February/février 2004 Volume/volume 98 Number/numéro 1 [704]

Journal

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

INSIDE THIS ISSUE

History of the Transits of Venus • Levers et couchers

The Uranic Muse • The Millman Fireball Archive II

February/février 2004

Journal

Vol. 98, No. 1 Whole Number 704

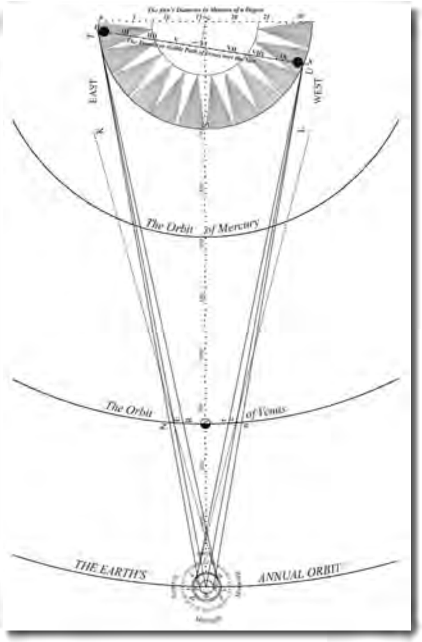
contents

table des matières

FEATURE ARTICLES/ARTICLES DE FOND

RESEARCH PAPERS/ARTICLES DE RECHERCHE

COLUMNS/RUBRIQUES

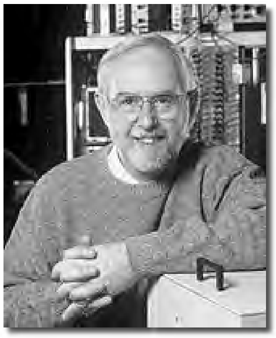


Transits of Venus
p. 6

Reflections
p. 30

Levers et couchers
p. 21

DEPARTMENTS/DÉPARTEMENTS

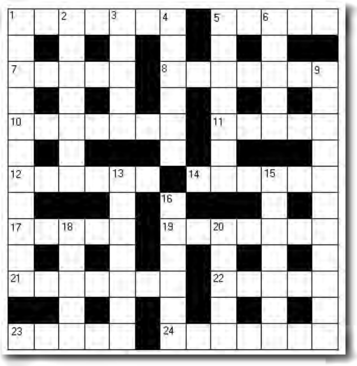


News Notes
p. 4

ACROSS THE RASC
DU NOUVEAU DANS LES CENTRES

Cover:
A New Image for the RASC
p. 45

The Michael Smith Award
p. 42



Astrocryptic
p. 29

President's Corner

by Rajiv Gupta (gupta@interchange.ubc.ca)

As I write this column in late 2003, I am in a reflective mood (hmmm…I wonder whether there is such a thing as a refractive mood?). The New Year is approaching, and I am thinking back on the highlights of the expiring year, many of which I've shared with you in earlier columns. And, I'm thinking about what 2004 may have in store for the Society.

I said in my December 2003 column that 2003 was a very special year. We celebrated, in our Royal Centenary, a longevity and stature that few other astronomical organizations share. And what a celebration it was, highlighted by the regal presence of the Honourable Iona Campagnolo, Lieutenant Governor of British Columbia, at the General Assembly in Vancouver in June.

And, as I also announced in my previous column, 2003 was made even more special by the receipt of a prestigious Michael Smith Award for Science Promotion from Canada's scientific granting agency, NSERC. I made a hurried 26-hour trip from Vancouver to Ottawa (a full half of which was spent in airports or airplanes) to accept the award on behalf of the Society at a gala ceremony in Ottawa on the evening of Nov. 19 at the Museum of Nature. The co-nominators, James Edgar and John Percy, as well as our past president, Bob Garrison, also traveled to Ottawa to represent the Society. As I delivered the acceptance speech on behalf of all 4700 of our members in the resplendent banquet hall at the Museum, I felt truly privileged to be representing the Society as it received a premier award for organizations of its type. For more details on the ceremony and the award, please read further in this issue of the *Journal*.

Another important Society event is covered in this issue — the adoption of a new official logo. For an organization with the long history of the RASC, a new "graphical identity" is a very important change. The black-and-white version of the new logo may at first glance seem very similar to the current Society logo that appears for example in our publications, but there are some important enhancements: the new logo includes the most-recognizable northern asterism — the Big Dipper — and the most-recognizable Canadian icon — the maple leaf — which makes it even more fitting as a symbol for the Society. The design elegantly merges these new elements with the existing ones, including Urania, and thus preserves a link to our rich heritage. Moreover, we also have a high-quality colour version of the new logo, which will be useful for merchandising of promotional items such as sweatshirts. The new logo came about through the hard work of Dan Collier and the Membership and Promotion Committee, and we owe many thanks to these members for

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.

Editor-in-Chief
Wayne A. Barkhouse
136 Dupont Street
Toronto ON M5R 1V2, Canada
Internet: editor@rasc.ca
Web site: www.rasc.ca
Telephone: (416) 924-7973
Fax: (416) 924-2911

Associate Editor, Research
Douglas Hube
Internet: dhube@phys.ualberta.ca

Associate Editor, General
Michael Attas
Internet: attasm@aecl.ca

Assistant Editors
Michael Allen
Martin Beech
Pierre Boulos
Ralph Chou
Patrick Kelly
Daniel Hudon

Editorial Assistant
Suzanne E. Moreau
Internet: semore@sympatico.ca

Production Manager
David Garner
Internet: jusloe@wightman.ca

Contributing Editors
Martin Beech (News Notes)
David Chapman
William Dodd (Education Notes)
Kim Hay (Society News)
Bruce McCurdy
Harry Pulley
Leslie Sage
Russell Sampson (News Notes)
David Turner (Reviews)

Proofreaders
James Edgar
Maureen Okun
Suzanne Moreau

Design/Production
Brian G. Segal, Redgull Incorporated

Advertising
Isaac McGillis
Telephone: (416) 924-7973

Printing
Print Atlantic Ltd.

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 2004, $44.00; life membership is $880. 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:

The Royal Astronomical Society of Canada
136 Dupont Street
Toronto ON M5R 1V2, Canada
Internet: nationaloffice@rasc.ca
Web site: www.rasc.ca
Telephone: (416) 924-7973
Fax: (416) 924-2911

Canadian Publications Mail Registration No. 09818
Canada Post: Send address changes to 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.

ISSN 0035-872X

producing such an elegant, modern, and appropriate graphical representation for the Society. For more details, please see the article by Denis Grey, a member of the Membership and Promotion Committee, in this issue.

