remaining Satellites

After I removed the observations belonging to the second satellite, two more were left to be solved. It was easier to pick an approximate period and amplitude for the third satellite. Seed values were 3.55, 30, and 27.757.

Results were 3.54605, 29.1952, and 27.70457. Once corrected using the second approach (rate of change of angle J), the synodic period found for the third satellite was 3.5528 days; the orbital distance was 700,300 km. Values given in the *Observer’s Handbook* (RASC 2006) for Europa are 3.551 days and 671,100 km.

The remaining values must belong to the fourth satellite (the closest to Jupiter). Results were 1.768096, 18.30409, and 36.65425. After corrections and interpolation, the parameters found were 1.7698 days for the synodic period and 439,100 km for the orbital distance. Values given in the *Observer’s Handbook* (RASC 2006) for Io are 1.769 days and 421,800 km.

## Sources of Error

All the errors that were identified and correctable were corrected unless otherwise noted. I also describe other potential sources of error.

### The Observer

My left eye has three blind spots near the centre (on the macula). My right eye is affected by a cataract. Presbyopia is gaining on me. I need reading glasses to take notes yet cannot observe while wearing glasses. This makes timing difficult if I have to look at a watch, but the metronome has solved this problem.

Medication affected my ability to concentrate, especially at night. Observations taken after midnight local time were the worst, but others were not immune. I noted that, as evenings turned into nights, I had a tendency to split fractions of seconds (in my notes) even though I certainly did not have the equipment to justify these “claims of precision.” I often caught myself reading numbers aloud as I was copying them into the log book and, even then, I’d still write them down incorrectly. Going over everything twice and thrice allowed me to get most of these mistakes.

Because of the manner in which I decided to proceed and the changes that took place in the nature of the data (from seconds to diameters to half-seconds), there were many transcriptions and translations of data. Some of the original timings, which had been entered as distances in apparent diameters, had to be converted back to time units without recourse to the original notes. Ditto with the tables and the use of Excel spreadsheets: my computer is set up along the French model where the decimal sign is a comma rather than a point so that numbers could not simply be “copied and pasted.” Often, an entire list had to be retyped. There are two obviously wrong data points and both plague Io (April 25 and May 1, 8:46); these could not be corrected (they were not removed). They directly affect the determination of Io’s amplitude and, indirectly, its period.

### Earth’s Orbital Plane versus Jupiter’s

This source of error arose from a lack of experience. At first, I placed Jupiter in the centre of the field of view and allowed it to drift. However, the angle that its equatorial plane made with Earth’s caused the line of moons to appear slanted in relation to the apparent movement of the field of view.

Before I realised the real nature of the problem, I had taken a month’s worth of observations by placing Jupiter in a position such that the time interval between it and the furthest moon would be maximized. This was not the proper way to correct for the angle that Jupiter’s equatorial plane makes with the Earth’s, but it was, unfortunately, the one I chose. Fortunately, I used the same method consistently throughout the project. It did not directly affect the determination of orbital periods.



However, it was probably the greatest contributor to the overestimates of orbital distances. A reticulated eyepiece could have partly solved this problem.

## Instruments

The metronome has a slide indicating the number of beats per second. Near the end of the two-month period, I thought of testing its timing and found it to be ever so slightly slow (a little over one second in seven minutes) — a value too low to have much effect on the amplitude. Cold temperatures probably had a larger effect. The metronome was used on a few occasions by another person (its rightful owner), who set it at a different beat; I did not notice for a few nights. I had to go back and correct entries in the log book.

The small telescopes were adequate for this project, but the eyepieces did not provide good-quality images near the edges. It took me a few nights to discover that I could alleviate the problem by turning the eyepiece in its holder until I found a portion of the edge that was better than the rest.

Three telescopes were used, and each one presented the image in a different manner: straight up, flipped, or inverted. On two occasions, I was confused by the orientation and entered values in reverse order. The problem was found and easily fixed.

## Speed of Light

In 1646, Römer determined that ephemerides for Jupiter's moons should be corrected for the finite speed of light. Soon thereafter, a relatively correct value (500 seconds for 1 AU) was used. The modern value is 499.0047838 (*Observer's Handbook* RASC 2006). In April 2006, Jupiter was approaching Earth at an average rate of 0.006 AU/day. Therefore, the timing of events appears compressed by a factor of three seconds per day. As a result, a synodic period calculated to be 16.687 (Callisto) should be reported as 50 seconds longer (16.6876). I did not apply this correction.

## Shape of Satellites' Orbits

The cosine formula used for the curve fitting is valid for a circular

TABLE 6: A COMPARISON OF CALCULATED AND ACCEPTED ORBITAL PARAMETERS.

	Io	Europa	Ganymede	Callisto
Calculated period	1.7698 d	3.5528	7.1524	16.687
Actual synodic period	1.7690 d	3.5510	7.155	16.689
Difference (parts)	1m09s (1:2211)	2m36s (1:1972)	3m45s (1:2750)	2m53s(1:8344)
Calculated distance	439,100 km	700,300	1,119,300 km	1,968,500 km
Actual distance	421,800 km	671,100	1,070,000 km	1,883,000 km
JD of elongation W	JD+36.65425	JD+27.70457	JD+54.25793	JD+50.7114
Calc. date/time	Apr 11, 03:42	Apr 2, 04:55	Apr 28, 18:11	Apr 25, 05:04
Real date/time <sup>3</sup>	Apr 11, 03:23	Apr 2, 04:31	Apr 28, 17:46	Apr 25, 03:38

JD = Julian date 2453800.0 + (corresponding to 12h UT on March 5, 2006)

<sup>3</sup> [www.calsky.com/cs.cgi/Planets/6/7](http://www.calsky.com/cs.cgi/Planets/6/7)

orbit, but fortunately the four orbits have low eccentricity (less than 0.01). I could have used an equation for the distance from one focus of an ellipse (these were known in the 17th century), or I could have approximated the deviation of the ellipse from a circle by adding one-cycle sinusoidal perturbations to the cosine formula (the same idea as the epicycles of old). I did not.

## Conclusion

It is relatively easy to find workable values for the period of Galilean moons using a small telescope, simple timing devices, and a simple analytical tool. Results can be compared with published values to determine the accuracy obtained (Table 6). ●

*Raymond Auclair has been an "unattached" member of the RASC since 1971. He was a marine navigator with the Canadian Coast Guard, a teacher, a dean of nautical science, and acting director at the Coast Guard College where he hosted the GA of 1989. In 1990, he moved to Ottawa. Because his health played tricks with him, he retired from work in 2006 and is following a programme leading to a Masters in Science (Astronomy). Raymond was awarded the RASC Service Award (1989) and served as National Secretary (1996-1999). Minor Planet 15838 bears his name.*

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# DSLR Astrophotography, Part IV

by Doug George, Ottawa Centre ([dgeorge@cyanogen.com](mailto:dgeorge@cyanogen.com))

As wonderful as DSLR cameras are, they are really intended for taking vacation pictures, not for shooting the sky. They are also designed, insofar as possible, to emulate the old film cameras that everyone is used to. Some basic, important things that are easy to do with a CCD camera require a little more tinkering with a DSLR.

If you look at the camera's built-in menus, you'll find there is a selector for image quality. It will have options for JPEG files at various quality and size levels, and also for "RAW." These are formats for the digital files that you download from the camera. JPEG is compatible with just about every computer-imaging program available, but it uses a lossy compression. In other words, it throws away image data to save space. It also uses only 256 brightness levels (8 bits). Both of these things are very bad for astrophotography. You will want to use the RAW format, which is uncompressed, provides the full 12-bit data, and should have had no processing performed on it whatsoever. This is the data "straight from the chip."

Some extra expense may be necessary at this point, as you may need to purchase some software. Few programs understand the RAW formats because they are not industry-standard. They are specific not only to the manufacturer of the camera, but also to the exact camera model you have! Usually plug-ins for reading these files are available for programs like *Photoshop*. There are also astronomy-specific imaging programs that know how to handle RAW formats.

There is another odd thing about RAW files — they are monochrome. If you view a RAW image directly, with no processing whatsoever, it looks like a black-and-white photo with a speckle pattern all over it. This pattern is caused by the Bayer array.

Imaging sensors are fundamentally monochrome devices — they see the whole spectrum of colours at once. For CCD cameras, a filter wheel is usually used: separate images are taken with red, green, and blue filters and then software puts them together into a colour picture. That's not very convenient for taking pictures of your family, though.

To get around that, DSLR cameras use a "Bayer Matrix" (Figure 1). Although this technique can give you headaches, it was actually named after its inventor. Colour dyes are printed right onto the sensor itself, so that individual pixels see different colours. A pattern of green-, red-, and blue-sensitive pixels extends across the whole array, like this:

TABLE 1: THE BAYER MATRIX

Red	Green	Red	Green
Green	Blue	Green	Blue
Red	Green	Red	Green
Green	Blue	Green	Blue

Each adjacent pixel sees a different colour. To create a full colour image, an algorithm must be run to interpolate the two missing colour values at each pixel. This is done by taking information from the adjacent pixels. This necessarily moves information around the image, resulting in a certain amount of blurring, and potentially, image artifacts. With a good interpolation algorithm, the loss of resolution is on the order of 30%. Usually that is negligible compared to optical blurring effects, so it's a very good compromise compared to putting three sensors in the camera!



Figure 1 — Unprocessed image of M81 showing a Bayer matrix superimposed on the image.

Okay, it still sounds simple...load the RAW image, convert to colour (hopefully automatically when you load it), and stack the images. Not so fast!

There's one other major "defect" that all digital cameras have: dark current. It turns out silicon chips are not just sensitive to light; they are sensitive to thermal energy. Temperature is simply a way of measuring microscopic vibrations, and those vibrations kick electrons loose in the silicon. The electrons accumulate in the pixels over time, and you can't tell whether any one electron came from light or from dark current. The dark-current accumulation is statistical in nature, so this effect cannot be eliminated, and essentially adds noise to the image,

reducing sensitivity. Cooling will reduce the dark current — this is part of the reason why CCD cameras are so sensitive — but sensor manufacturers have also devised clever ways to minimize the effects in the chip itself.

That would be the end of the story, except for one thing. Each pixel has a different rate of accumulation of dark current. If that is left uncorrected, it adds a large amount of noise to the image, reducing the sensitivity significantly. Even worse, some pixels are much “hotter” than the others, resulting in bright speckles all over the image.

The solution is simple: subtract a “dark frame.” This means that you take a picture of the same duration and at the same temperature as your “light frame,” but with the camera capped. Thus you get a dark frame. Subtract this dark frame pixel-by-pixel from the light frame, and all that’s left is the light...plus the residual noise caused by the randomness of the dark current. Actually you have 1.41 times that noise, because now you have contributions from two frames instead of one, and the noise adds by root-sum-square. For the best results, to get rid of that extra 41% noise, you need to average a bunch of dark frames.

There are a few nuisances that arise from this. The DSLR cameras don’t have cooling and temperature regulation like CCD cameras do, yet you have to shoot dark frames at the same temperature. This means you usually need to do them at about the same time as your light frames — or at least keep track of the ambient temperature and try to do them at the same point. The Bayer colour-conversion process spreads pixel values around the sensor, so for best results you really must subtract the dark frame first, then convert. That means using specialized astrophotography software.

Some cameras have this capability built-in, via a special mode. It’s usually called “in-camera noise reduction” or something similar. Every time you take a picture, the camera closes the shutter and takes a dark frame, then subtracts it. This guarantees the dark frame is taken at very close to the right temperature, but every exposure takes twice as long. That really is overkill, and it wastes a lot of dark-sky time. In practice, I prefer to take

the dark frames separately; perhaps pausing in the middle of an imaging run to take some dark frames, and then continuing. Unfortunately, the camera manufacturers didn’t think of letting their software interfaces control this, so even when using specialized software, you still have to manually cap the telescope or lens yourself.

Dark-frame subtraction is one part of a more general process called “image calibration” or “image reduction.” The most important calibration step after dark-frame subtraction is flat-fielding. For flat-fielding, an image is taken of a white surface that is completely blank: a flat-field image ideally should look completely flat, but it never is. There will be dark spots from dust on the optics or sensor, and the image will likely be darker in the corners due to optical vignetting (lenses do not illuminate the corners as brightly as the centre). These effects can all be removed by *dividing* the flat-field image into the light frame, pixel-by-pixel. Again, this can be done easily using astrophotography software; the trick is getting the perfectly flat target.

Using the above techniques, I usually spend several hours targeting a single object with four-minute exposures. The images are each dark-subtracted, flat-fielded, converted to colour, aligned, and stacked. Usually some additional processing is done to fix background sky gradients, adjust colour balance, sharpen detail, and adjust to suit display on a video monitor or printer. That might seem like a lot of work, but it’s all part of the fun...and it’s wonderful to be able to continue working on your hobby on a cloudy night! ●

*Doug George is President of Diffraction Limited, an Ottawa-based company that produces astronomical imaging products including MaxIm DL and MaxDSLR. In addition to engaging in astrophotography and observing occultations, he enjoys participating in patrol programs. He has co-discovered one comet visually and co-discovered 12 supernovae as a member of the Puckett Observatory Supernova Search team. Doug is also a Past President of the RASC.*

## RASC INTERNET RESOURCES



**Visit the RASC Web site**

[www.rasc.ca](http://www.rasc.ca)

**Renew your Membership**

[www.store.rasc.ca](http://www.store.rasc.ca)

**Contact the National Office**

[nationaloffice@rasc.ca](mailto:nationaloffice@rasc.ca)



### Join the RASC's email Discussion List

The RASCals list is a forum for discussion among members of the RASC. The forum encourages communication among members across the country and beyond. It began in November 1995 and currently has about 300 members.

To join the list, send an email to [listserv@ap.stmarys.ca](mailto:listserv@ap.stmarys.ca) with the words “subscribe rascals Your Name (Your Centre)” as the first line of the message. For further information see: [www.rasc.ca/computer/rasclist.htm](http://www.rasc.ca/computer/rasclist.htm)

# Net Astronomy

by Paul J. Langan (paul@langan.ca)

## An Astronaut's View

Astronomers look upward at the stars, but there are also a few human observers looking downward from a unique perspective — the astronauts. In “Earth from Space,” NASA provides us with a collection of astronauts’ photographs of our home planet, and helps us to understand where we fit into the immense Universe that reveals itself to our telescopes. This site is a great exploration tool, with an opening page that allows the virtual adventurer to focus on subject areas such as Earth landscapes, hurricanes and weather, or particular geographic regions. Have you wondered what an astronaut sees when he or she looks at the Grand Canyon or the polar ice caps? Are you curious about the reefs of Bermuda? Perhaps your project needs some imagery of Brazilian jungles or Himalayan glaciers. Well, here is your chance to find out. The site’s layout is simple, but that simplicity masks a huge trove of images that can be viewed alone or with explanatory text. The complexity of our own globe revealed in these images can help us to understand the hidden details in the stars that must lie beyond the resolution of our instruments. What other clouds and storms, canyons and mountains, rivers and seas, lie in the hidden worlds of the galaxies? I recommend this site to those who appreciate that to truly understand and enjoy astronomy requires a greater familiarity of the stage on which they stand.