While perhaps not as prominent an event as the receipt of the Michael Smith Award or the adoption of the new logo, there was also an important administrative change in the Society in 2003, the creation of new standing committees to promote observing and education. I encouraged members to support the creation of these committees in my February 2003 column, and I'm happy to report that the necessary bylaw changes were approved at the Annual Meeting in Vancouver in June. As I explained earlier, I think the new committees could represent an important change in the role of the national Society in these core activities that have always been carried on, vigorously, by Centres.

In spite of all this positive news, there's a dark lining on our silver starcloud. As I explained in my August 2003 column, the sudden rise in the value of the Canadian dollar had a significant impact on our publication sales revenue in 2003, since the bulk of our sales are at fixed US-dollar prices. National Council is very concerned about the roughly $25,000 drop in our revenue caused by the loonie's ascent, and it is likely that some financial adjustments may need to be made in order to accommodate the loss of income.

But, with so much going so right in the Society right now, I'm absolutely confident that we can meet the financial challenge we're currently in, and that 2004 will be another banner year for the Society. We've got a new "look," new committees to help us fulfill our mandate, and the prestige of having celebrated our Royal Centenary and having received a major award. How can we go wrong?

Editorial

by Wayne A. Barkhouse (editor@rasc.ca)

This issue of the *Journal* celebrates the awarding to the RASC of the Michael Smith Award for astronomy public outreach (*i.e.,* science promotion; see accompanying article by James Edgar and John Percy). At the same time, the RASC is announcing the release of a newly redesigned Royal Seal as the Society marks the end of the Royal Centenary year. To promote these achievements, the *Journal* includes a colour layout to depict this historical moment. Although the *Journal* looks great in colour, the high cost of production prevents us from making the transition to full-colour for every issue at this time. However, we will whet your appetite when appropriate. I hope you enjoy!

The receipt of the Michael Smith Award signifies the importance of science outreach that is the hallmark of the RASC. I have always been impressed by the dedication to "public awareness" that the RASC and other astronomy groups have demonstrated. Last year's Mars observing campaign allowed thousands of ordinary citizens to partake in the thrill and excitement of observing Mars, which has captured the imagination of astronomers since the invention of the telescope. This year's Venus transit (see article in this issue by Daniel Hudon) will surely fall into this same category as the public will witness an event that hasn't occurred for over a hundred years. I expect that the RASC will be out in full force to insure that non-astronomers will be given the opportunity to view the celestial show.

As I write this column (early December) there are rumors in the news media that the United States will soon announce plans to return to the Moon. If this occurs (and you probably already know the answer by the time you read this), the space industry will receive a much-needed jump-start that has been lacking since the early 1970s. Canada will hopefully be asked to participate and will emphasize the importance of informing the public as to the benefits of having a strong and healthy space program (both manned and unmanned).

The arrival of a fleet of spacecraft at Mars, the transit of Venus, the start of the Saturnian encounter by the Cassini spacecraft, and the possible resumption of Space Shuttle flights will make 2004 a very interesting and exciting time for space enthusiasts. I hope that public outreach will continue to play a very important role!

News Notes
En Manchettes

SNO LEADER WINS PRIZE

The 2003 Gerhard Herzberg Canada Gold Medal for Science and Engineering was awarded this past November to Dr. Arthur McDonald, of Queen's University. The prize guarantees Dr. McDonald will receive $1 million in research funding from the Natural Sciences and Engineering Research Council (NSERC).

"Dr. McDonald was the driving force for the Sudbury Neutrino Observatory (SNO), which has been such an outstanding international scientific success story and a source of great pride for all Canadians," said Ottawa-Vanier M.P. Mauril Bélanger, who announced the award on behalf of Allan Rock, Minister of Industry and Dr. Rey Pagtakhan, Secretary of State (Science, Research and Development). "Like Gerhard Herzberg, he has had an outstanding influence on science in Canada and also on how Canadians perceive themselves as an innovative, science-friendly nation."

"Designing and building a large underground experiment to reveal the ultimate truth about solar neutrinos was both a novel and high risk endeavour," said NSERC President Tom Brzustowski. "Yet Art McDonald recognized that Canada had the ingredients to pull it off, and he did. Thanks to his great abilities as a scientist, mentor, leader, and coordinator, we have an amazing scientific facility in Sudbury, and Canada is recognized as a major training ground for particle, nuclear, and astrophysicists from around the world." For more information on the SNO project see the Web page at `www.sno.phy.queensu.ca`.

Dr. McDonald received his Herzberg Medal at a gala dinner evening at the National Gallery of Canada. In addition, two other finalists for the 2003 Herzberg prize, John Smol, also of Queen's University and Richard Bond of the University of Toronto, received NSERC awards of excellence and $50,000 each in research support. Dr. Bond is one of the world's leading cosmologists, and has been responsible for major new insights into the nature of dark matter and black holes and for greatly expanding our knowledge of the structure and evolution of the early universe. Dr. Smol is credited with transforming paleolimnology and the study of ancient lake sediments into one of the hottest fields in ecology.

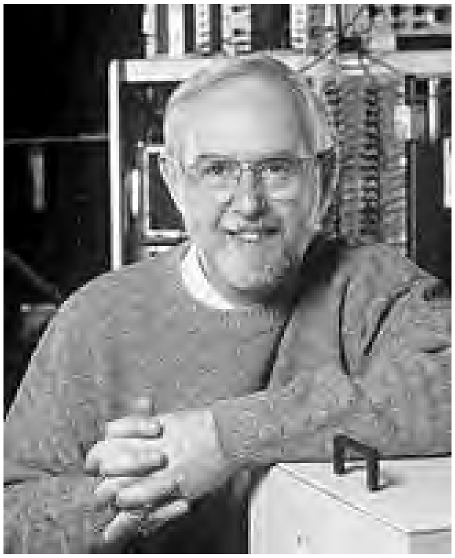


Figure 1. — Dr. Arthur McDonald, Director of the Sudbury Neutrino Observatory Institute, Professor and University Research Chair, Department of Physics Queen's University, recipient of the 2003 Herzberg Gold Medal. Image courtesy of NSERC.

TMT MEETING BLOWS INTO VICTORIA

Wind dynamics experts from both Canada and the United States visited the National Research Council's Herzberg Institute of Astrophysics (NRC-HIA) in Victoria this past November to discuss how Aeolian conditions might affect the operation of a huge, 30-m telescope. The meeting was called in response to the initiation of the Thirty Metre Telescope (TMT) project, whose goal is to build a giant telescope in Hawaii or Chile, and of which Canada is a partner.

Just as a photograph will be blurry if taken when your hands are shaking, so too will the images obtained with a shaky telescope be blurry. Literally, if there is too much wind, the whole telescope will twist and yaw — and the bigger the telescope, the bigger the problem. Worse still, large telescopes are typically situated on high mountain peaks; locations prone to windy conditions. Astronomers have traditionally placed telescopes in domes and/or carefully engineered telescope structures to reduce "wind shake," but when it comes to constructing a 30-m telescope, standard design specifications are literally stretched to the limit.

"Wind shake" has traditionally been studied in two ways. One approach is to use a scale model of the dome and telescope in a large wind tunnel, and then subject the model to extreme wind conditions. The second approach is to develop a detailed computer model and numerically model the wind interaction. At this stage no clear design consensus for dome and telescope has been reached.

NRC-HIA has invested almost $3M over the past three years into studies concerning the construction as well as the scientific value of a "modest" 20-metre telescope. The Association of Canadian Universities for Research in Astronomy, with NRC-HIA as a partner, has asked the Canadian Foundation for Innovation to fund Canada's share in the TMT project. The initial Design and Development Phase will cost over $100M, of which Canada's share is some $25M. The estimated total cost to build the massive 30-metre telescope is $1B. It is envisioned that the telescope could be operational by the year 2015.

Canada's partners in the TMT project include the University of California, the California Institute of Technology, and the Association of Universities for Research in Astronomy.

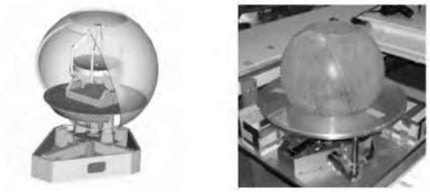


Figure 2. — A 1 to 100th scale wind-tunnel model of a large telescope dome. Image courtesy of NRC-HIA. For further details see the Web page at `www.hia-iha.nrc-cnrc.gc.ca/main_e.html`.

ARE YOU MOVING? IS YOUR ADDRESS INCORRECT?

If you are planning to move, or your address is incorrect on the label of your *Journal*, please contact the National Office immediately:

(888) 924-7272 (in Canada)
(416) 924-7973 (outside Canada)
email: nationaloffice@rasc.ca

By changing your address in advance, you will continue to receive all issues of the *Journal* and *SkyNews*.

Feature Articles
Articles de Fond

A (Not So) Brief History of the Transits of Venus

by Daniel Hudon (hudon@bu.edu)

> "This great marvel which we have just witnessed, fellow savants (it almost takes my breath away), is nothing less than the transit of Venus!"
>
> — *Some Learned Tales for Good Old Boys and Girls,*
> Mark Twain, 1875

How is it possible to measure distances in the solar system? Today, astronomers simply bounce a radar signal off the planet Venus and calculate the distance between Earth and the Sun using Kepler's laws. But in the 18th century, astronomers had to be much more clever in their measurements. Like surveyors out to measure their surroundings, astronomers set sail around the world with a surveyor's method to measure the solar system.

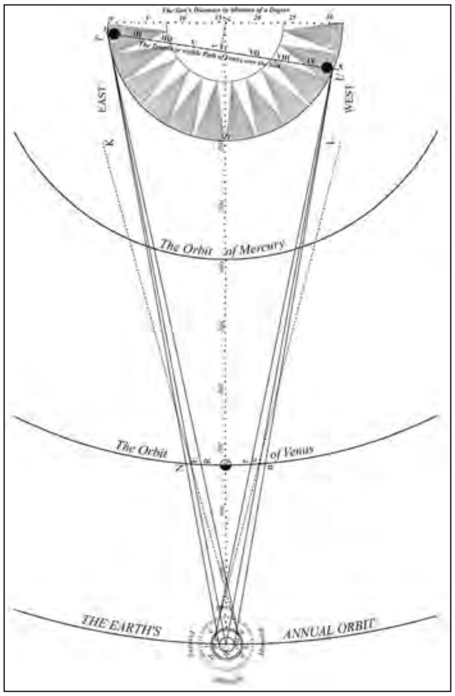


Figure 1a. — A rendition of the Transit of Venus by James Ferguson, 1778. Reprinted with permission from *The Transit of Venus: the Quest to Find the True Distance of the Sun* by David Sellers (Magavelda Press 2001).

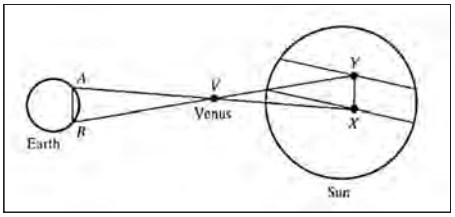


Figure 1b. — Observers at different latitudes on Earth will measure different parallel tracks of Venus across the Sun. From precise timings of the duration of the transit, the angle that the two terrestrial stations subtend at Venus can be determined, and hence both the distance to Venus and the scale of the solar system (from known orbital parameters).

The surveyor's method is called triangulation or parallax. By sighting an object from two widely separated positions and measuring how its image appears to shift against the background, the unknown distance to the object can be determined through basic geometry (see Figure 1a and 1b). It's the same as holding your thumb at arm's length: by measuring how its angular position changes first with one eye, then the other, and knowing the distance between your eyes, you can calculate the length of your arm.

However, the method can't be applied to measure the Sun's parallax directly because in the daytime, the Sun blocks out all the background stars — there's nothing to compare the Sun's position with. Could the disk of the Sun itself be used as a background? In 1629, Kepler predicted that Venus would pass directly across the face of the Sun two years hence, in 1631, and that it would just miss in 1639. Because of the tilt of Venus' orbit compared to Earth's orbit, this is a rare event — it occurs in pairs separated by eight years, with more than a century between the pairs (see Table 1 and Figure 2). After the 17th-century pair, the next wouldn't be until 1761 and 1769. Observers in this century will see transits next year, in June 2004, and 2012. No one alive has seen a transit of Venus.

Table 1

Past and Future Transits of Venus
December 7, 1631
December, 4, 1639
June 6, 1761
June 3-4, 1769
December 9, 1874
December 6, 1882
June 8, 2004
June 6-7, 2012

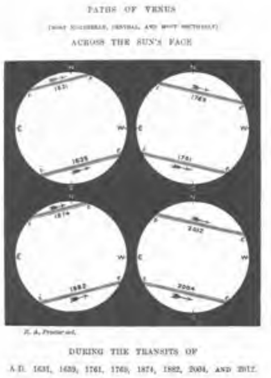


Figure 2. — Past and future transit paths (Proctor 1874).

The 1631 transit occurred when it was nighttime in Europe so there are no recorded observations. In the spring of 1639, the promising young scientist, Jeremiah Horrocks, discovered that Kepler was wrong: Venus *would* transit across the Sun that year, and in only a few weeks time (Fernie 2002). Horrocks and another Englishman, William Crabtree, were the only two people to observe the transit. They lived 30 miles apart but had never met — they communicated by letter. Both were so excited to see the small black dot of Venus dwarfed by the bright disk of the Sun that they failed to make any useful timings.