<http://eol.jsc.nasa.gov/sseop/EFS>



Figure 1 — Noctilucent clouds and the crescent Moon as seen from the International Space Station. This image was taken over central Asia in 2003.

## At Home Astronomy

When a child asks, “How far is the Sun?” or “What is the order of the planets?” a simple response (after a quick peek at the *Handbook*) may leave the questioner with another factoid but little appreciation for a method of obtaining the answer. This site encourages an exploration of the question, with the answer following from the results of a measurement or assembly of data. *At Home Astronomy* gives us ten projects that appeal to the whole family. “Where is the Sun?” traces out the seasonal analemma with a stick and a shadow. “Finding the Size of the Sun and the Moon” makes use of a pinhole viewer and a little trigonometry. “Meteoroids and the Craters they Make” has students dropping pebbles into cocoa. Other explorations include “Building a Lunar Settlement,” “Making a Simple Astrolabe,” and “The Size and Distance of the Planets.” Though the site is geared for families, teachers will also find that most of the experiments are easy classroom projects, with a full list of the resources needed to complete each activity. *At Home Astronomy* is a fun site that educates in a hands-on manner — the best way to learn. ●

<http://cse.ssl.berkeley.edu/AtHomeAstronomy/index.html>



Figure 2 — Barringer Meteor Crater in Arizona - a real experiment in crater creation.

*Paul Langan is President and CEO of a multinational company and a Fellow of the Royal Commonwealth Society, but his heart is more directed to the stars. If you have recommendations for future site visits, please email him at the address above.*



# Three Lunar Extravaganzas

by Mike Wirths



Figure 1 — This exquisite image of Sinus Iridum was captured by Mike Wirths of the Ottawa Centre using a Starmaster 18-inch Dobsonian, a Lumenera camera (Infinity 2-2) and a 2.5× Powermate Barlow with a R/IR filter. “I think this is my best image so far,” he says. It’s almost like being there.

Sinus Iridum (Rainbow Sea) is a tilted impact crater filled with basaltic lava that forms an extension to the Mare Imbrium. The Montes Jura forms its rugged northeast boundary, while the southwest opens to the craters Helicon and Leverrier with their stepped walls. The crater Laplace A guards the opening to the Sea, between the headlands Promontorium Heraclides and Promontorium Laplace. Sinus Iridum is one of the most beautiful views on the Moon when the lighting is right.

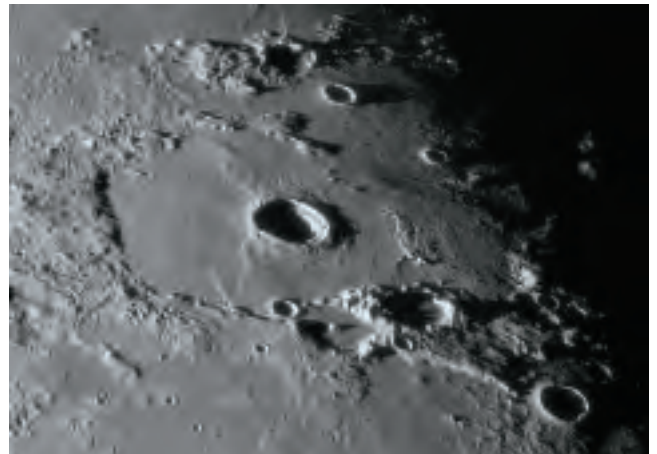


Figure 2 — Lacus Mortis (Lake of Death) also fell to Mike Wirths’ cameras with this low-light view that highlights the ejecta around the crater Bürg, and the delicate rilles that cut the surrounding basin. Small pits can be seen along the floor of the rille to the left of the crater.

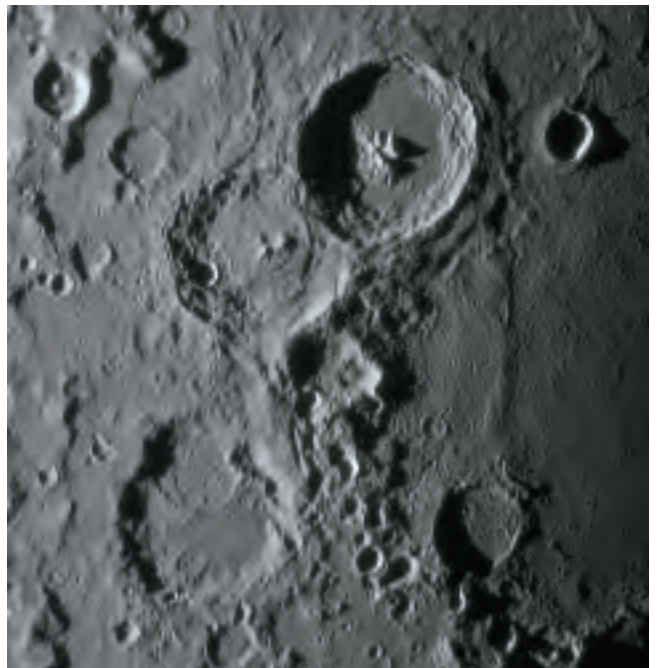


Figure 3 — Mike Wirth's image of the crater Theophilus invites hours of examination and speculation. Central mountain peaks stand out sharply in the early morning sun and tiny craterlets are just visible on the smoother sections of the crater interior. To the southwest, partially overlapped, is the crater Cyrillus.

# Reclaiming Our Night Skies: Fighting Light Pollution

by Mark Coady, Belleville Centre, Peterborough Astronomical Association (mark.coady@sympatico.ca)

Despite the good work of the International Dark-Sky Association (IDA) and our own RASC Light-Pollution Abatement Committee, many astronomy clubs and RASC Centres seem to pay lip service to the issue of light-pollution abatement. For some, the reason may be as simple as that it never occurred to them to start the effort, or that they or their membership are ignorant of the issue. For others, the reason might be the old problem of there not being enough support from the general membership — you can't expect one or two people to do everything in your club or Centre. In the Peterborough Astronomical Association, it seemed the reason for our level of inactivity was a combination of the two. With an influx of new members, we decided, in the fall of 2004, to start fighting for light-pollution abatement. The Light-Pollution Awareness Committee was established with my wife, Susan, as Vice-Chair, and me as Chair, with a few members lending assistance on an intermittent basis. Now, some two-and-a-half years since our inception, we have met with some considerable success.

The City of Peterborough, some 60 km northeast of Toronto and home to 75,000 people, has decided that all future and replacement streetlights will be of full-cut-off design. All existing lighting will be replaced, as funds allow, over a period of years — probably ten. In addition, they are looking into the possibility of implementing a light-pollution abatement By-Law with our help. The beautiful part of this is that they have credited our group with being the catalyst for this positive change.

The Township of Smith-Ennismore-Lakefield, a rural and urban mix of some 16,000 people, is on Peterborough's northern boundary. The township already has basic light-pollution abatement rules on the books — within their noise and property standards By-Laws. Just this past February they decided that all replacement and future streetlights will be of full-cut-off design. They are also replacing outdoor lighting on township properties with full-cut-off fixtures, beginning with the Lakefield Arena, where ten driveway and parking-lot lights were replaced with nice-looking, but effective, fixtures.

With these successes behind us, and hopefully many more ahead, the Peterborough Astronomical Association has decided to help other astronomy clubs, RASC Centres, and environmentally active groups to get their own light-pollution abatement programs established by making

presentations to them and offering our ongoing assistance as mentors.

This program began with last year's Fall n Stars star party, hosted by Kingston and Belleville Centres, where I made a hastily thrown-together presentation, filling in for our Past President John Crossen, who had taken ill. It was basically a slide presentation along with a couple of videos. A new presentation, consisting of a *PowerPoint* presentation, a locally produced DVD, and the IDA-produced "Preserving Our Night Skies" video, has been developed. This presentation was recently given to the Belleville Centre. It encouraged Belleville Centre President Greg Lisk to kick-start light-pollution abatement activities within the Centre and to plead for more support from the membership. The next scheduled presentation is with the Kingston Centre in June. More presentations for the coming year are in the early stages of planning.

So, if your local astronomy club or Centre does not currently have a light-pollution abatement program, or has one that hasn't gotten off the ground yet, how do you start the fight in your community? You can start by following these simple steps:

## *Start a Light-Pollution Abatement Committee*

Your local club or Centre needs a committee of more than a couple of members. There will be a lot of work to do in the early stages. The chair of this committee needs to be a real go-getter or a "like-a-dog-with-a-bone" kind of individual. He or she is better suited to this position than any other one on your executive. After all, fighting light pollution is something that will benefit everyone — not only astronomers — through increased security, lower costs of outdoor lighting, and a night sky restored to more pristine conditions. It should be the most important aspect of your public outreach.

## *Research the Topic*

Don't act too quickly. For the first few months, gather all the information you can find on the issue. Some excellent sources of material are: the IDA, the RASC Light-Pollution Abatement Committee, RASC Centres active in the field (e.g. Calgary, Saskatoon, and Kingston), other astronomy clubs (e.g. the Peterborough Astronomical Association and the Durham Region Astronomical Association), and libraries (especially university libraries and research institutes). Most

of these will be available to you through the Internet.

During this process, find out from your community the number of streetlights under their jurisdiction. This information will become useful when trying to estimate how much energy might be saved.

Get to know who the important staff members are for your community, as well as who are your local elected officials. Quite often your city clerk or Chief Administrative Officer (CAO) carry more weight with the decision-making process than your elected officials. It is these people who your councillors go to for advice before making a decision.

### *Join the IDA*

Consider having your astronomy club, or Centre, take out organizational membership with the IDA. Membership for a small astronomy club (fewer than 100 members) is only \$50 US. A larger club would only pay \$100 US.

The IDA has information sheets that can be downloaded and a sample *PowerPoint* presentation for viewing on the Internet to give you an idea of how to make up one of your own. They also sell slide sets (or CDs) and videos on both VHS and DVD, along with promotional items.

### *Include Light-Pollution Displays with Your Public Outreach*

Whether you are doing sidewalk observing sessions or full-blown astronomy presentations, especially for International Astronomy Day, include posters, videos, and brochures on light-pollution abatement. Point out the economic, environmental, and energy-saving benefits of adopting light-pollution abatement. Make sure you have people available to field questions from the public. We have found, that once they start reading or hearing about it, the questions really start flying. It is a cause to which people can easily relate. Once they know something about it, the response from the public might actually astound you.

If your nighttime public-observing session is from within a city — or has the light dome of a local city or town nearby — by all means point this out. This is an excellent opportunity to show the public what light pollution in your particular community actually looks like.

### *Include the Media with Your Public Outreach*

It is important to include the media to get your message out at your event. On a slow news day, they will be happy to cover the event, and you might be able to get them interested in your light-pollution abatement work, especially if it looks good to them.

If local radio stations have those “community cruisers” that go around publicizing events, then get them involved. They love showing off their logo, as it is free advertising for them. And be sure to steer them towards your light-pollution display.

### *Include Your Local Politicians with Your Public Outreach*

Invite your local politicians to take in your event. Far too often we neglect municipal politics, especially at election time, but this is the level of government that affects us the most. In Ontario, the provincial government has granted municipal government the sole right to regulate outdoor lighting. We got our first break because one of our members invited the local city councillor to International Astronomy Day in 2005.

### *You Can Fight City Hall*

Once you have reached this step, it's time to make a presentation to your local city or town council. Find out how you can go about scheduling a presentation. Your local city clerk or CAO will be able to help you. You might have to have one of the councillors schedule a presentation.

Make up an informative booklet on the topic that explains light pollution and demonstrates the tangible benefits of light-pollution abatement. Distribute the booklet to all councillors well before the meeting so that they have an opportunity to read up on it.

When making your presentation try to be as brief and direct as possible. Be assertive in your presentation but do not chastise council members. Treat them as if no one expected them to know about the benefits of light-pollution abatement. You probably won't need any audio or visual aids, especially if you included images in your booklet, but be sure to point out that the benefits are quite tangible. Try estimating what the city or town might save by replacing their streetlights — but stress that you are only estimating the potential savings. Be knowledgeable. Be prepared to answer any questions from council. While being courteous, make sure your local government knows that you are serious about this issue and will not let it rest until light-pollution abatement has been adopted in your community.

### *Make It an Election Issue*

This step may not be necessary but, if you find your local government is stonewalling or dragging their feet, you may need to make it an election issue. Get your entire membership to become politically active. Attend all candidates meetings and ask questions. Hold a news conference if you can. Politicians don't like being told that they are wasting taxpayers' money, but if you have done your research well, you will have the indisputable facts showing the voting public that money really is being wasted.

### *Be Persistent*

If necessary, return to the beginning or to an earlier point in the process and start over again. Eventually your local elected officials will get tired of hearing they are wasting taxpayers'



money, and will have to act, especially if they cannot dispute the facts and figures you have set before them.

### *Spread the Gospel*

The day will come when you are successful. In that event, spread the news about your victory. Tell the IDA, the RASC Light-Pollution Abatement Committee, *SkyNews*, *Astronomy*, and *Sky & Telescope* magazines. Coincidentally, Kelly Beatty, of *Sky & Telescope* magazine, is also on the board of directors of the IDA.

Take your message of light-pollution abatement to other communities in your local area. Keep at them until

they all start practicing light-pollution abatement. Then become a resource for other astronomy clubs, RASC Centres, and environmental groups. Hopefully, the process will end up becoming an unbreakable chain, promoting positive change that causes local governments across the country to act and eradicate light pollution, forever. ●

*Mark is a member of RASC Belleville Centre and the Peterborough Astronomical Association, where he is the Director of Publicity and Light-Pollution Abatement — something about which he is very passionate.*

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## Second Light

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# A New Kind of Transient in the Galaxy M85

by Leslie J. Sage ([l.sage@naturedc.com](mailto:l.sage@naturedc.com))

**T**ransient and variable sources in the sky are of interest to both professional and amateur astronomers. Amateurs track variable stars, discover many comets, and, until fairly recently, found a good number of the known supernovae. One amateur even found the optical counterpart to a gamma-ray burst (GRB)! Given the wide attention to GRBs, and with the expectation that the Large Synoptic Survey Telescope will soon be a reality, interest amongst professional astronomers in what is called “time domain” astronomy has been increasing over the last decade. Just to add to this pot, Shri Kulkarni of the California Institute of Technology and his collaborators have discovered a new kind of optical transient in the nearby galaxy M85 (see the May 24, 2007 issue of *Nature*).