Horrocks details Crabtree's experience: "But a little before the time of sunset…the Sun breaking out for the first time from the clouds, he eagerly betook himself to his observation, and happily saw the most agreeable of all sights, *Venus* just entered upon the *Sun*. He was so ravished with this most pleasing contemplation, that he stood viewing it leisurely, as it were; and from an excess of joy, could scarce prevail upon himself to trust his own senses."[1] Indeed, the surprise must have been great, for Kepler had thought the Sun was much closer and that Venus would cover one quarter of its disk. Both Horrocks and Crabtree suddenly got an image of the immensity of the solar system. Horrocks dutifully filed a report anyway and indicated that the event could be useful for determining solar distance.

During the subsequent decades astronomy got organized. National societies formed that held regular meetings and published papers and transactions. The most important of these were the Royal Society of London and the French Academy in Paris.

Edmund Halley, an esteemed member of the Royal Society, published a paper in 1716 outlining how the upcoming transits could be used to find the Earth-Sun distance. Knowing he would probably be dead by the time of the next transits, he issued a call-to-arms to astronomers worldwide, "Therefore, again and again, I recommend it to the curious strenuously to apply themselves to this observation."[2] Halley further pointed out the desirability of making observations from multiple widely separated stations, both to improve the observations and to guard against the problem of one station being clouded out.

Under the auspices of the professional scientific societies, it was now possible to heed Halley's call and mount major expeditions. Expeditions were sent to many of the world's far-flung places: Northern Canada and Siberia, South Africa and the South Pacific, Baja, Mexico, and the Indian Ocean.

During an age when travel was decidedly less comfortable, if not downright dangerous, the scale of the expeditions was truly impressive. More than 100 astronomers participated. For those traveling by sea, the normal problems of navigational errors, monsoons, and scurvy were exacerbated by the Seven Years' War, fought between France and Britain in every hemisphere in the early 1760s. For some it was the adventure of their lives. For the less fortunate, it cost their lives.

The 18th-Century British Expeditions: Mason and Dixon's Trip to South Africa

Before gaining lasting fame for surveying the eastern United States in 1763, the British team of Charles Mason and Jeremiah Dixon set sail for Bencoolen (modern Bengkulu), Sumatra in December 1760. They gained firsthand knowledge of the hazardous state of affairs, for within hours of leaving port they were attacked by a French frigate. With 11 dead and 37 wounded, they limped back to port and promptly wrote to the Royal Society threatening to quit. Not only was the Royal Society unsympathetic, they went so far as to warn the rattled astronomers that their refusal to continue could not "…fail to bring an indelible Scandal upon their Character, and probably end in their utter Ruin."[3] For good measure, the Society added the threat of court prosecution "with the utmost severity of the Law."[4]

Mason and Dixon reluctantly capitulated and set sail again two months later when the ship was repaired, this time having at least secured an escort. As it took three months to round the tip of Africa, they decided to stop and set up their observatory at Cape Town, South Africa. The fact that Bencoolen had been captured by the French may have contributed to their decision.

On transit day, June 6, the sky was perfectly clear and Mason and Dixon obtained valuable readings. This was fortunate for the British because their other Southern Hemisphere observer, Neville Maskelyne, the Astronomer Royal, who was sent to the island of Saint Helena — located between the middle of the South Atlantic and the middle of nowhere — was completely clouded out. (Perhaps that's why Maskelyne's liquor expenses topped out at £141, nearly half his total expenditure of £292.)

Mason and Dixon stayed on at Cape Town for a while to measure Earth's gravity and the longitude and latitude of Cape Town. The precision of their geodetic work didn't go unnoticed, for two years later they were summoned to the American colonies to survey the disputed Pennsylvania-Maryland border — casting a line that bears their name to this day.

Other 18th-Century Expeditions

Transit fever reached the American colonies too. The Governor of the Province of Massachusetts gave a stirring appeal to the House of Representatives on behalf of John Winthrop, professor of mathematics and natural philosophy at Harvard, that this was a "[P]henomenon which has been observed but once before since the

---

[1] J. Donald Fernie, *The Whisper and the Vision: The Voyages of the Astronomers*, p. 10.

[2] `www.dsellers.demon.co.uk/venus/ven_ch8.htm`

[3] Fernie 1976, p. 16.

[4] Ibid.

Creation of the world."[5] Winthrop was duly equipped with observational instruments and assistants and sailed to St. John's, Newfoundland in the Province-sloop "Massachusetts" (see the recent *JRASC* article by Smith, 2003). Despite an unabating plague of "venomous" insects, the team enjoyed clear weather and made useful timings of the end of the transit (the beginning of the transit occurred before sunrise in North America).

Intrigue and adventure came in various forms during the transit expeditions. Maximilian Hell, an Austrian Jesuit and member of the French Academy, was renowned in Europe as a writer, educator, and astronomy popularizer. In 1755, he was named court astronomer by Archduchess of Austria Maria Theresa and commissioned to set up an observatory in Vienna. From there he made good observations of the 1761 transit.

For the 1769 transit, Hell was invited by King Charles VII of Denmark and Norway to lead an expedition to the island station Vardö, located near Lapland north of the Arctic Circle. On transit day, Hell and his assistants were so pleased to see the clouds part just before the transit began that they loudly celebrated afterwards by firing their ship's cannon nine times and singing a *Te Deum* in gratitude. Hell then stayed on for eight months to collect additional scientific data for a proposed encyclopedia on arctic regions.

Back in Paris, French Academy members grew impatient with Hell's delay in reporting his data and some suspected him of waiting to hear other reports so that he could adjust his data accordingly. Though greatly esteemed as scholars, academic opinion had recently turned against Jesuits because they were thought to have too much political power. The insinuations ceased for a while when Hell finally published his full observations in 1772, three years after the transit. This was a year before the Jesuit Society as a whole was suppressed and many Jesuits were expelled from their respective countries. Hell maintained his position in Vienna, but despite collecting available data and publishing the best value of the solar parallax for his time, the last two decades of Hell's life were seriously affected by the initial suspicions over his data.

The matter didn't end with Hell's death. In 1823, when Johann Encke made a comprehensive evaluation of both the 1761 and 1769 transits, discussed further below, he rejected Hell's data. Ten years later, Carl Littrow took the opportunity as director of the Vienna observatory (Hell's old position) to examine a rediscovered fragment of Hell's original data sheets. Littrow claimed at last to have found evidence that Hell erased some figures and corrected them in a slightly different coloured ink. On the strength of this purported evidence, Hell's reputation was destroyed.

It wasn't until 1883 that American astronomer Simon Newcomb, who figures prominently in the 19th-century transits, discredited Littrow's evidence and exonerated Hell. Newcomb found that Hell's changes were due to using a defective pen at the time of the observations, and further, that Littrow had been colourblind.

The 18th-Century French Expeditions: Pingré's Voyage to Roderigue

The French Academy launched several expeditions for the 1761 transit. Alexander-Gui Pingré, a prolific 50-year-old astronomer and theologian, ventured out from Paris in November 1760 to the French island of Roderigue, east of Madagascar, in the Indian Ocean. Amongst his half-ton of baggage was a letter addressed to the British Admiralty directing them not to interfere with his important expedition. At a time when first contact between warring ships was typically made by cannon fire, it's hard to see what good such a letter would do, but perhaps it provided moral support.

Pingré got off to a slow start. Arriving at port with his considerable load, the shipping agents refused to let him take so much baggage, whether it was essential astronomical equipment or not. The problem was finally rectified by the intervention of the French Academy. He was further delayed in the south seas when his ship met a hobbled French ship whose captain demanded that they escort him back to Isle de France (today known as Mauritius), a slowdown that cost Pingré six or seven weeks.

Arriving at Roderigue only a week before the transit, Pingré and his assistant worked 'round-the-clock to get their instruments in working order after the long sea voyage, using turtle oil — from the local delicacy — as a lubricant. With little time to spare, they built a crude shelter to act as an observatory. "I think there never was a more inconvenient one."[6]

No matter: on transit day it was cloudy. Undaunted, Pingré held out hope that the weather would clear. His patience paid off and he was able to obtain observations and timings for the end of the transit.

With the transit over, Pingré's much-prized letter seemed to act as a magnet for British ships because three weeks later one sailed into the harbour, sacked and looted the small settlement and took away Pingré's ship as spoils of war. Pingré was stranded until another French ship came along three months later — but not before two more British ships arrived to wreak more havoc. Finally, on his way home again, Pingré had yet another run-in with British ships that this time captured his ship and escorted him into port in Lisbon.

No doubt happy to see land again, Pingré stuck to it and finished his journey by carriage. Despite the rough ride, at least he was rid of the British. Crossing the Pyrennees into France, he noted with some exasperation in his journal that he'd been away 1 year, 3 months, 18 days, 19 hours, and 53 minutes.

Back in Paris, Pingré resumed his work at the Academy[7]. One of his main interests was the problem of determining

---

[5] Donald Fernie, *American Scientist*, Sept-Oct 1997.

[6] Angue Armitage, *The Pilgrimage of Pingré: An Astronomer-Monk of Eighteenth-Century France*, p. 51.

[7] Pingré was a free associate of the Academy. Scientists in Orders were barred from ordinary membership.

the longitude of a ship at sea. In 1767, he made a two-month voyage with the famed comet-hunter, Charles Messier, to test a new marine chronometer. Subsequently, he tested another chronometer on a much longer voyage to Santo Domingo in what is now the Dominican Republic. From there he observed the 1769 transit of Venus at a picturesque coastal mountain site. With this data, he was able to calculate one of the better values for the solar parallax from that period.

The 18th-Century French Expeditions: Chappe's Journeys to Siberia and Mexico

For widescreen cinematic drama, few expeditions can match that of Jean Baptiste Chappe d'Autoroche who undertook a 4000-mile trek to Tobolsk, Siberia, in the dead of winter. A gifted Jesuit with a great enthusiasm for astronomy, Chappe gained a reputation as a skilled scientist beginning at the age of 25 when he observed a transit of Mercury at the Paris Observatory with another French astronomer, J.B. le Gentil (whose considerable adventures are detailed further below). Tobolsk was chosen because from there the transit would have the shortest duration (Van Helden 1995). Chappe's plan was to travel east from Paris to Vienna, then northeast through Warsaw to St. Petersburg and finally across the vast Russian steppes.

Chappe might have dreamed of today's superhighways and automobiles with shock absorbers because during the eight-day journey by carriage to Strasbourg, near the German border, all of his thermometers and barometers were shattered and the carriages were damaged. While the carriages were being replaced, Chappe industriously made himself a new set of instruments.

To avoid a repeat of that ordeal, when he got to Ulm, Germany, he switched modes of transport and took a boat down to Vienna. There he met and discussed transit problems with the astronomer Hell who was making his own preparations to observe it there. Upon reaching Warsaw, he again switched modes of transport, this time to horse-drawn sleds and made good time to St. Petersburg, arriving by mid-February.

But his Russian colleagues feared he wasn't coming and had sent their own observers on ahead. Aware of the scientific urgency of the expedition, and the onrushing spring, they quickly outfitted Chappe with an interpreter, guides, new giant sleds drawn by five horses abreast, plus supplies and provisions for his stay at the remote outpost. In early March, Chappe was off again. A vivid imagining is given by Donald Fernie: "One can picture them racing for the Urals through the silence of the frozen countryside, great clouds of snow rising from the horses' flying hooves."[8] Had *Dr. Zhivago* been about an astronomer, this would have been a pivotal scene.

It was a month of steady winter travel, often overnight, with sleep gained *en route*. Chappe wrote that it was anything but a smooth ride: "had very little rest, on account of the frequent shocks and overthrows I met with."[9] Other problems included his guides' daily complaints about the rapid pace — Chappe often bribed them along with brandy. Through sheer determination, Chappe beat the thaw — and the prospect of being mired forevermore in the Siberian mud. They rumbled into Tobolsk on April 10, 1761.

Chappe got to work immediately and set up his observatory on a mountain out of town. He must have been pleased to get settled and started on his scientific program. Soon he determined the longitude and latitude of his observatory, crucial data for the transit observations.

However, trouble now came from the spring thaw. This year it was unusually early and severe, and the two local rivers flooded the town. The superstitious townspeople acted accordingly: they blamed the foreign astronomer for messing with the Sun. To quell the rising mob, the local Governor posted guards for both Chappe and his observatory.

The day before the transit, Chappe had everything ready and he took a moment to reflect on the situation: "The sky was clear, the Sun sunk below the horizon, free from all vapors; the mild glimmering of twilight, and the perfect stillness of the Universe, completed my satisfaction and added to the serenity of my mind."[10]

But the perfect weather didn't last. By 10 p.m., the sky was completely clouded over. Naturally, Chappe feared his heroic expedition — and his honour in participating in this rare event — was now in jeopardy and he grew increasingly despondent. He wrote: "In these dreadful agitations I passed the whole night; I went out and came in again every instant, and could not continue a moment in the same position."[11]

In the morning, Chappe's hopes were revived as the clouds began to disperse. The gradual improvement in the sky seemed to affect his very being: "a pleasing satisfaction diffused itself through all my frame, and inspired me with a new kind of life…everything seemed to rejoice at the return of a fine day…and as my hopes became more sanguine, the joy of my mind was still more complete."[12] The governor and the archbishop came to visit, but the rest of the townspeople shut themselves up in their houses or in the churches.