A supernova search team based at Lick Observatory reported a new source on January 7, 2006. The source had an apparent magnitude of 19.3 (absolute magnitude of -12), and was ~2.3 kpc from the center of the S0 galaxy (located in the Virgo cluster). That portion of M85 had been observed with the *Hubble Space Telescope* just three years previously, and there was no star at that position with an absolute magnitude <-4.3, ruling out an eruption from a luminous blue variable star, like the outburst that created the homunculus nebula around  $\eta$  Carina. It is too dim to be a type Ia supernova (the kind expected in a lenticular galaxy), yet too bright to be a nova. It is a factor of 100 fainter than supernova 1987A (an exploding massive star), and almost a factor of 10 fainter than really faint type II supernovae. What is it?

Over the two-month period that the transient was visible it radiated ~ $10^{47}$  erg. For comparison, a typical supernova radiates ~ $10^{50}$  erg, and a GRB about ten times that. During the same two-month period the Sun radiates ~ $10^{40}$  erg. There is no evidence from the *HST* observations that there is any active star formation

happening in the vicinity of the transient, and given the upper limit on the brightness of any star in the area, Kulkarni concludes that it comes from a population of stars of a few solar masses, or possibly even smaller.

The only other transient that looks like the one in M85 was discovered serendipitously in the bulge of M31 — that transient too lacks a satisfactory explanation (and was a factor of six fainter), so it is of little use in guiding ideas. Kulkarni speculates that the M85 transient may be associated with the merger of two stars — we know that such mergers must happen — but calls for more observations. As is usual with a new source in astronomy, we need more examples of similar objects to try to sort out what it is.

The LSST, when completed, will be capable of doing the entire Palomar sky survey — an essential tool for professional astronomers for the last 50 years — to 100 times fainter in just a week (the original took several years to complete). At that point, investigations into transients will really take off. But in the meantime, perhaps amateurs can think about taking images of nearby galaxies on a regular basis, to see if any more examples can be found!

As an interesting sidebar, Kulkarni’s paper is his 51st in *Nature*. That is a testament to one of the most gifted astronomers of our time. ●

*Leslie J. Sage is Senior Editor, Physical Science (Astronomy) 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.*



# In Dobson's Footsteps

by Miriam Martin, Regina Centre ([mmmartin@sasktel.net](mailto:mmmartin@sasktel.net))

John Dobson believed that the worth of a telescope was not measured by its aperture and optics but by the number of people who got to look through it. He made telescopes from salvaged materials and set them up on city corners and in national parks on his tours of the western United States. One park ranger objected to Dobson's activities and the long lines of viewers, claiming that the sky is not part of the park. "No, but the park is a part of the sky," Dobson replied (from *Seeing in the Dark* by Timothy Ferris).

Interpretive staff at Cypress Hills Interprovincial Park took the first tentative steps along Dobson's path last summer. Our new 10-inch Dobsonian was not made of cardboard tubing and portholes as were its founder's. In fact, its unblemished exterior and sparkling mirrors made it rather intimidating until Alden Foraie and Norm Leier of the Regina Centre taught us how to use it. Next we had to figure out how to bring astronomy, light-pollution awareness, and the park's Dark-Sky Preserve status to the visiting public.

I've been an interpreter for twenty years in the Cypress Hills. I learned the cultural history and presented it as though I were an 1873-era whiskey trader's wife. I've talked about the natural history of the hills in a canoe, from the back of a horse, on trails in foul weather and fine, and around roaring campfires. I've sung, I've danced, and I've worn fake beaver teeth, weird hats, tree branches, elf ears, dinosaur slippers, and more — all for the sake of presenting the information and the park's messages in a fun way. Then came astronomy!

A successful program requires that you figure out the basics before you ever set foot in front of an audience: know who your target audience is, the program's duration, and where it will take place. In our case, the two-hour summer program is for the visiting public at Lookout Point.

Then we developed objectives to keep the program focussed and the presenter on topic. We had four main points:

- Visitors will recognize why Cypress Hills is a Dark-Sky Preserve,
- Visitors will understand the causes and effects of light pollution and learn ways to prevent it,
- Participants will learn the basics of using sky charts,
- Visitors will identify the main constellations, planets, and

individual stars that will help them navigate the night sky using the unaided eye, binoculars, and a telescope.

With these goals in mind, my astronomy partner, Nicole Dancey, and I began our research. We knew virtually nothing in the spring, but through lots of reading and many late nights under the stars, we learned and we practiced. Next, we relied on our imaginations, interpretive training, and trial and error.

We began the program at 10 p.m. Any earlier in southwestern Saskatchewan in July and we would have too long to wait for the sky to darken. Any later, and people with children would be unlikely to come, and the others would have settled in around their campfires with a cold beer. As visitors arrived, we handed them star charts, red cellophane with elastics, and star cards. In the dusky light, we could even use an important interpretive tool — audience participation. Visitors referred to the star cards we gave them, reading the name of a star or deep-sky object, and then turning the card over to read out an idea of how to prevent light pollution or an interesting astronomy tidbit.

A lengthy introduction is an interpretive no-no. People, especially kids, don't like sitting around and listening for too long. They want to get on with the show, the hike, or in this case, look at cool stuff through "that really big telescope." Throughout July we had no choice. So we talked about the history of astronomy and the development of telescopes, defined an asterism, and talked about the 88 official constellations, then reviewed the significance of Cypress Hills' designation as a Dark-Sky Preserve. We showed them how to use the sky charts, discussed how our eyes adapt to darkness (hence the red cellophane over flashlights), and practiced with the charts as the first stars appeared.

When the sky was dark enough, we headed to the equipment. Jupiter was a sure hit through the telescope and binoculars, and we tested people's vision on Alcor and Mizar. With crowds of 15 to 90 people, we rarely viewed more than 2 or 3 objects before the kids got tired or people became cold, and they slowly faded away in the darkness. The sky was at its best by the time most visitors were gone, and only a few benefitted from a constellation tour using the audience-wowing laser.

All good programs become better with practice and more

knowledge. By the time August rolled around, Nicole and I were introducing ourselves as Polaris and Thuban, wearing glow-in-the-dark stars on our heads, and presenting the introduction in a more theatrical way. (We are natural hams, so it was inevitable.)

By mid-August, the program began in the dark. Passing out sky charts and cellophane became a game of “Marco Polo,” and our glowing headbands were important for the audience as visual reference points. The introduction was pared down to the essentials (refer to our objectives), and we expanded our constellation tour to include the myths behind them. People would lie on their blankets around us, and go on a magical mystery tour of kings and queens, heroes and monsters, hunters, bears, and dogs.

More time was spent at the telescope and we loved showing the lustrous M31, the delicate colours of Albireo, the glittering M13, and the glow of the Ring Nebula. Pointing to the object with the laser before or after the visitors look through the scope is important so they know exactly where the object is. The best part of the program was listening to the “oohs” and “ahs” as people looked through a telescope for the first time in their lives. It became my favourite program, so much so that I joined the RASC, and continue to study and plan for next year’s astronomy programs.

Many astronomy clubs have public viewing nights, and do what interpreters call “point duty.” That is, people come and go over a period of time without benefit of an introduction. I experienced this during our program with 90+ participants and while helping out at the Saskatchewan Summer Star Party public

viewing night. On those nights, I did mini-constellation tours, defined an asterism, and talked about the different names the Big Dipper has had in various cultures. I found that knowing the light-year distances of some stars and deep-sky objects and corresponding world events (e.g. the light of Mizar left that star when World War I ended) helped pass the time for those waiting in line. Other topics are galaxies (are we alone in the Universe?), star formation, red giants, white dwarfs, black holes. The information was presented as “tidbits.” Just enough to pique the interest of the participants and, hopefully, send them home with a desire to learn more.

Being new to astronomy and technologically inhibited, there never will be any fear of my presentation becoming too technical. For you astronomy experts, remember to keep your information relevant to the participants — a group of Boy Scouts will need something different than a group of third-year engineering students will. And, don’t forget to explain light pollution and ways to avoid it. Make John Dobson proud and turn your telescope into a priceless instrument as you share the wonders of the night sky with those who would otherwise never have the opportunity to see them. ●

*Mimi lives with her husband and daughter on a delightfully dark-as-the-dickens ranch 50 kilometres north of the even-darker Cypress Hills Interprovincial Park, where she works seasonally. She kidnapped the park’s telescope for the off-season and is holding it for ransom until she gets her recall notice. She is thrilled to have a Big Dob in her possession.*

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# International Solar Eclipse Conference

**T**he International Solar Eclipse Conference SEC2007 will be August 24 to 26, 2007 at Griffith Observatory in Los Angeles. There will be an informal meeting and reception at the Mount Wilson Observatory, California on Friday night followed by two days of lectures — Saturday and Sunday — at the renovated Griffith Observatory. Only registered and confirmed delegates can participate. Seats and spaces are limited. Meet the eclipse gurus of the world. See our program, A Crossroad on Physics & Eclipses of the Sun, on our Web pages at <http://uk.geocities.com/solareclipsewebpages@btopenworld.com/SEC2007.html>

Speakers lined up are (preliminary): Bob Morris (Canada), Claudio Carlos Mallamaci (Brazil), Dava Sobel (USA), David Dunham (USA), David Levy (USA), Ed C. Krupp (USA), Fred Espenak (USA), Gernot Meiser & Pascale Demi (Germany), Jay

Anderson (Canada), Glenn Schneider (USA), Jay M. Pasachoff (USA), Jean-Luc Dighaye (Belgium), John Tilley & Xavier Jubier (UK/France), Joel Harris (USA), John E. Westfall (USA), Kenneth J.H. Phillips (UK), Landon Curt Noll (USA), Marcel Belik (Czech Republic), Mike Simmons (USA), Miloslav Druckmüller (Czech Republic), Philip Veerman (Australia), Ralph Chou (Canada), Raymond Brooks (USA), Richard Woo (USA), Serge Koutchmy (France), Stephen J. Edberg (USA), Tony Misch (USA), Vojtech Rusin (Slovakia), William C. Livingston (USA), and Zoran Mikic (USA). Abstracts and biographies are on the Web pages above. ●

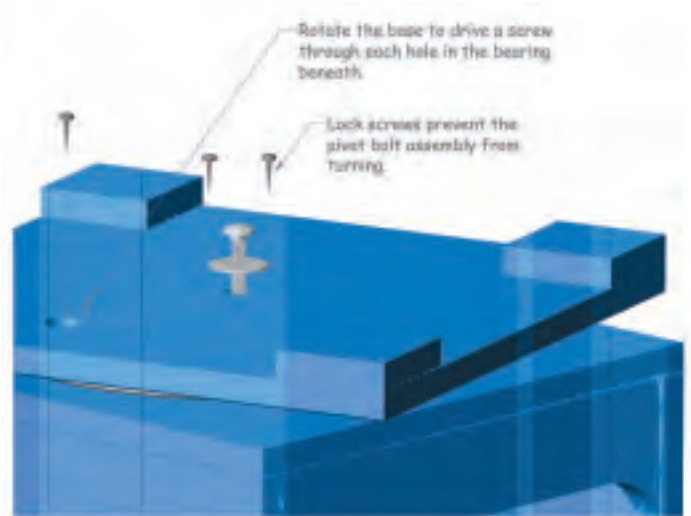
For registration and information, email:  
[solareclipsewebpages@btopenworld.com](mailto:solareclipsewebpages@btopenworld.com)

## Lazy Susan

by Don van Akker, Edmonton Centre ([don@knappett.com](mailto:don@knappett.com))

Elizabeth's Dob, like thousands of others, gives crisp and lovely views reflected from a wonderful mirror, but outside the glass it's a pretty crude piece of equipment. A cardboard tube pivots on a particle-board rocker box that rides on a few bits of nylon and laminate. The surprise is not that it works so well but that it works at all. Yet the tube always stays where you point it and the motion is silky smooth...until you get to the zenith. Then, with the tube straight up, it becomes jerky and hard to turn. Not a major problem maybe, but certainly a nuisance and, for me, as good an excuse as any to take a very hard look at the great Lazy Susan bearing I had seen in the Lee Valley hardware catalogue. Lee Valley is a Canadian mail-order store that sells astronomy equipment cleverly disguised as woodworkers' hardware, and this bearing is a case in point. It is 12 1/2" in diameter (and available larger), rated for 180 lbs, and is described as having "more ball bearings than we wished to count." That last note alone made it irresistible — that, and the fact that it is the perfect bearing for a Dob.

I started by turning over the rocker box, removing the pivot bolt in the centre, and removing the base. The bearing surfaces consisted of some kind of plastic laminate on the underside of the rocker box, and three nylon furniture glides on the base. The laminate stayed, the furniture glides I pried off, before centring the Lazy Susan bearing carefully on the base by measuring to the edges. Next I scribed a pencil line around the perimeter and then, with the pencil, marked a point through one of the mounting holes on the inside race. I drilled a 1" diameter hole



at this point. I then put the bearing back on the circle I'd scribed and screwed it down. I turned the base over onto the rocker box and carefully aligned the two. Then, working through the hole, I screwed the inside race of the bearing to the underside of the rocker box. I turned the whole thing right side up, put the tube in place and stood back to collect the compliments.

They were slow in coming.

The action was now silky smooth even at the zenith but the scope wouldn't stay put. The least touch would start it spinning and if it was even slightly out of level it went to the low point like a compass needle to north. My spouse was not impressed.

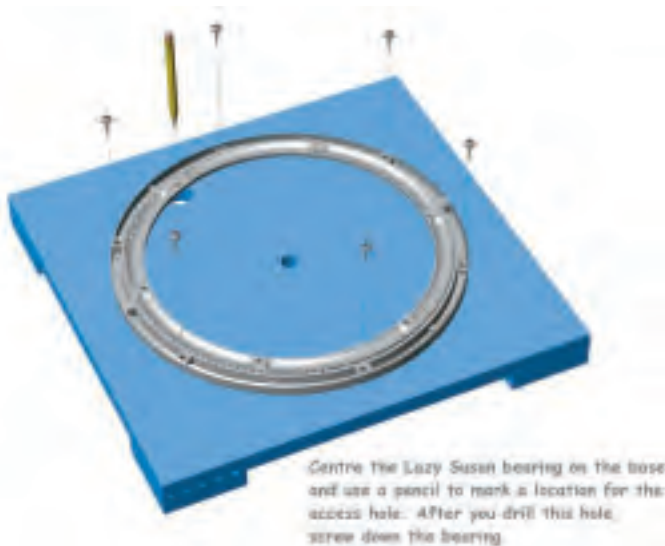
So I put the centre-pivot bolt back in and used it to load the bearing. The action could be adjusted by tightening the bolt. But now the scope would bind when you turned it because the pivot holes no longer lined up very well and they were not quite centred on the Lazy Susan.

I wasn't looking good here.

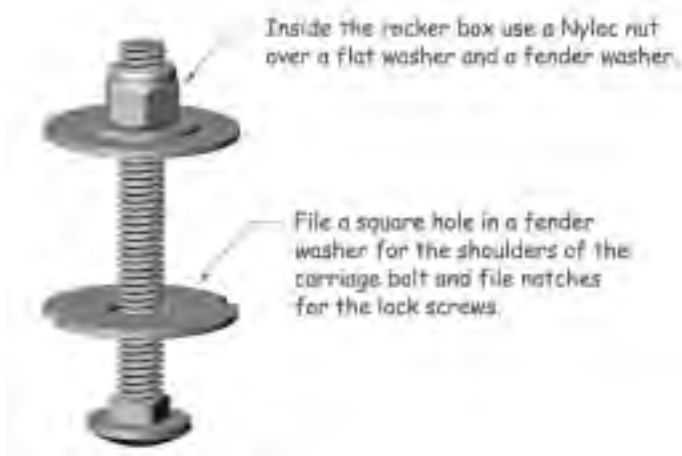
All I could do was drill out the holes oversize. 'Way oversize. I used a 1/2" drill bit and beavered it around. I put the bolt back in with no idea of how to get it centred perfectly, but to my delight it centred itself! Off-centre on the base worked against off-centre on the bottom of the rocker until, as I turned the scope round and round the bolt found centre on its own.

I was beginning to look a little better.

Since the pivot was a carriage bolt, I could keep the head from spinning by filing out a fender washer to socket the square







shoulders. I filed notches in the perimeter of the washer for locking screws. Finally I replaced the nut inside the rocker box

with a Nyloc nut to prevent it from unwinding on its own. It works. The action is smooth and can be adjusted for just the right amount of drag.

But I think I was more impressed than she was. She just smiled at me and told me to get away from her scope.

Lee Valley is at [www.leevalley.com](http://www.leevalley.com). The Lazy Susan bearing I used is part number 12K68.12 but you can use a different one. A fender washer is an oversize flat washer. A Nyloc nut has a nylon bushing built in that prevents it coming loose easily. If you have more questions email [don@knappett.com](mailto:don@knappett.com). I will be glad to hear from you and will help out any way I can. ●

*Don Van Akker and his wife Elizabeth observe together from the Victoria area. As of this writing they are waiting under clouds so Don has lots of time to help you with this or any other Gizmos project. As well, he would love to hear your ideas.*

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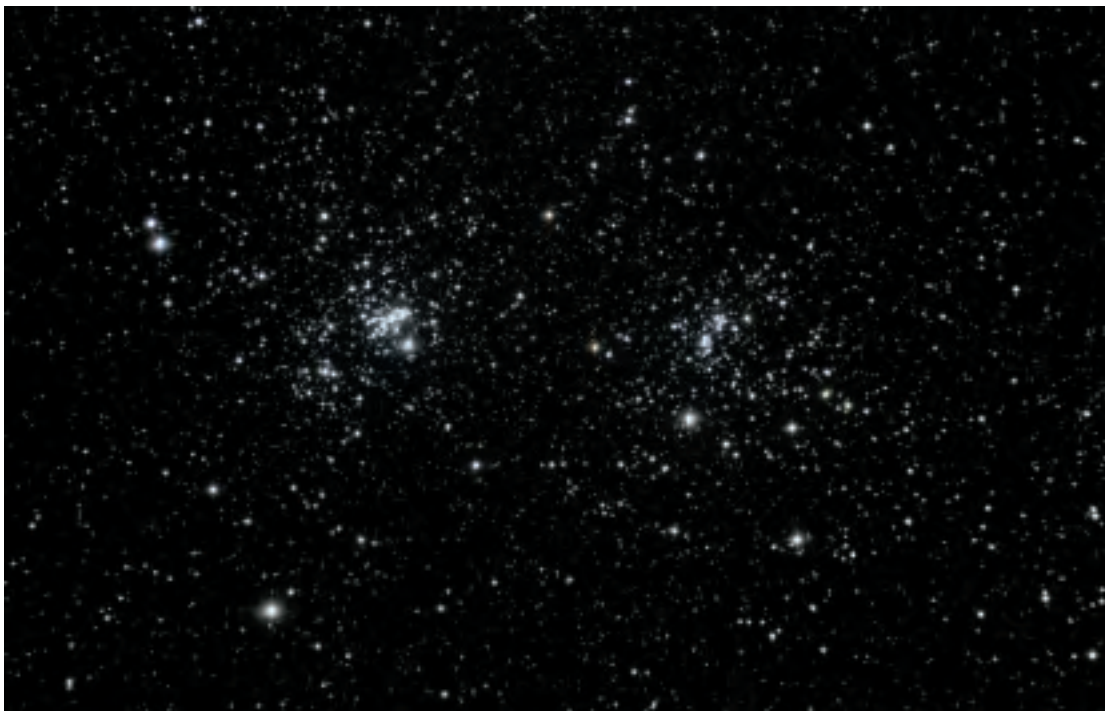
## Feature Articles

### Articles de Fond

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# Edmonton Centre Photos

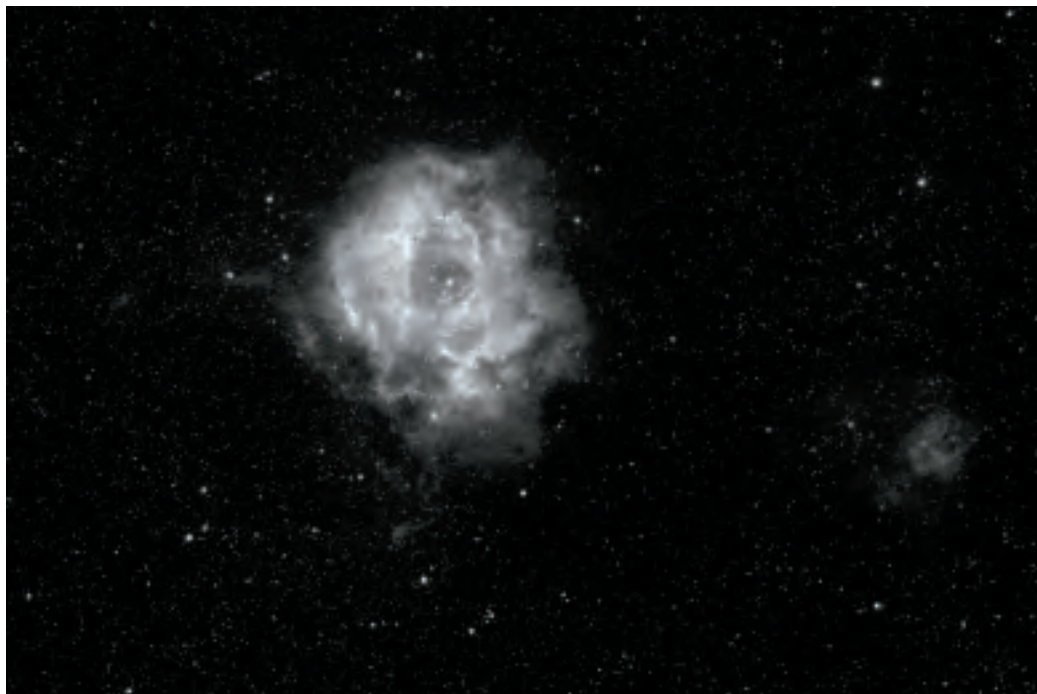
by Mike Noble & Wayne Malkin



This image of the popular Double Cluster in Perseus was taken by Edmonton's Wayne Malkin using an SBIG STL-11000M camera and a Vixen R200SS 8-inch reflector. Exposures were 1 hour of luminance data, and 45 minutes of combined colour. These beautiful clusters, NGC 884 and NGC 869, lie about 7000 light-years away and are relatively young (3.2 million years and 5.6 million years, respectively).

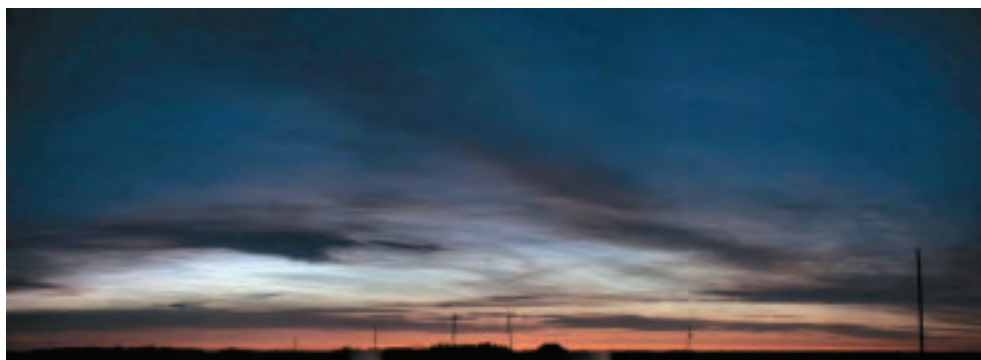


The Edmonton Centre's Wayne Malkin bought a telescope in 2004, and his first camera, a Meade DSI, in early 2005. He shoots images such as this of the Rosette Nebula from his back deck at almost every opportunity. The Rosette lies at an estimated distance of 5500 light-years, which results in a true diameter of about 130 light-years. At the centre of the nebula lies the open star cluster NGC 2244, which formed from the material in the nebula, and now provides the energy to light it.



This image of the eastern section of the Veil Nebula (NGC 6992) was provided by Mike Noble of the Edmonton Centre. Images were acquired on August 1 - 5, 2006 from a well site north-west of Pigeon Lake, Alberta. Hand guiding using a 4-inch refractor at f/10, Mike assembled the image from a total of three hours of exposure using a Canon 20Da attached to an 8-inch f/6.3 Celestron Schmidt Cassegrain.

This image by Edmonton Centre's Mike Noble is a 3-frame mosaic of noctilucent clouds captured on July 23, 2006 at 03:45 a.m. from a site 30 kilometres east of Camrose, Alberta.



## Barnard 361

by Doug Hube ([jdhub@telus.net](mailto:jdhub@telus.net)) and Warren Finlay ([warren.finlay@interbaun.com](mailto:warren.finlay@interbaun.com)), Edmonton Centre

In last issue's column, we highlighted two giant dark nebulae, the Great Rift and the Coal Sack, which are best seen with the unaided eye. Interstellar dust hovering like black smoke in front of the Milky Way backdrop provides the physical explanation for these dark nebulae. The same phenomenon, albeit on a smaller scale, is responsible for one of the best examples of a telescopic dark nebula: Barnard 361 (B 361, also designated as LDN 970), a 20' diameter, pitch-black blotch that cloaks a glittering background field.

A satisfying apparition of B 361 [RA(2000) = 12<sup>h</sup> 12.9<sup>m</sup>, DEC(2000) = +47° 22'] is seen by first finding the open cluster IC 1369, a 4' diameter, mag. 8.8, unspectacular bunch in an already dense Milky Way star field. With your eye glued to the eyepiece, slowly move your telescope south while watching for the blackness of B 361 to creep into view. Within approximately half a degree, you should see stars begin to vanish as you enter the apparently all-consuming void of B 361.



Figure 1 — Position of Barnard 361 in the night sky.

The dust particles within B 361 that give this nebula its darkness are a few tenths of a micrometre in diameter. Coincidentally, this is the same size as smoke particles emanating from a campfire or a cigarette. The number of dust particles per unit volume in B 361 (*i.e.* the number density) is also surprisingly similar to that occurring in smoke that wafts annoyingly into your face from your summer campfire. However,

you probably don't want to try holding your breath when a smoke cloud the size of B 361 comes your way, since its diameter is more than ten light-years.

Like many pairings of deep-sky objects, the proximity of IC 1369 to B 361 is simply a product of the chance alignment of two distant objects projected onto our two-dimensional view of the sky. In fact, at a distance of more than 6000 light-years, IC 1369 lies more than three times further away from us than B 361. Professional telescopes count more than 150 stars in IC 1369 and estimate its age at about 400 million years.

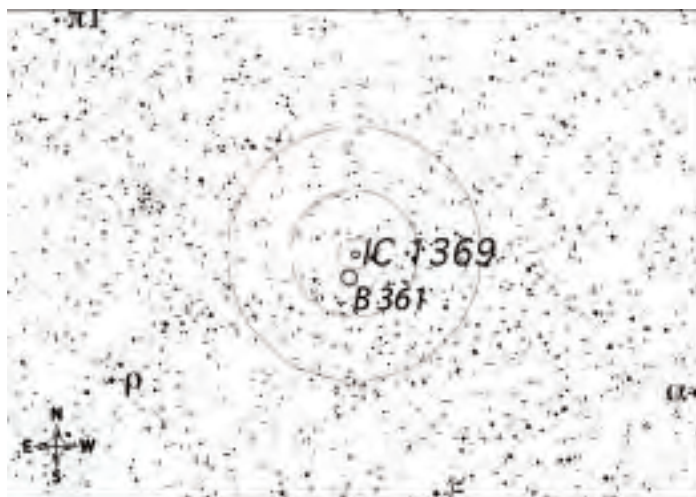


Figure 2 — Finder chart for Barnard 361 and IC 1369 shown with 0.5°, 2°, and 4° Telrad circles.

The best views of B 361 occur of course when the night sky is as dark as possible. Light pollution or twilight turns the blackness of this nebula into a muted gray, and ruins its otherwise amazingly pure blackness. Unfortunately, in Canada our long summer twilight interferes in this regard. One solution is to head south and camp under dark skies. However, for those planning summer vacations with family or significant others, it can be difficult to find a spot that combines a good observing location with interesting daytime activities. In addition, most campgrounds are impossible to observe from due to light trespass from nearby campsites, vehicle headlights, or permanent campground lighting.

Fortunately, it is possible to find astronomy-friendly campsites with amazing daytime sights that are sure to enthrall. One such



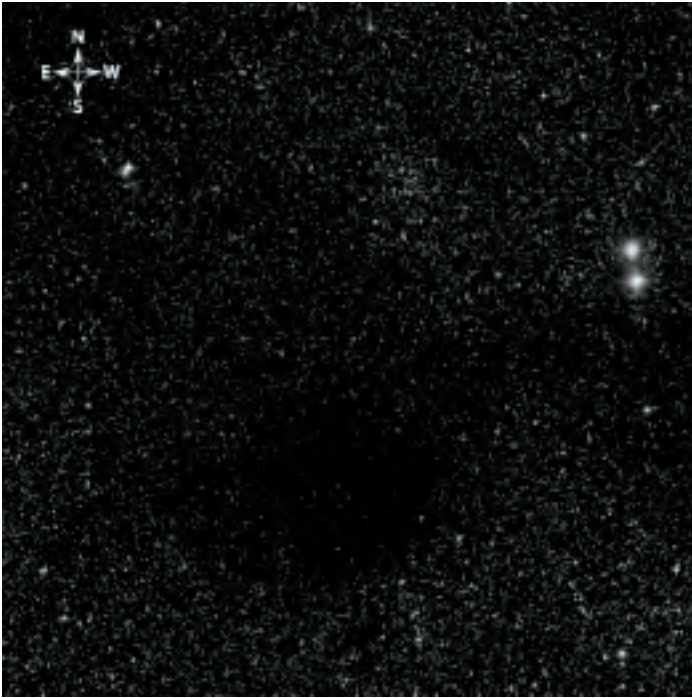


Figure 3 — 50' × 50' POSS image of the field that includes Barnard 361.

place is McPhee State campground in southwest Colorado, minutes from the Cortez airport, and with commanding views of soaring snow-capped peaks. With measured sky brightness darker than 21.6 mag/arcsec<sup>2</sup>, and having several campsites with unobstructed southern views completely shielded from light intrusion by piñon pine and juniper trees, the astronomy viewing here is first class. During the day, the incredible Ancestral Puebloan cliff dweller ruins of Mesa Verde National Park will amaze young and old with their haunting mystery. With high elevation giving surprising relief from the otherwise scorching southwest summer heat, this spot is an oasis from which to see B 361 in all its summertime glory. Many of you will have your own favourite summer-solstice dark-sky camping destinations, and we'd love to hear from you about such publicly accessible spots.