Chappe's luck with the weather continued to improve and at last he was ready: "I stood fixed with my eye to the telescope, wandering over the immense space between us and the Sun a thousand times in a minute…. The moment of the observation was now at hand; I was seized with an universal shivering, and was

---

[8] Donald Fernie, *The Whisper and the Vision: The Voyages of the Astronomers*, p. 34.

[9] Jean-Baptiste Chappe d'Autoroche, *A Journey to Siberia,* p. 46.

[10] Ibid., p. 80.

[11] Ibid., p. 82.

[12] Ibid., p. 82.

obliged to collect all my thoughts in order not to miss it."[13] From there, things seemed to go well, and Chappe made good observations.

Chappe dispatched his data back to Paris days later via mounted courier and stayed on another couple of months to make additional observations of the region. He took a leisurely trip back to France, and a glimpse into his character is seen from his visit to Echaterinenburg, where he stopped to make some observations. Evidently smitten with one of the local women, he hired a band and threw a party, hoping to gain her attention. Unfortunately, he doesn't report on the outcome of the event. Chappe also spent some time in St. Petersburg and finally arrived back in Paris in November 1762.

By the time of the next transit in 1769, Chappe wanted to go somewhere different — likely somewhere tropical. He decided on Baja, Mexico. After nearly three months at sea crossing the Atlantic, a lengthy hike across the breadth of Mexico (in which Chappe and his colleagues travelled by litter), and a three week voyage across the Gulf of California in which they were becalmed and saw their food, water, and time run perilously short, Chappe's team at last arrived at a small village on the tip of Baja on May 19. As the village was suffering from an epidemic of yellow fever, they took a considerable risk when they decided to stay there. Chappe thought they wouldn't have time to find a new location and went ahead with the preparations. It was a costly decision.

Chappe recorded the following in his journal: "Myself and all my train took up our abode in a very large barn. I had half the roof taken off towards the south, and put up an awning, that could be spread out or contracted at will. All my instruments were fixed just as they were to stand to observe the transit of Venus. The weather favored me to my utmost wish. I had full time to make accurate and repeated observations for the setting of my clock. At last came the third of June, and I had the opportunity of making the most compleat [sic] observations."[14]

This was his last journal entry. In the days after the transit, he cared for his colleagues who had caught the deadly disease until he too fell ill. Despite fits of pain and fever, Chappe rallied himself to view a lunar eclipse on June 18, as an independent longitude determination. The epidemic that claimed three-fourths of the village also claimed Chappe on August 1. Only one member survived to bring the data back to Paris.

Chappe's team gathered some of the best data of all and his words from the earlier 1761 transit have a lingering poignancy, "Pleasures of the like nature may sometimes be experienced; but at this instant, I truly enjoyed that of my observation, and was delighted with the hopes of its being still useful to posterity, when I had quitted this life."

The 18th-Century French Expeditions: Le Gentil's Epic Voyages

If Chappe's previous sled journey across frozen Siberia was a scene from a cinematic epic, then the voyage of Guillaume Le Gentil (full name: Guillaume-Joseph-Hyacinthe-Jean Baptiste le Gentil de la Galasière) to the Indian Ocean was a comedy of errors and a bounty of bad luck. As Helen Sawyer Hogg wrote once in this *Journal,* it "is probably the longest lasting astronomical expedition in history. In fact, it is quite possible that, except for interplanetary travel, there will never be astronomical expeditions to equal in duration and severity those made for that particular pair of transits."[15]

Le Gentil, a young member of the French Academy, set out from Paris on March 26, 1760, for Pondicherry, on the east coast of India, a full 14 months in advance of the transit. He intended to sail around the southern tip of Africa — the Cape of Good Hope — to Isle de France where he would catch another boat for India. Little did he know how familiar he was to become with Isle de France. He arrived there in July 1760, after a four-month voyage, and learned that because war had flared up between the French and British at Pondicherry, no boats were travelling there. So he waited. Six months later, he was still waiting. Just as he was about to give up and join Pingré in Roderigue, a few hundred miles to the east, a French frigate arrived on February 19, 1761 bound for the coast of India. Local officials assured Le Gentil that despite the monsoon winds, the ship would easily make it to the coast of India within two months — plenty of time to make preparations for the transit. Le Gentil decided to chance it.

Initially, they made good progress but soon the favourable winds abandoned them and they were blown away off course. Le Gentil wrote in his journal, "[W]e wandered around for five weeks in the seas of Africa, along the coast of Ajan, in the Arabian seas."[16] In other words, they wandered everywhere except towards their destination.

Finally, on May 24, they came within sight of Mahé, on the west coast of India, directly across from Pondicherry. Here they received news from another ship that Pondicherry was now in English hands. To Le Gentil's "great regret," the captain decided to return to Isle de France. Consequently, when transit day (June 6) arrived, Le Gentil was aboard a rolling ship in the middle of the Indian Ocean, unable to make any reliable observations. He dutifully observed the transit and measured his longitude and latitude but knew full well that his data was useless.

Rather than make the long journey back to France, Le Gentil was determined

---

[13] Jean-Baptiste Chappe d'Autoroche, *A Journey to Siberia*, p. 83.

[14] Doyce B. Nunis, *The 1769 Transits of Venus*, 1982.

[15] Helen Sawyer Hogg, *Out of Old Books: Le Gentil and the Transits of Venus, 1761 and 1769,* Journal of the Royal Astronomical Society of Canada, volume 45, p. 37, 1951.

[16] In Sawyer Hogg 1951, p. 41 and Fernie 1976, p. 42.

to make some useful scientific observations of the region. He writes, "I resolved then not to leave the Indian Ocean until this time [after the next transit in 1769], to make all the observations I could on geography, natural history, physics, astronomy, navigation, winds, and tides."[17] Indeed, 18th-century scientists were much more broadly trained than those of today. After a few years of this work, he began to think about the next transit. According to his calculations, the best place to observe the transit would be in Manila, Philippines.

He dashed off a letter to the French Academy informing them of his intentions and caught the next boat for Manila. His satisfaction at moving on was evident in his journal: "I finally left the Isle de France May 1, 1766, quite resolved to say good-bye forever to that island."[18] He was soon to learn, however, that sometimes personal resolve just isn't enough.

Le Gentil arrived in Manila in August 1766 and began getting settled. Though the climate appeared promising, Le Gentil soon had doubts because the Spanish governor was not kindly disposed towards the French and, on top of that, he ran the place like a tyrant. Le Gentil's doubts became genuine worries when letters of introduction from the French Academy arrived in July 1767; the governor rejected them as forgeries, saying that 14 months was too short a time to receive a reply to his letter.