Whatever your summer plans, be sure to find a spot with dark skies and see this wonderful dark nebula for yourself. You won't be disappointed! ●

*Doug Hube is a professional astronomer actively retired from the University of Alberta, and Associate Editor of this Journal. Warren Finlay is the author of Concise Catalog of Deep-Sky Objects: Astrophysical Information for 500 Galaxies, Clusters and Nebulae (Springer 2003), and is a professor of engineering at the University of Alberta.*

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## Feature Articles

### Articles de Fond

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# The Telrad Finderscope Story - A Revolution in Amateur Astronomy

by Ray Khan, Khan Scope Centre (rkastro@yahoo.com)

**B**efore the days of computerized, digital, and GOTO-type telescopes, one of the biggest challenges for any amateur astronomer was finding his or her way around the sky.

No easy task, with printed star maps and charts, and trying to make sense of them under a dark sky. Many amateur astronomers who own telescope equipment can recall with delight when they first acquired one of their most important telescope accessories — the Telrad finderscope. To understand why the invention of this product was so important to many amateur astronomers in finding their way around the sky, allow me to digress.

When amateur telescopes first started to appear in the marketplace many years ago, most of them came with the traditional type of finderscope supplied by the majority of telescope manufacturers. This was basically a circular tube with

optics, 5 to 8 inches in length, with a low-power eyepiece of about 6× magnification, a crosshair to look through, and an objective size anywhere from 25 to 50 mm. And, it came with an inverted image. The idea was that because most telescopes had a narrow field of view, usually less than one degree (you can just about fit two Moons into that field), manufacturers would supply an auxiliary “finderscope” that usually had a three- to five-degree field of view — almost like looking through half a binocular, if you will. Once the finder was lined up with the main telescope, the observer could star-hop to the desired target according to the patterns in a star chart, using the wide field of the finder to see fainter *en route* stars and perhaps even the object itself.

So, while the image in your telescope was either inverted, if a Newtonian, or reversed left to right, if a refractor with a star



Figure 1 — A Telrad finder

diagonal, you were totally baffled when you looked through your inverted finderscope, and at your non-inverted star maps. Much mental duress! And, all very good in theory, but not so great in practice.

I recall that my first telescope had a 5 ×, 24-mm-objective finderscope mounted on a single bracket, and in fact was stopped down to an actual aperture of 15 mm. The bracket would never stay aligned with the main telescope, so the telescope and the finder would usually be pointing off in different directions. To top it off, even the three alignment screws used to align the finder to the main telescope would shift position while in use. Surely an exercise in frustration, making it very difficult to acquire night-sky objects.

Steve Kufeld was an active amateur astronomer, living in Huntington Beach, California, and a member of the Los Angeles Astronomical Society. I met Steve several years ago at the Riverside Star Party held in Big Bear, California. He told me the story of how the Telrad was invented. He based the concept on the World War II “Norden” bombsight that he had obtained at a surplus store.

Steve’s prototype consisted of three illuminated red circles that were projected against the night sky through a small window, through which the observer peered — essentially the device sold today. When you look through a Telrad, you see a zero-magnification set of concentric circles that provide a “what you

see is what you get”-type of display. This made it easy to star hop from one star to another to locate your target, though without the magnification provided by a finderscope. A very clever three-knob alignment system and a simple mounting base (double-sided tape) to attach the Telrad to your telescope added to the appeal. He was able to experiment with and test several prototypes until he finally developed the now well-recognized Telrad design.

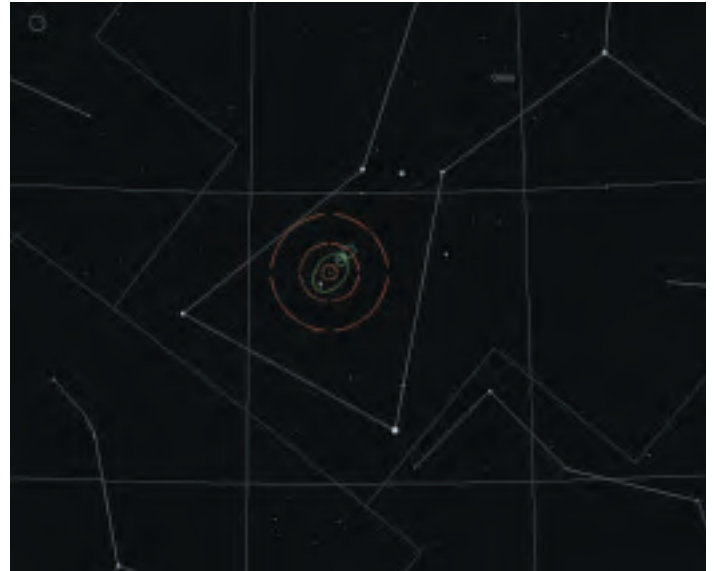


Figure 2 — Telrad projection circles superimposed on a chart of the Orion Nebula area.

Kufeld started advertising the product in popular astronomy magazines; word spread, and the Telrad industry was born! Eventually Steve utilized an ABS plastic-injection mold to increase production. Not bad for a part-time venture!

I called Steve many times on behalf of Khan Scopes to ask when the next shipment of Telrads would be coming through, as they were usually backordered because of high demand and slow production. Steve would usually say, “Soon!”

Sadly, in 1999 at the age of 57, Steve Kufeld became ill and passed away. The company Telrad Inc. is still in operation today, and the Telrad still remains one of the most popular devices for locating night-sky objects. Many star charts and software programs incorporate the Telrad overlay. At a price of about \$54 Cdn, it is still a great product for amateur astronomers. ●

### WEB ACCESS TO THE 2007 ISSUES OF THE JRASC

The 2007 issues of the *Journal* can be accessed from the RASC Web site at [www.rasc.ca/currentjrasc](http://www.rasc.ca/currentjrasc). Issues are posted immediately after the final production version is complete. Username and password are sent by email to RASC members.



## Educating Edmonton

by Bruce McCurdy, Edmonton Centre (bmccurdy@telusplanet.net)

*“The stars belong to everyone.”*

— HELEN SAWYER HOGG

*“Come and see the sunspots.”*

— JOHN DOBSON

“**Y**ou know about horsepower?” I ask the incredulous faces who have suddenly encountered a moving building during their walk in the park. “This facility operates on middle-aged-fat-guy power.”

The facility in question is the public observatory in scenic Coronation Park in central Edmonton, where this middle-aged guy of thickening torso is starting another shift by opening the doors to the public and the roofs to the sky. Most of the time — or at least during those five or six months not known as “winter” in these parts — the creaking roof is a nice match for my creaky back and I can just manage to roll each one-tonne wing down the rails on my own. Mass is more important than strength in this contest.

In the process, an ungainly looking oversized shed of indeterminate purpose is transformed into an open-air funhouse loaded with high-quality telescopes and higher-quality volunteers that admits free of charge anybody who cares to look. Hundreds of thousands of people have done so since the observatory first spread its wings and looked to the sky in summertime 1984 as a showpiece “field” exhibit of the nearby Edmonton Space Sciences Centre (now known as Telus World of Science — Edmonton, or TWoSE for short).

The RASC Edmonton Centre played a key role in the establishment of both science centre and observatory, and a quarter century before that, the Queen Elizabeth Planetarium, Canada’s first public planetarium. Throughout our 75-year history, public education has always been a primary focus of our group, consistent with our earliest roots in the University of Alberta.

From conception, a key component of the Science Centre was the establishment of a public observatory. The observatory deck initially housed four telescopes: a 4-inch Zeiss refractor and three Celestron SCTs: two C-8s and a C-14. Their new permanent home was a great relief to volunteers who had previously lugged some of these scopes from storage within the QEP every time we held a public star night. Much easier to move a mere building than to drag a C-14 around!



Figure 1— The observatory deck at the Science Centre.

Science centre staffers like Alan Dyer and Russ Sampson (RASCals both) were responsible for early operations. An early success was the return of Halley’s Comet in January 1986, when some 10,000 people lined up for a look at the sky’s most famous visitor over the course of 10 frigid nights.

I was swept back into astronomy on the tail of Comet Halley, so can take up the rest of the story in the first person. As a neophyte RASCAl, I somehow missed out that Halley could be seen through good telescopes from a location only a couple of kilometres from home. However, the following summer I discovered the observation deck one beautiful evening, and found myself returning there again and again. Watching Richard Reid describe the starhop to M57 in the sky, and then sweep it up with a telescope time and again, I thought “I could do that.” By the following spring, I was a volunteer.

While I had some initial trepidation about handling the expensive telescopes, I quickly found a comfort level talking to visitors about the sky. In my experience, a significant majority of people has an innate curiosity about the Universe and our place in it. Often this interest lies dormant until they are confronted with an opportunity to look for themselves and talk to a (relative) expert. I try to avoid lecturing the visitor, keep jargon to a minimum, use analogies from the everyday world, encourage questions, and ask a few of my own. Establishing meaningful two-way communication can be the difference

between a guest leaving the deck thinking he is stupid or knowing that she has just learned something. One of those people is far likelier to return.

I also quickly learned that “I don’t know” is an acceptable answer, especially if followed up with “Let’s see what we can find out.” Key resources like the *Observer’s Handbook* and *Burnham’s Celestial Handbook* are on hand, and nowadays much can be done on the Internet. Often the best solution is to ask another volunteer, as we each bring our own interests and insights.

By 1991, the Science Centre had financial struggles and proposed to cut back deck operations to summertime only. RASC Edmonton Centre stepped into the breach, offering to run the facility on a volunteer basis, five shifts every weekend throughout the school year. Several dozen RASC volunteers have kept that promise from that day to this. TWoSE, meanwhile, does fund full-time summer programming that runs seven days a week and has provided seasonal employment for several RASCals over the years.

Soon after formalizing our involvement at the observatory, Edmonton Centre tapped into a major source of fund-raising for charitable organizations, namely casinos. The requirement that revenues be spent in the public interest is easily met within our public observing program, and we have invested in several major upgrades over subsequent years. While the original Zeiss refractor and C-14 remain, several additional telescopes have been installed: a 7-inch Starfire refractor, a 16-inch Meade GPS, 10- and 8-inch SCTs for solar viewing, and a 70-mm Coronado H-alpha scope.

In recent years, the Observatory Planning Committee, under the able leadership of Paul Campbell, has made a number of improvements designed to make the deck more accessible to the handicapped. Large-footprint tripods are a thing of the past, as resident engineers Roman Unyk and Dave Robinson have crafted a series of handsome pier mounts for the various scopes. The electrical system has been upgraded and electronic eyepieces and various imaging devices allow for “live” viewing on a video monitor when the circumstances are appropriate.

While light-polluted urban skies are hardly ideal, the Observatory’s location in a city park close to the Science Centre makes it highly accessible. We get far more visitors than could possibly be expected at a truly dark location — a fair trade-off. And, while we might decry the nebulous objects that are lost to sky glow (raising awareness of light pollution in the process), there is much worthwhile observing that can be done. Artificial lights have relatively little effect on bright objects like the Moon, planets, and showpiece double stars, and none at all on the solar observing that dominates our summer program. The Observatory has been defined by a few major events over the years. The three Great Comets of the mid-1990s — Shoemaker-Levy 9, Hyakutake, and Hale-Bopp — all generated tremendous public interest, drawing over 50,000 visitors among them. Then 2003 brought Mars Mania and its huge line-ups that stretched all the way to the parking lot over a hundred metres distant. The Red Planet

rose late and low, but that didn’t deter folks from lining up for a look: 5000 of them one memorable night when the last person in line crossed the threshold to the deck at 4 a.m. As with the great comets, an overworked volunteer crew was supported in large numbers by other RASC members.

On such occasions, observing for oneself becomes a distant second priority, but this sacrifice is repaid during the many quiet moments. Over the years, I have conducted sunspot counts, strolled through a catalogue of double stars, observed countless mutual events of Jupiter’s satellites, and worked on my Isabel Williamson Lunar Observing Certificate. Other notable observations include my first successful asteroid occultation, all eight planets in a single day, the annulus of Venus, several near-earth asteroids, and eclipses at all hours of the day and night.

From this volunteer’s perspective, the Observatory experience is truly about people. Of course, that includes the many talented and generous folk whom it has been my privilege to call co-workers over the years. I have met countless thousands of visitors aged from 2 to 102, from every corner of the globe. While showing the planets to people of all ages and nationalities, I have learned much about our own.

Even after 20 years, I have never tired of hearing the involuntary gasp that frequently accompanies somebody’s first view of Saturn. I do wish I had a twoonie for every time somebody accused me of putting a picture of the ringed wonder in the tube! I’ve heard that “original” comment literally thousands of times. I have concluded that this gut reaction is the result of Saturn’s impossibly perfect appearance.

Some experiences border on the bizarre — UFO reports, suspected “meteorites,” creationist theories, astrological implications, impossible questions from teens looking to impress their date by stumping the astronomer. One day my log entry under “problems encountered” consisted of the single word “Thomas,” a precocious youngster who confused telescopes with monkey bars. One day I had physically to restrain a non-English-speaking visitor from sweeping an unfiltered refractor to the Sun, one of the nearest misses in the Observatory’s still-perfect safety record.

One of our more successful initiatives has been the development of “astro cards,” a set of 36 trading cards featuring a variety of Solar System and deep-sky objects, along with members’ photographs. These are given out to kids (of all ages) who visit the deck. Often it provides a surprising teachable moment: “The rings of Saturn are one of the flattest natural structures known. If you were to make a scale model the thickness of this card, the rings would encircle Coronation Park.” Upon hearing this, one enterprising young family left the deck, only to return about an hour later having walked the perimeter of the park! I rewarded them with an entire set of cards.

One of the more controversial aspects of astronomy these days is the questionable practice of “selling” stars. While I am dubious of such outfits as the International Star Registry, if a visitor has already taken the bait there is absolutely no point in expressing a caustic opinion on the subject. For better or

worse, they do provide a personal connection to the stars, especially a memorial star dedicated to a departed loved one. I remember wincing one summer evening when an elderly English lady brought me her ISR documents, but I let her down as gently as I could while conducting a lengthy search for the 7th magnitude star in Sagittarius (!) that commemorated her late husband. Her effusive thanks, accompanied by a tearful hug, confirmed I had done the right thing.

Our local science centre has a similar program, albeit they are upfront about its function as a fund-raiser that confers no real ownership. We often get requests from visitors to track down “their” star. On one memorable occasion, a young couple observed such a star at length and in complete silence, punctuated by long hugs. A discreet inquiry confirmed that they were honouring the tragic memory of a stillborn child.

Another more sociable occasion occurred last winter, when about 50 family members, friends, and classmates made a pilgrimage from central Alberta to Edmonton to see a star dedicated to a teenage girl lost to a car accident. With the star slowly rising in the southeast, Frank Florian of TWoSE arranged to show them its location in the planetarium theatre before

they came out to look at the real thing. I swept it up fairly easily, but noticed that sky conditions were gradually worsening, so made the executive decision to have Frank bring the group out immediately. Sure enough, there was just enough time for all eyes to have a look, while I eavesdropped on a number of conversations about the girl who had made an impact on so many lives. After the group departed, I continued to observe alone as the star gradually faded into the mist. Unexpectedly, I was overcome with the symbolism of the moment that Katelyn’s Star was extinguished, as a single tear rolled from my observing eye and froze on my cheek.

Moments such as this are just one of the reasons I am a committed Observatory “lifer.” There are far too many anecdotes to share here — if you like this sort of thing, track me down in the common room at the GA. The opportunity to share the wonders of the Universe with whoever cares to drop in is a great privilege. ●

*Bruce McCurdy recently marked his 20th year of volunteer service providing public education and outreach at the TWoSE Observatory.*

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## Through My Eyepiece

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# Starting Out: A Most Pleasant Way to Spend an Evening

by Geoff Gaherty, Toronto Centre ([geoff@foxmead.ca](mailto:geoff@foxmead.ca))

Over the years, I have tried just about every form of astronomical observing there is. I’ve enjoyed almost all of them, with the possible exception of hunting down faint galaxies on bitterly cold winter nights. Almost any time spent under a night sky is a pleasure to me. But one form of observation stands out: timing central-meridian transits on Jupiter.

Central-meridian transits used to be a mainstay of anyone seriously interested in planetary observation, but strangely, they have become less popular in recent years. In my early years as an amateur astronomer, I devoted more time to transit observations than all my other observing combined. In the last year, they have again come to dominate my observing schedule.

The idea behind these observations is a simple one. Using a high-quality telescope and a reasonably high magnification (around 240× seems to work best for me), you simply sit and watch Jupiter. After a few minutes, your eye starts to notice finer detail in the cloud bands, and Jupiter’s rapid rotation (once every ten hours) becomes obvious. As I have said before, I’m a sucker for astronomical phenomena that move and change,

and Jupiter is the champion for these. As you watch the features of Jupiter’s cloud tops stream past your eye, you try to decide when a particular feature is exactly central between the east and west limbs of the planet. No special equipment is needed, as the human brain and eye are pretty good at deciding when some image is symmetrical. When the feature is central, you note the time to the nearest minute, along with a brief description of the feature.

How can such a vague “measurement” be of any use? The secret lies in Jupiter’s rapid rotation. Say your estimate is only good to plus or minus five minutes (with a bit of practice, most people can do much better than that). This time error converts to a longitude error of plus or minus three degrees, which is pretty darned good.

Such timings wouldn’t be worth much, if they were performed for a planet much different from Jupiter. Unlike the clouds of Earth, the clouds of Jupiter have considerable persistence. We have all heard of the Great Red Spot, the gigantic anticyclone in Jupiter’s atmosphere, which has persisted for *centuries*. Many other features of Jupiter’s atmosphere have persisted for decades,



and even the most ephemeral are usually observable over a period of months. An atmospheric feature followed over a period of months with observations of plus or minus three degrees can result in a calculated rotation period accurate to a few seconds!

Members of the British Astronomical Society (BAA) started timing transits on Jupiter in the last decade of the 19th century. They immediately noticed some patterns in the rotation of Jupiter's atmosphere. We are looking at a gaseous body, so the planet doesn't rotate at a uniform rate. Instead, objects in the equatorial regions rotate noticeably faster than objects at more temperate latitudes. The Sun shows exactly the same behaviour. Objects close to Jupiter's equator have an average rotation period of 9 hours 50 minutes 30.0 seconds, while the Great Red Spot takes 9 hours 55 minutes 40.6 seconds. These rotation periods, measured by the BAA in 1895, were arbitrarily defined as Jupiter's main rotation periods, and designated System I and System II. Many years later, a third rotation period, based on radio-astronomical measurements, and perhaps more directly related to the rotation of Jupiter's core, was established, and named System III.

These rotation periods have no basis in reality, but are used as frames of reference to measure the longitudes of Jupiter's atmospheric features. Real features in Jupiter's atmosphere drift east or west relative to these reference systems, but that drift can be used to calculate the actual rotation periods of individual features. Carrying this one step further, it is possible to calculate the relative wind velocities in Jupiter's upper atmosphere — numbers studied and used by professional planetary scientists.

These ideas form part of the appeal of observing central-meridian transits. Simple observations with relatively low accuracy ultimately yield highly accurate data studied by professional astronomers. Neat!

Back in the 1950s and 1960s, when I first started making these observations, the recording and analysis of the observations was quite complex. Nowadays, it has become much simpler thanks to the work of Hans-Joerg Mettig and Grischa Hahn. They have developed a wonderful software program called WinJUPOS (Figure 1), which makes entry and analysis of Jovian transit data easy.

The manual that comes with the program is also an excellent introduction to the nomenclature used to describe the objects in Jupiter's atmosphere and their location. Everything you need is available on the JUPOS Web site: <http://jupos.privat.t-online.de>.

This program also enables imagers to measure their images of Jupiter for positional data in a straightforward graphical way. The only requirement is that the time the image was made must be known to the nearest minute.

Last summer I rediscovered the joys of timing central-meridian transits on Jupiter. It is a wonderfully relaxing activity, watching "old Jupe" slowly rotate, and pausing now and then to jot down a transit time. And, like variable-star observing, it is highly addictive. Jupiter is now coming into the evening sky and the nights are warm. Give it a try! ●

*Geoff Gaherty started out as a teen when he joined the RASC in 1957. Now he's semi-retired but still enjoying his hobby in various ways — one is sharing his accumulated wisdom as a specialist for Starry Night Customer Support.*

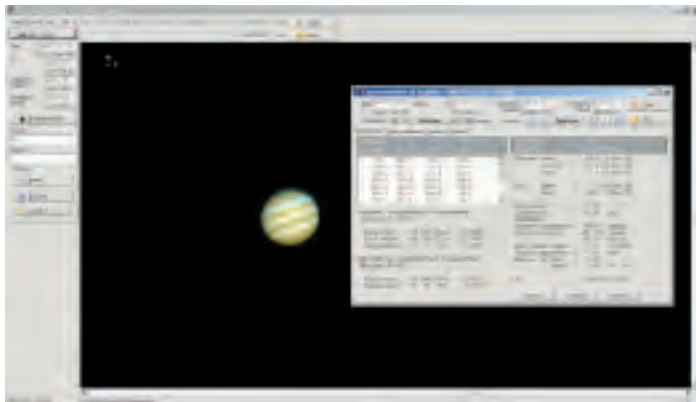


Figure 1

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# Dr. Tom Bolton

by Philip Mozel, Mississauga Centre ([phil.mozel@sympatico.ca](mailto:phil.mozel@sympatico.ca))

**P**hotons. It's all about the photons. Astronomers go to incredible lengths and build enormous machines to trap rare bits of light that may have traveled across much of the Universe. Doing so is how we have gained most of our knowledge about the cosmos. Today, astronomers find themselves in the ironic position of also trying to fend off, not attract, certain kinds of photons. From star-studded heavens to light-polluted skies, Dr. Tom Bolton has done both during his long career.

Astronomy has always been a passion for Dr. Bolton. In fact, the first word he ever uttered, according to family tradition, was "moon." Growing up under the big sky of the Illinois prairies, he never tired of looking upward at night. The stars have "always been with me." He received his Bachelor's degree from the University of Illinois and his Master's and Ph.D. degrees from the University of Michigan. Offered a post-doctoral position at the University of Toronto's David Dunlap Observatory (DDO), Dr. Bolton eagerly accepted. The position was an ideal fit for his research interests and would allow him frequent access to observing with the 74-inch telescope. He has made excellent use of this opportunity in the intervening years, being the recipient of a number of awards including election as a Fellow of the Royal Society of Canada.

Dr. Bolton categorizes himself as a stellar spectroscopist. Using spectroscopy, he studies the detailed nature of stars, especially those that are massive or in binary systems. Interest in the latter stems from summer work at Kitt Peak National Observatory in Arizona. "I really love working on stars where I can look at data and tease out the properties of the system. I would love to go to a star and see if it looks like what I thought it would."

Until that trip is arranged, he continues his study of binaries and variables, the atmospheres and winds of early type stars, and the structure and evolution of massive stars. With the help of optical interferometry, he obtains accurate masses, sizes, and brightnesses of stars, and studies the effects of magnetic fields on stellar winds from magnetic B stars. A spectroscopic case in point is Dr. Bolton's research indicating that the unusually high level of nitrogen in some hot O- and B-type stars is due to their membership in binary systems and the concomitant transfer of material to the companion star. It is, in fact, his interest in binaries that led Dr. Bolton to a most exciting summer in 1971, when he accumulated overwhelming evidence for the existence of black holes.



Dr. Tom Bolton

At the time, he thought black holes were just so much nonsense. Papers were being published saying that black holes existed in binary systems but Dr. Bolton's opinion was "No way!" He was aware of an X-ray-producing binary called Cygnus X-1 and, surmising that its giant blue star was orbited by a neutron star, he set out to measure the latter's mass. What he determined by spectroscopy in 1971 was that a massive object was indeed wheeling around the blue giant, but at the incredible speed of 70 kilometres per second. This did not fit the neutron star profile; it simply did not have the required mass and density. Based on his observations, Dr. Bolton concluded that black holes are real, and he had one in hand. At the time, many people remained skeptical, but Dr. Bolton's observations were unassailable, and Cygnus X-1 is today firmly established as the first known black hole. One of his papers describing this work was included in a Harvard University Press selection of the most important astronomy papers published between 1900 and 1975.

Conducting this sort of research at DDO has become imperiled of late. One big problem is in actually finding researchers willing to use an instrument as "small" as the 74-inch. There are currently only four people using the telescope and only two

of those are what might be termed primary users. There is a lot of observing time available but few astronomers, like Dr. Bolton, to take advantage.

Another issue, not surprisingly, is light pollution at the observatory's location north of Toronto. While the encroachment of a photon-profligate civilization has limited the type of observations that may be made, DDO remains an excellent spectroscopic site and is still productive. With digital detectors and other specialized equipment to expunge light-pollution photons, the 74-inch is capable of doing spectroscopy on stars fainter than 15th magnitude. This means there are still tens of millions of potential target stars.

Dr. Bolton has also tried eliminating light pollution at its source. Since attending a meeting with municipal authorities years ago, he has become the designated light-pollution officer at the observatory. He is now "on a mission" to reduce this form of pollution, which must happen if DDO is to have a future. It has not been easy. To get the necessary municipal by-laws changed at that time, corresponding legislation at the provincial level had to be enacted. The by-law had to be precisely worded, and to lay out the technical aspects of the issue in such a way that it could be interpreted by astronomically challenged judges and lawyers. The process of getting the by-law in place took Dr. Bolton from 1987 to 1994. That anything was done at all was, he explains, the result of the town and developers saying, "We need to make this go away." Eventually, every building development

had to have a light plan approved by Dr. Bolton, and he was getting around a hundred per year crossing his desk!

More than just the sky above DDO is under assault. The very existence of the observatory is in question. Developers covet the land, although many people living near the observatory and other long-term residents hold the DDO near and dear. The university would like to sell the land but the terms of the original bequest make this difficult.

As more longtime DDO astronomers reach retirement, a brain drain of sorts is occurring, and the in-house knowledge of how to care for and operate the observatory is being lost. As Dr. Bolton continues to use the facility, and encourages others to do so, he sees a looming deadline of three to five years for a decision concerning the fate of DDO. While the observatory may be declared an architectural and heritage site, and the grounds protected as a woodlot, the future is far from certain.

So, ultimately it *is* about the photons. What kind of photon does one trap or discard or follow into a black hole? How does one obtain and maintain the required instruments? Many questions...but really just another night at the office for the modern astronomer. *Per ardua ad astra.* ●

*Philip Mozel is a past librarian of the Society and was the Producer/Educator at the former McLaughlin Planetarium. He is currently an educator at the Ontario Science Centre.*

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## Carpe Umbram

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# Finding Yourself

by Guy Nason, Toronto Centre ([asteroids@toronto.rasc.ca](mailto:asteroids@toronto.rasc.ca))

*Do you know where you're going to?*

*Do you like the things that life is showing you?*

*Where are you going to?*

*Do you know?*

— M. Masser/G. Goffin

(Recorded by Mariah Carey, Diana Ross, and others)

**K**nowing your location on the surface of Earth to at least an accuracy of 0.5 arc-second of latitude and longitude (and within several metres of altitude) is just as crucial to good occultation data collection as is accurate timing of the star's disappearance and reappearance. These days, there are two acceptable ways of "finding yourself." You can plot your location on a large-scale (1:50,000 or larger) topographical map, or you can use the GPS system.

Topo Maps: While in the field, measure the distance from your observing site to a landmark (crossroads, railway crossing,

bridge). Back at home, very carefully plot your location on a large-scale topographical map by measuring from the landmark, using the scale reference in the map's margin. Then draw horizontal and vertical lines through your location to the edges of the map. Where the lines cross the latitude and longitude scales, respectively, will define your location. With great care, using a very fine pencil (0.2mm), and a magnifier, you can determine your position to about 0.5 arc-second. Topographical maps are published by the federal government and are available through government bookstores, outdoor outfitters, and some map retailers.

Altitude can be found by extrapolating between the topographical lines on the map. Typically, these are in ten-metre increments, which is well within the required resolution. So if your viewing site falls between, say, 250 and 260 metres above sea level, report your altitude as +255 metres,  $\pm 5$  metres.

An essential piece of information is the geodetic datum

of the map. It will be printed somewhere in the margins and will most likely be NAD 27 (North American Datum 1927) or possibly NAD 83. These define the baseline from which the map is generated and is a necessary component of your report. Without it, your location information is meaningless.

GPS: The Global Positioning System is a major boon to occultationists. In the past, GPS signals were intentionally degraded to yield a positional accuracy of ~100 metres. This degradation, called “selective availability,” was turned off several years ago, resulting in an improvement to about 25 metres accuracy. This is good, but still not accurate enough for occultation work. But there is a trick to make it so. By noting readings every minute for about 15 minutes, then averaging the results, one can improve the positional accuracy, probably to <10 metres, which is sufficient.