An additional letter noted that Pingré, now safely returned to Paris — and perhaps wishing further seagoing adventures for his colleague — thought that Pondicherry would be a better site for observing the transit than Manila. By this time, Pondicherry was back in French hands, so, rather than expose himself further "to the caprice of him who governed,"[19] Le Gentil decided to have another attempt at viewing the transit in India. After all, he wrote, he was now a veteran traveller: "Sea voyages no longer cost me anything, I had become so familiar with this element."[20]

He embarked on a Portuguese vessel and was soon on his way to India again. *En route*, he mediated an argument between the ship's pilot and captain and took over the helm himself. Nevertheless, he described it as the finest of voyages and reached Pondicherry in a mere 32 days.

Le Gentil arrived at Pondicherry on March 27, 1768. The Governor welcomed him with a feast that very night; it seemed he'd made the right decision. The next day, the Governor invited him to choose a spot for his observatory; he chose a partially ruined palace (thanks to the British), that, aside from being well situated, still had a large gunpowder magazine in its basement.

Over the months, Le Gentil occupied himself by studying Indian astronomy and local customs. From Pondicherry, the transit was to be visible first thing in the morning on June 4. As the clear mornings of May passed, Le Gentil was nearly beside himself with impatience. The night before the transit was perfectly clear and Le Gentil observed the satellites of Jupiter with the Governor, using a telescope sent by the now-friendly British at Madras.

But his good fortune couldn't last. He awoke at 2 a.m. and "saw with the greatest astonishment that the sky was covered everywhere, especially in the north and north-east, where it was brightening; besides there was a profound calm. From that moment on I felt doomed, I threw myself on the bed, without being able to close my eyes."[21]

From there, his journal contains a long passage that would be familiar to anyone trying to observe a particular astronomical event. He veers back and forth between "hope and fear" that the winds would change and clear the clouds from the sky. Instead, the weather got worse. A freak squall blew in, piling the clouds together and completely obscuring the Sun when it rose. When the transit was over, the winds calmed and the sky cleared — the Sun shone brilliantly for the rest of the day.

Le Gentil was so stupefied at his misfortune that it seems only fair to quote him at length.

"That is the fate that often awaits astronomers. I had gone more than ten thousand leagues [30,000 miles]; it seemed that I had crossed such a great expanse of seas, exiling myself from my native land, only to be the spectator of a fatal cloud which came to place itself before the Sun at the precise moment of my observation, to carry off from me the fruits of my pains and of my fatigues….

"I was unable to recover from my astonishment, I had difficulty in realizing that the transit of Venus was finally over…. At length I was more than two weeks in a singular dejection and almost did not have the courage to take up my pen to continue my journal; and several times it fell from my hands, when the moment came to report to France the fate of my operations…."[22]

To make matters worse, he soon learned that the skies had been clear in Manila that day!

Now, Le Gentil wanted nothing more than to return to Paris. In the world of Le Gentil, this was easier said than done. His departure from Pondicherry was delayed by a recurring fever and dysentery that prevented him from travelling. He finally left Pondicherry, still ill, in March 1770, making it only as far as his former home-away-from-home, Isle de France, where he decided he was too ill to continue. Here, his spirits were further dampened by the death of an astronomer named Veron, whom he'd met in India. Incidentally,

---

[17] In Sawyer Hogg 1951, p. 42.

[18] In Sawyer Hogg 1951, p. 43 and Fernie 1976, p. 43.

[19] In Sawyer Hogg 1951, p. 90.

[20] Ibid.

[21] In Sawyer Hogg 1951, p. 131 and Fernie 1976, p. 48.

[22] In Sawyer Hogg 1951, p. 132 and Fernie 1976, p. 49.

Veron had suffered the same misfortune as Le Gentil for the 1761 transit — finding himself stuck at sea. Le Gentil described his death as "from a fever which he had acquired by his great zeal to observe throughout the night on land when he was at the Moluccas."[23]

By July, Le Gentil thought he was finally fit for travel and more than ready to leave Isle de France for good. But it wasn't until November that a ship was ready to take him. Two weeks into the voyage, the ship met a hurricane that took down parts of its main masts. Unable to continue, the ship hobbled back to Isle de France. As if returning to the island wasn't bad enough, here Le Gentil received news that his heirs were spreading rumours of his death and that the only thing holding up their taking possession of his estate was a death certificate.

With renewed determination, he left Isle de France on March 31, 1771 on a Spanish frigate. Around the Cape of Good Hope, the ship met "tempests upon tempests" but Le Gentil wrote that "My sole worry in the midst of all these storms was the fear of being forced to see again the Isle de France."[24]

But the Spanish sailors were more than capable and the ship arrived in Cadiz, Spain on August 1, 1771. Le Gentil finished his journey on land, like Pingré before him, and crossed the Pyrennees on October 8. It was an absence of eleven years, six months, and thirteen days.

Le Gentil's return was not entirely happy. He immediately had a lengthy court battle to regain part of his estate that had been lost due to a careless manager, and he'd lost his seat at the French Academy — on whose behalf he'd taken his journeys in the first place.

On the positive side, he gained some satisfaction from "hearing people recognize me and attest loudly that I was really alive."[25] He married, had a daughter, and took up a quiet life writing his memoirs. Having met many untimely tempests in his life, he mercifully died in 1792, months before the great storm of the French Revolution descended upon Paris.

Everyone seemed to fare better in the 1769 transits than poor Le Gentil. Mason and Dixon, who got off to such a rotten start in 1761 for the Royal Society, stayed closer to home for the 1769 event. They split up, with Mason venturing to Ireland and Dixon to northern Europe and viewed it without incident. The Royal Society sent out other expeditions, including that of William Wales to Hudson's Bay, and the most famous of all, that of Captain Cook and the *Endeavour,* both described below.

The 18th-Century British Expeditions: William Wales' Expedition to Hudson's Bay

Having heard about all the adventures in 1761, William Wales, who had recently computed lunar navigation tables for Neville Maskelyne's *Nautical Almanac* volunteered to observe the 1769 transit for the Royal Society as long as the destination was warm and not too far out of the way. Naturally, he got the opposite. He was sent to Fort Churchill, on the Hudson's Bay, known even then as the Polar Bear capital of the world.

As the shipping routes to the Hudson's Bay would be frozen solid until early summer, it was necessary for Wales and his assistant, Joseph Dymond, to sail in late-spring 1768 and winter over in Churchill. An agreement with the Hudson's Bay Company was reached to drop the astronomers off and pick them up a year later. The journey across the North Atlantic was unremarkable until they got to the Hudson Straits where the fog was exceedingly thick. When it lifted, Wales spent much time counting ice floes: one day 32, another 58.