One can do even better, though, by using a more recent GPS receiver that includes a feature called WAAS (Wide Area Augmentation System). A WAAS-equipped GPS unit can yield a positional accuracy of five metres or better by using the averaging technique. Many WAAS-capable GPS units have a built-in averaging feature that takes a measurement every second for as long as you like, and computes a running average of the results. I recommend this method for even better positional accuracy. It is essential to verify that your unit is using the WGS84 datum. Most GPS units are defaulted to WGS84, but check to make sure.

There is a potential complication, however, in using consumer GPS receivers to measure altitude and it goes back to a major difference between the old and new data. The NAD27 datum references altitude to mean sea level (MSL). The WGS84 datum uses a specific baseline “ellipsoid” that can, and often does, differ from MSL by as much as 100 metres. This is why users of early GPS units often found that their display read 50 metres or more *below* sea level, when in fact their boat was floating safely on the ocean surface. To avoid confusion, many newer GPS receivers, even those set to WGS84, convert altitude to MSL (but leave latitude and longitude referenced to WGS84). So how do you know which system your unit is using? First of all, read the manual. If it does not address the issue, then compare your reading to a known reference, such as a high-quality topo

map or a known geodetic benchmark. To find a benchmark near you, go to [www.geocaching.com/mark/nearest.aspx](http://www.geocaching.com/mark/nearest.aspx). If the reference agrees with your GPS receiver to within about ten metres, then, for asteroidal occultation purposes, treat the read-out as MSL and state that in your report. However, if you find there is a large discrepancy, then your GPS unit is probably calculating altitude with respect to the WGS84 ellipsoid. To convert that to MSL, use the “Geoid Calculator” at <http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/intpt.html>. If you elect to report altitude referenced to MSL, then do the conversion for every new location you use. Either way, remember to state which datum was used to determine your altitude separately from the datum used for your horizontal coordinates.

Of course, it is not necessary for every occultationist to purchase a WAAS GPS receiver. Many astronomy clubs will have at least one member who already owns one. That person could take measurements afterwards at marked locations where observers obtained useful data. If not, perhaps the club itself could purchase one for members’ use.

So, whichever system you use — topographical maps, GPS, or a combination of both — measure your location with great care and accuracy, and report the datum(s) used, so you’ll know not only to where you’re going, but also where you’ve been!

Check this list for upcoming occultations in your area, then go to [www.asteroidoccultation.com](http://www.asteroidoccultation.com) for more information, including local circumstances, predicted times, and finder charts. Go to [www.poyntsource.com/New/Google.htm](http://www.poyntsource.com/New/Google.htm) for Google maps of the occultation path. Locate your preferred observing site on the map, and measure your distance and direction from the centreline. Please advise me (email address above) if you plan to participate in any of these events. Good luck and clear skies! ●

*Guy Nason is a long-time member of the RASC Toronto Centre and IOTA (International Occultation Timing Association). He has served the Toronto Centre as Observational Activities Coordinator, Councillor, National Council Representative, Secretary, Vice-President, President, and was, until recently, Past President. He received the RASC Service Award in 2004. He has successfully timed several lunar grazes, total occultations, and eight asteroidal occultations*

DATE(UT) 2007	ASTEROID # NAME	STAR MAG	Δ-MAG	MAX DUR (Secs)	PATH
Jun 15	1858 Lobachevshij	10.4	4.6	2.2	sON - sMB
Jun 17	2617 Jiangxi	11.9	3.8	3.3	swQC - sON
Jun 19	433 Eros	11.4	1.3	1.9	cON - sSK
Jun 22	923 Herluga	11.2	4.6	2.5	NS - nwON
Jun 27	365 Corduba	11.8	2.0	8.7	sNL - cON + swBC
Jul 2	4505 Okamura	9.5	6.0	1.4	sMB
Jul 16	225 Henrietta	10.6	2.1	15.1	NL - ON
Jul 20	85 Io	11.4	0.7	53.6	nwON
Jul 23	502 Sigune	10.5	4.2	1.2	seNL
Jul 29	27 Euterpe	11.0	0.6	11.4	nwON
Jul 30	225 Henrietta	12.4	0.8	14.0	neMB - seSK
Aug 8	85 Io	11.9	0.6	25.4	MB



# Reviews of Publications

## Critiques d'ouvrages

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**Comets II**, edited by Michel C. Festou, H. Uwe Keller, and Harold A. Weaver, pages 745 + xvii, 22 cm × 28 cm, The University of Arizona Press, 2004. Price \$113.50 Cdn hardcover (ISBN 0-8165-2450-5).



Comets rank among the most impressive of the night sky's cast of characters, owing in part perhaps to the seeming randomness of their limited-time-only appearances. Long thought to be portents of impending war and disaster, these wanderers among the planets are coming to be better understood, and are now known to be at least somewhat predictable in their behaviour, and in the timing of their appearances.

We now know the heart of a comet to be a body a few kilometres in size, seemingly insignificant when compared with the planets, but nonetheless beautiful, and important scientifically for the information it can provide. Comets are similar in size to asteroids, but differ in having a significant component of frozen water and other ices in addition to rocky material. It is the ice which (should the comet pass sufficiently close to the Sun) vaporizes to produce the glowing tail that is the comet's most dramatic feature.

The book *Comets II*, edited by Michel C. Festou, H. Uwe Keller, and Harold A. Weaver, is part of the well-respected University of Arizona Space Science series. Containing over 30 volumes, the series of books has addressed a variety of topics in the study of the Solar System, from each of the planets through their satellite systems and on to the Sun itself. Each volume is widely regarded as a benchmark in the progress of a scientific discipline, and summarizes the current state of understanding as perceived by the scientists at the forefront of the discipline.

*Comets II* contains individual articles on every aspect of cometary science, compiled by 88 authors from around the world, all experts in the field. Broad topic areas include the formation of comets alongside the planets during the Solar System's early days, as well as studies of cometary death, whether as baked-out rocky bodies depleted of ice, or through breakup into interplanetary debris. This second "fragmentation" end state was well illustrated recently by the spectacular breakup of comet 73P/Schwassmann-Wachmann earlier this year.

The volume also includes reports on the chemical composition of comets, as gleaned from the gas and dust they release during

their intermittent appearances. The vapour that comets produce is a rich source of information, one which inert bodies like asteroids lack, and provides a rare window into the chemistry of our Solar System. Observations of comets are particularly important because they remain relatively unprocessed compared to bodies like our own Earth, and thus give us a clearer view of the original ingredients from which our planetary system formed.

The intended audience for *Comets II* is a technical one, and the volume will appeal most to professional astronomers and planetary scientists. The editors produced a book designed for "new students entering with unfettered ideas, as well as current planetary science practitioners who have the experience to recognize new connections across broad disciplines." At the indicated level, the volume is a superb one that will continue to be referenced for decades — I heartily recommend it. For less technical readers, the volume is a heavyweight at 745 pages, and it is not priced for the amateur's library. There is a wealth of information here that cannot be found anywhere else, however, and each of the 37 articles has a one-paragraph abstract summarizing its contents. In the abstracts, the interested amateur will find a succinct recap of the state of the art. From them, she or he may pick and choose which articles to delve into more deeply. Such delving could require considerable effort, but would be rewarded with a wealth of understanding about the showy, short-lived apparitions we call comets.

In short, if you are enthusiastic about comets, do not miss this book. But it is not a light read.

— PAUL WIEGERT

*Paul Wiegert has an abiding interest in comets, asteroids, and the other small bodies of our Solar System. He is an assistant professor of astronomy at the University of Western Ontario in London.*

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**Nature Exposed: Photography as Eyewitness in Victorian Science**, by Jennifer Tucker, pages 294 + ix, 15 cm × 23 cm, The Johns Hopkins Press, Baltimore, 2005. Price \$55 US, hardcover (ISBN 0-8018-79991-4).

*Nature Exposed* is a history of scientific photography unlike any other. In this book of modest size one finds a discussion of photography of ghostly spirits, meteorological phenomena, bacteria, Mars, and a host of other areas relating to science.



The common thread is the nature of evidence and how authenticity is determined. Though the time frame is the first 80 years of photography, we need only think of alleged UFO photos or of techniques used in manipulating digital images to realize the continuing importance of questioning the old canard that “the camera never lies.”

The author, Jennifer Tucker, brings her perspective as an assistant professor of history and women’s studies at Wesleyan University. The reader will not find, and probably should not expect, accounts of the discoveries of Daguerre, or technical aspects of wet and dry plates. The author does cover the interaction of photography with English-speaking society with remarkable insight, and provides enough technical background for clarity. She has used archives in Britain, Ireland, and the United States, and provides a prolific bibliography of books and periodical articles as well as a very useful “Essay on Sources.” At times, when she speaks in the voice of academe, I wish for a more lowbrow approach. For example, the headings of the first two chapters, “Constructing Science and Brotherhood in Photographic Culture” and “Testing the Unity of Science and Fraternity,” are hardly enticing.

Since this review is intended for an astronomical audience, I will emphasize that aspect of the book, though it is only in the fifth, and last, chapter of the book that it comes to the fore. The social focus of Tucker’s analysis will, I hope, be evident even from this selective overview. She begins by reminding us that British scientific societies were funded by a combination of public and private sources and that they therefore felt a duty to make the public aware of the utility of science. Photographic exhibitions were held, and collections of images and lantern slides were made, to strengthen the association between scientific investigation and the natural world. Eclipse expeditions reinforced interest in the Empire. After the advent of dry plates in the 1870s, photography became a popular hobby, and that provided a convenient way for societies like the Royal Astronomical Society (RAS) to broaden their bases.

Indeed, the RAS Photographic Committee was established in 1888, and included some of the best astronomical photographers in the world — Warren De la Rue, Andrew Common, Norman Lockyer, the Maunder, and Isaac Roberts among them. In describing their contributions, Tucker touches on De la Rue’s pioneering work on using clock-driven mounts, Huggins’ stellar spectra, each like a tiny jewel only a centimetre long, but which hinted at the distinct classes of stars, Roberts’ unprecedented photograph of M31 showing details invisible to the eye, and so on. But the point of the Committee was to receive photographs from around the world, so that the best of them could be catalogued, studied, reproduced, and sold. It was seen as a means of democratizing and publicizing the Society and the science of astronomy. The halftone process used for reproducing photographs in books and journals was a poor substitute for the photographic reproductions offered by the RAS. Tucker misses no opportunity to look into side issues such as copyright, gender, art, and the role of amateurs.

Most of chapter 5 revolves around Percival Lowell’s photographs of Mars, published in 1905. The debate which raged over Lowell’s claim that his photos showed canals and that they were evidence of intelligent life is well known. Tucker recounts the story, but her point is not the controversy itself, but the light it sheds on several issues. She emphasizes the influence of E.W. Maunder’s criticism of Lowell’s claim by reminding us that he was a founder of the BAA, and the first director of its Mars section. This group of amateurs had the leisure time, equipment, and skills to specialize in observing and sketching Mars night after night. They were well aware of the discordances between their own drawings and the dangers of finding patterns where none actually existed. We are reminded of discussions in earlier chapters of the value to meteorologists of sketches of clouds, as opposed to photographs, and the necessity of drawings of bacteria to supplement photographs, which only showed their gross features. Lowell found it advantageous to explain the fine points of his pictures, and to supervise their reproduction. It is not a huge stretch to see similarities with the mediums, who found it necessary to interpret their photos of spirits, as Tucker described in chapter 2. Context is important as well — Lowell’s dry Arizona made him well aware of the need for irrigation, and the building of the Panama canal (1904-14) was often in the news.

Any reader will be struck with the admirable breadth of investigation which Tucker, as a serious historian of science, has undertaken. She notes the tendency of modern historians and sociologists of science to focus on controversy to elucidate assumptions and practices that normally go unnoticed, and I think it is fair to put her in that category. Consequently she does not even mention such important landmarks as E.C. Pickering’s stellar spectrographic work at Harvard or the nebular photographs of Keeler at Lick and Ritchey at Yerkes Observatory. Whether or not you find such an approach hard to swallow, the book is worth a careful reading.

—PETER BROUGHTON

*Peter Broughton is a retired teacher and a former President of the RASC. He has written several articles on the history of astronomy and a book on the history of our Society.*

**The Last of the Great Observatories: Spitzer and the Era of Faster, Better, Cheaper at NASA**, by George H. Rieke, pages 232 + xiv, 16 cm × 24 cm, The University of Arizona Press, 2006. Price \$40US hardcover (ISBN 0-8165-2522-6), \$19.95 US, paperback (ISBN 0-8165-2558-7).

If you tried to gaze at your favourite astronomical objects with a white-painted telescope in daytime against the glare of



the sky, you would quickly appreciate the huge challenge of making infrared observations from the ground. In the infrared, everything glows, particularly the telescope and the sky. By contrast, a telescope in space, refrigerated by liquid helium, and above our warm atmosphere, is hugely more sensitive. NASA issued an announcement of opportunity to build instruments for the Shuttle Infrared Telescope Facility (SIRTF) on Friday, May 13, 1983. By Monday, August 25, 2003, the 0.6-metre telescope and instruments were successfully launched, and renamed for the astrophysicist Lyman Spitzer. George Rieke, who was involved from day one, provides a highly readable saga of this interminable weekend from concept through all of the funding and technical crises, and introduces the large cast of dedicated players who brought it about. Despite knowing the ultimate, successful outcome of the mission, the book is a page turner, especially for anyone who has spent too much of their scientific career promoting and trying to realize major scientific facilities in the face of continual cutbacks, endless delays and presentations, plus inevitable bureaucratic restrictions. There was only one shot at getting such a space mission right because *Spitzer* ended up in a solar orbit, quite beyond the sort of repair mission that saved Hubble. Absolutely nothing could be left to chance.

*Spitzer* is not of course the last great observatory, and only one of many successful space infrared missions. But it was the final one of the quartet of great NASA observatories, the others being *Hubble*, *Chandra* (X-ray), and *Compton* (gamma-ray) — each one sensitive to a different component of the Universe. *Spitzer* has a cluster of cameras fed by the telescope, which detect and characterize warm cosmic material such as dusty discs around stars where planets form, and even planets around other stars, or the huge populations of cool stars much less luminous than the Sun. In contrast to the generous treatment and lack of public scrutiny for Defence projects, *SIRTF* was continually left hanging by a thread because of technical and funding setbacks at NASA, which demanded endless, gruelling Congressional lobbying efforts to keep the project alive — nobly led by Marcia Rieke. The most successful major instruments are the product of dynamic tension between creative scientists and gifted engineers, something extraordinarily well documented here in Rieke's book, and particularly revealing in the case of Frank Low.

Dan Goldin became NASA Administrator in 1992 and, in an effort to save the organization and its funding, introduced the “faster, better, cheaper” mantra, which drums all through the book and title. Frank Low came up with a simple, brilliant response to that requirement: launch the telescope warm and let it cool to ambient in space, shielded from sunlight, and only then refrigerate it. Not only did it save launch weight and cost, but the liquid helium lasts many times longer than for a “cold” launch — an immense scientific advantage.

The book is not a primer on the *Spitzer* observatory itself, but there are clear and comprehensive appendices which provide all the necessary detail and philosophy behind

the design, as well as a highly readable account of the scientific goals and capabilities. There is a very good index and bibliography. The text ends in 2004, where the really spectacular discoveries begin, but one can easily catch up on them through the *Spitzer* Web site.

While this chronicle of tribulations may not make it appropriate for the young astronomical enthusiast, I highly recommend it as an exciting read for those interested in, or who have participated in, the remarkable developments in astronomical observations of the last few decades.

— GORDON WALKER

*Gordon Walker was a Professor of Astronomy at the University of British Columbia until 1998, and now lives in Victoria. He was involved in the development of the Canada-France-Hawaii and Gemini Telescopes, and is currently part of the research team working with Canada's first space telescope, MOST, which he helped to design.*

•••••  
**Canada in Space: The People & Stories behind Canada's Role in the Exploration of Space**, by Chris Gainor, pages 264 + 0, 14 cm × 21 cm, Folklore Publishing, 2006. Price \$18.95 Cdn, paperback (ISBN 1-894864-59-X).



Space — truly the final frontier — is a region from which Canada has never shied. In many cases, it is not so much the country itself as a national entity that has played a role here, but its people: the engineers, scientists, medical doctors, technicians, visionaries, explorers, and, yes, even astronomers, who have paved the way and claimed a role.

The story behind *Canada in Space* is one of vision — personal or sometimes national — followed by an occasional fall in federal political will, a loss attributable to a changing national budgetary climate, advances in delivery systems for weapons of mass destruction, or even a disintegrating international balance of superpowers, resulting in reformulated national agendas in which intense competition and rivalry were replaced by space programs, and eventually by co-operation among various international players. Depending on the specific situation, such as the demise of the Avro Arrow project in 1959, it is a story of federal action serendipitously leading to opportunity south of the Canadian border, a chance for our best and brightest, the dreamers, and the determined, to help build upon an emerging space adventure in another country, stepping up with their can-do expertise, and eventually standing high on the shoulders of their predecessors.

It is also a story of developing niche expertise, not so much as a drive fuelled by national determination but by individual ambition, contribution and, later, by much greater corporate involvement. Chris Gainor, a long-time Royal Astronomical

Society of Canada (RASC) member (Victoria Centre) and former RASC National Council representative, has neatly captured the story of Canada and, more precisely, of its citizens in space in his book *Canada in Space: The People & Stories behind Canada's Role in the Exploration of Space*. Gainor's recently published paperback, as he writes in his introduction, "looks at Canadians who have opened the roads into space with rockets and satellites." It is certainly that and much more.

The book is an easy read, fast-moving with a story told in short, bite-sized sentences. It is aimed at a wide audience — the young and the older. If you are looking for a tome that provides significant details on each topic addressed and accompanied by heavy footnoting, this book is not for you. There is not even an index section for those of an academic bent. But if you wish a broad, quickly paced account that touches on key milestones and offers general details, open the cover to *Canada in Space*, read on, and enjoy the historical ride.

Two points are suggested to the reader, perhaps as a result of a kind of osmosis as he or she moves through the chapters. First, Canada has highly talented and educated people who sometimes with, and in many cases without, central government interest or participation, have contributed immensely to the exploration of space, whether through space programs or the field of astronomy. Second, space exploration itself, which includes the full gamut of activities from rocket design leading to satellite deployment and space travel, on the one hand, to the study of planetary bodies and systems, on the other, is a team-based activity that crosses national boundaries. Yes, Canada can now boast the Canadarm and Canadarm2, but such a space tool needed a purpose and use, which the American *Space Shuttle* program provided. The U.S. got Canada to develop it, and we became a world leader in this area of space engineering.

The Canadian astronaut program exists because of U.S. space initiatives in which we are occasional and welcome partners. We are also part of the International Space Station, and have links to European space activities. So, at the end of the day, we can boast NASA scientists, engineers, astronauts, internationally renowned astronomers, and commercial enterprises that have satellite, microchip, and software development know-how.

We have been involved in *Alouette I*, *Mercury*, *Gemini*, *Apollo*, and the *Shuttle* programs, as well as space telescopes. The Mars rovers have image sensor chips developed in Canada, and *Sojourner* rolled off on Canadian-made ramps using modems

built in Montreal. There have been many other contributions as well.

Astronomers, described by Gainor as Canada's "original space explorers," have also had their share of successes — both professionals and amateurs alike. A recent development was the *MOST* (Microvariability and Oscillations of STars) mission, a suitcase-sized, 60-kilogram satellite that many people call the "Humble Space Telescope." *MOST*, the first Canadian astronomy micro-satellite, has been seeking planets orbiting other stars.

Gainor makes a point of noting that "Like the Canadian space program, Canadian astronomers have helped lead the world despite receiving government support that is a fraction of spending in other countries, even when adjusted for Canada's small population." In astronomy, before the space programs, Gainor identifies such professional luminaries as C.A. Chant, Frank Hogg, and Helen Sawyer Hogg, names all familiar to RASC members. He also notes the scientific philanthropy of the Dunlap family that resulted in the construction of the David Dunlap Observatory, just north of Toronto.

There are also, writes Gainor, well-known Canadian popularizers of astronomy, such as Jack Newton, Terence Dickinson, and David Levy, and before them, Helen Sawyer Hogg, who found time in her professional career as an astronomer to write astronomy books and articles for the public. And not to be overlooked, Gainor points to the 107-year-old Royal Astronomical Society of Canada with nearly 5000 members across the country, which publishes the annual *Observer's Handbook*, "an indispensable reference for amateur astronomers."

But what of the future?

Gainor begins his book with a dedication that sets the tone and the possibilities. He writes: "To Taylor and Brian, Aidan and Sarah, Amanda and Taylor, and Lyra and Solomia, who will witness our future endeavours in space and maybe even live them." He ends the book with a revealing and quite appropriate quote from Robert Thirsk, one of Canada's astronauts: "Exploration is a Canadian core competency."

How true and how exciting!

— Andrew I. Oakes

*Andrew Oakes is an arm-chair astronomer who read Chris Gainor's book on the GO Train during his daily commute to the centre of the Universe (downtown Toronto) from a bedroom community some 80 kilometres "east of [this] Eden." ●*

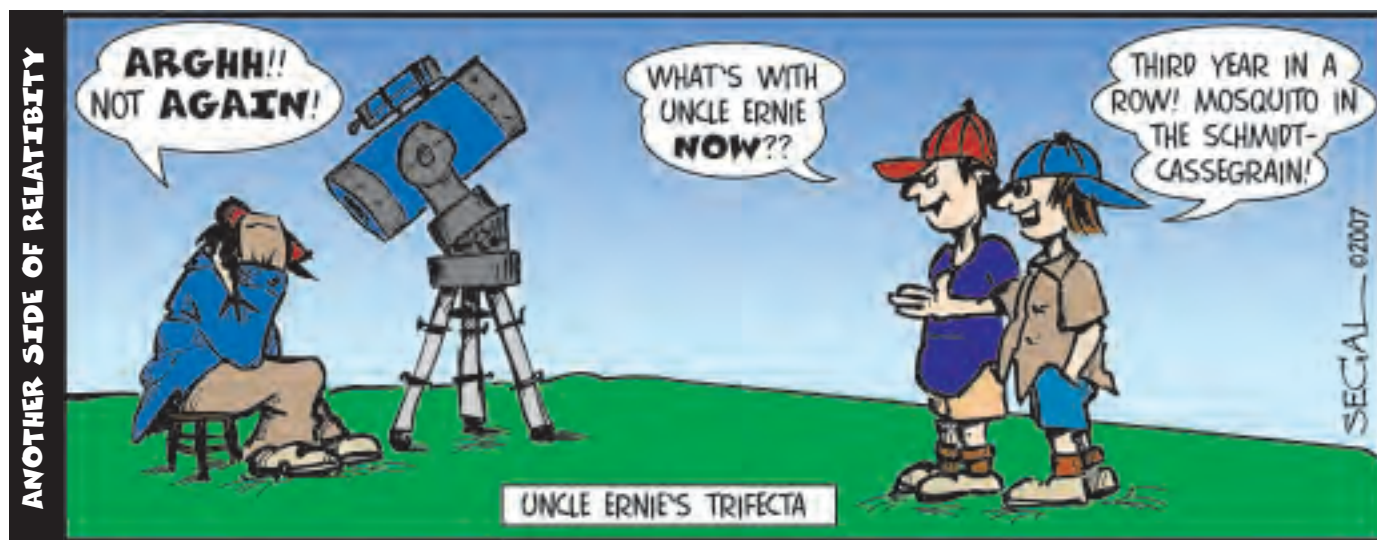


# James Edgar's Venus and Moon



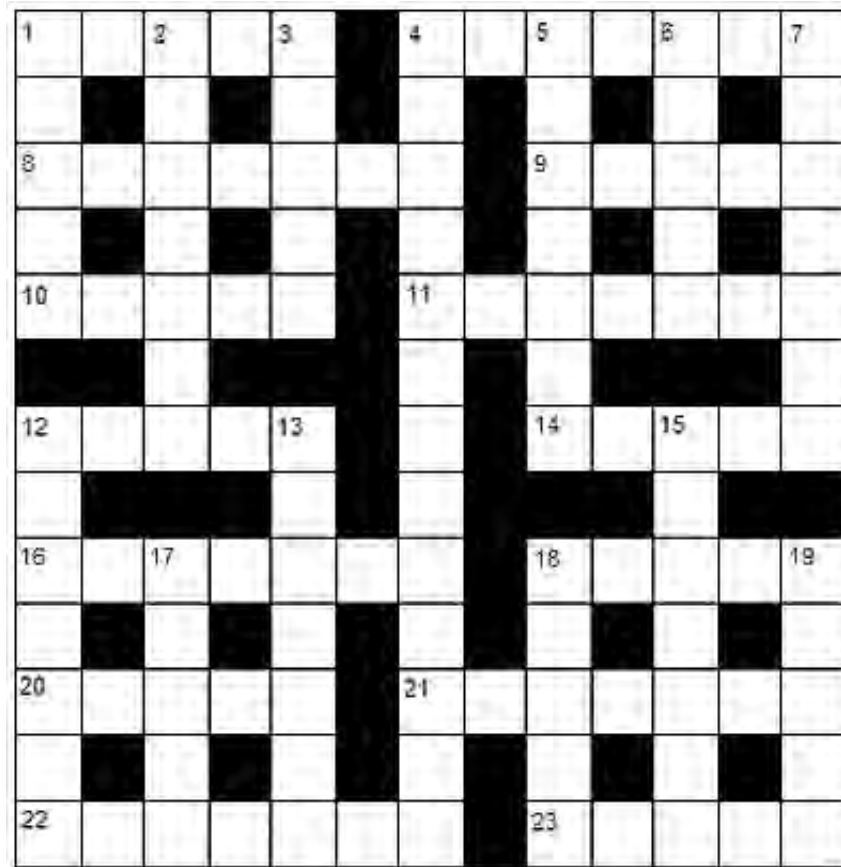
The early evening of March 20, 2007 found Venus and the new Moon creating a striking pose against the dark twilight sky, with clouds lit from beneath by the lights of the Melville rail yard — sometimes light pollution can be a good thing!

"I used my Canon 20D camera, equipped with a 17 to 35-mm aspherical wide-angle zoom lens set at 17 mm and f/3.5; exposure was 10 seconds at ISO 400. The gradient, from the almost-daylight sky above the clouds to the inky blue surrounding the Pleiades, makes it a captivating shot."



# Astrocryptic

by Curt Nason, Moncton Centre



## ACROSS

1. Dark matter speculator leaves Britain's capital in ruin (5)
4. Composer Bela eats a bee with the galactic researcher (4,3)
8. Darn! I am wrong about Uranus (7)
9. Halton trails his Schmidt-Cassegrain up a lunar cliff (5)
10. Start researching and I follow an amazing debunker (5)
11. Reap the benefits of an autumn Moon (7)
12. Morning returns around Trojan location to fly in the southern sky (5)
14. Hubble damaged by east wind storm (5)
16. Destimulating point on the main sequence (7)
18. This star is barely perceptible in fat surroundings (5)
20. Shelton cuffed by the District Attorney at a Venusian chasm (5)
21. Fifty pieces somehow hidden by shadow (7)
22. Supernova leftover that men rant about (7)
23. Albert Einstein initially attended half a clinic about a chisel (5)

## DOWN

1. Roger makes GM build the first transit instrument (5)
2. Soundly see where the Mjolnir crater formed (7)
3. Sister gets half a kiss in a teapot handle (5)
4. If you block haze,  $T_{\text{eff}}$  somehow increases pulsating variable modulation (7,6)
5. Reticence veers off in Raman effect (7)
6. Uplifting support to the northeast for multidimensional superstrings (5)
7. His star moves quickly in a Type K explosion to the north (7)
12. Unusual drama to watch like Orion to Taurus (7)
13. Bustle leads Aries to a telescope shop in New York (7)
15. He discovered comets while going around very softly (7)
17. Virgo's galactic expanse concerns part of Almagest (5)
18. French cop has nothing to do with B acid in mushrooms (5)
19. Rivet pops from Neptune's fountain (5)

# Segal's "Astro-Trifecta"



Brian Segal is the graphic artist who lays out the *RASC Journal*. He is also an amateur astronomer with a passion for astrophotography. Back in the days of "real film" as he likes to put it, he shot this image of M 51 using his Meade 8" SCT and the then "new" Fujichrome ISO 1600 transparency film. At the time he didn't realize that his 40-minute exposure would bag a triplet of astronomical delights — M 51 (the intended subject) along with the bonus of an aurora and, just below the galaxy, a meteor speeding through the night sky. "A true astro-trifecta," says Segal, who shot the image in the "velvety darkness" of Lochaber in Antigonish County, Nova Scotia, on May 27, 1990, using his Meade and a 30-year-old Nikon F-1 body, with "a variety of add-ons the identity of which I can't remember."



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## Observer's Calendar — 2007

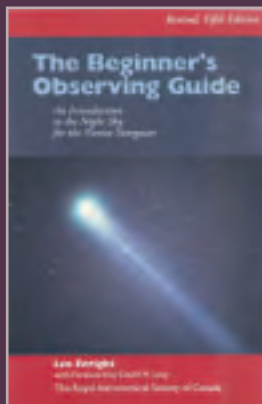
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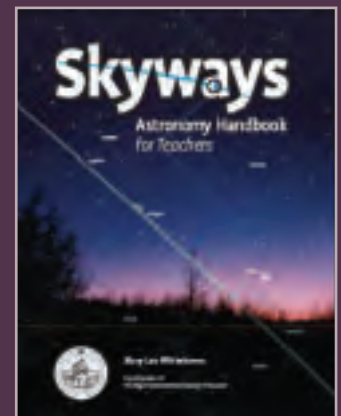
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