Upon arrival in Churchill, August 10, 1768, Wales writes about the "intolerably troublesome" hordes of "moschettos" and sand-flies: "There are continually millions of them about one's face and eyes, so that it is impossible either to speak, breathe, or look, without having one's mouth, nose, or eyes full of them."[26]

For the first month, Wales and Dymond busied themselves with building their observatory and making it secure for the winter. Once that was done, Wales ceased keeping a journal "except of the weather…which is, in reality, the only thing we have to keep a journal of here in the winter season,"[27] giving an indication of how little they had to occupy themselves.

Wales gives additional details in some "short memorandums," where he writes of proudly donning his "winter rigging," decking himself out head to toe in furs furnished by the Hudson's Bay Company[28] and of sleepless nights due to the loud cracking of the cabin boards under the stress of the frost. Though the aurorae were unimpressive that year, the nights were cold enough to ice over a half-pint of brandy left in the open air in five minutes. By February, the bedboards dripped with icicles. Even so, when the clouds of "moschettos" returned in the summer, Wales began to think that winter was "the more agreeable part of the year."[29]

After more than a year of preparation and waiting, transit day, June 3, dawned partly cloudy. At noon, the transit began and the two astronomers differed in their initial contact times of Venus on the disk of the Sun by 11 seconds, a result that was a great disappointment to Wales. They stayed in Churchill another three months before sailing back to England, with the great comet of 1769 (discovered

---

[23] In Sawyer Hogg 1951, p. 133 and Fernie 1976, p. 50.

[24] In Sawyer Hogg 1951, p. 174.

[25] In Sawyer Hogg 1951, p. 177 and Fernie 1976, p. 53.

[26] Helen Sawyer Hogg, *JRASC*, volume 42, p. 158; and Fernie 1976, p. 20.

[27] In Sawyer Hogg 1952, p. 159.

[28] Unfortunately, these were all confiscated by customs officials on his return to England.

[29] In Sawyer Hogg 1952, p. 192 and Fernie 1976, p. 24.

by Messier) visible in the night sky. Robbed of favourable winds in the English Channel, they made the final leg of the trip to London via stagecoach.

Back home, Wales was so distressed by his transit observations that he refused to submit them to the Royal Society because they were inaccurate. However, the Society would not be denied. In March 1770, Wales presented his results to the members of the Society and read a 50-page manuscript of his journal excerpts detailing the various botanical, climatic, and scientific information he obtained. Happily, he was applauded for his efforts and now on his way to warmer climes: Captain Cook recruited him to act as navigator for Cook's second and third voyages around the world. Wales then finished his career as a mathematics teacher in London and taught the likes of Samuel Taylor Coleridge and Charles Lamb (Fernie 2002). In his essay, *Recollections of Christ's Hospital,* Lamb describes his schoolmaster, "There was in William Wales a perpetual fund of humour, a constant glee about him, which heightened by an inveterate provincialism of north-county dialect, absolutely took away the sting of his severities."[30] Despite all the "moschetto" stings, Wales seems to have enjoyed his tenure as a world traveller and it is tempting to wonder how much of Coleridge's *Rime of the Ancient Mariner* was inspired by Wales' stories.

The 18th-Century British Expeditions: Lieutenant Cook's Voyage to Tahiti

For the Royal Society, the 1769 transit of Venus coincided perfectly with their plans to explore the South Pacific. Alexander Dalrymple, among others, was certain that it hid another continent, *Terra Australis Incognita,* the unknown southern land. The idea of such a place had lurked in geographers' minds since Ptolemy had put it on his map in his *Geography*. But an exploratory expedition, with the aim of claiming newly discovered lands for Britain, would surely raise the suspicions of the other European powers. The transit was the perfect ruse.

The Royal Society proudly proclaimed that the transit would benefit navigation, knowing full well that the size of the Solar System had nothing whatsoever to do with getting ships around the Earth. However, as navigation went before shipping, trade and profits, such boosterism was the only way to secure funding from the government for the expedition. Then, the Royal Society wrote a spirited, patriotic letter to their patron, King George III, about the importance of the observations. The King was good enough to chip in with the requested £4000 (equivalent to about £300,000 today).

The Royal Navy agreed to loan a ship for the expedition but refused to have it be commanded by a mere civilian. For his part, Dalrymple refused to be a mere passenger and thus withdrew from the entire expedition. Desperate to find a commander for their ship, the Navy cast about until a man who had at least two things going for him was nominated. He had charted the Gulf of St. Lawrence and had submitted observations to the Royal Society of a solar eclipse seen from Newfoundland (to better determine its longitude). The man was James Cook.

Here the Navy hit an embarrassing snag because Cook was not a commissioned officer. Did they have no one of higher ranks, with some astronomical abilities, who could lead the expedition into uncharted waters? Apparently not. So, Cook was promoted to lieutenant — not to captain, that only came later — and given command of the *HMS Endeavour.*

The official astronomer was Charles Green, an assistant at Greenwich (and brother-in-law of William Wales) adept at finding longitude at sea solely based on observations of the Moon and stars. He sailed with Neville Maskelyne in 1763-4 to Barbados to test John Harrison's fourth marine chronometer — the device that finally solved the problem of determining longitude at sea. Interestingly, by the time the *Endeavour* sailed in August 1768, similar chronometers were still very expensive and the ship went without.

The *Endeavour* carried another scientist, Joseph Banks, a young aristocrat who was devoting his life to science, particularly botany. Banks, a formidable personality, travelled with an entourage of assistants, including two illustrators for his botanical samples. He later became President of the Royal Society and dominated science in late 18th-century England.

At sea, Green was dismayed to find out none of the naval officers knew the lunar observations method for determining longitude. For four years, the Royal Greenwich Observatory had been publishing the *Nautical Almanac*. What was the point of publishing it, he grumbled, when naval officers didn't know how to make appropriate observations. However, when shown, Cook quickly mastered the method. Evidently, Cook's reputation for knowing the precise whereabouts of his ship was due in part to Green who enthusiastically took lunar observations at any opportunity.

The *Endeavour* sailed west down the length of the Atlantic in nearly four months, took four attempts to cross the tumultuous Strait Le Mare at the tip of Tierra del Fuego and passed Cape Horn on January 25, 1769.

As part of the purpose of the expedition was to find *Terra Australis*, Cook now sailed in a northwest direction, contrary to the winds and currents. The days passed on and no unknown continents were sighted. In his journal, Banks took a jab at armchair philosophers like Dalrymple: "It is however some pleasure to be able to disprove that which does not exist but in the opinions of theoretical writers, of which sort most who have wrote [sic] anything about the seas without having themselves been in them. They have generally supposed that every foot of sea which they believed no ship had passed over to be land, though they had little or nothing to support that opinion but vague reports."[31]

---

[30] Charles Lamb, *Recollections of Christ's Hospital*.

[31] J.C. Beaglehole, *The Endeavour Journal of Joseph Banks,* p. 240.

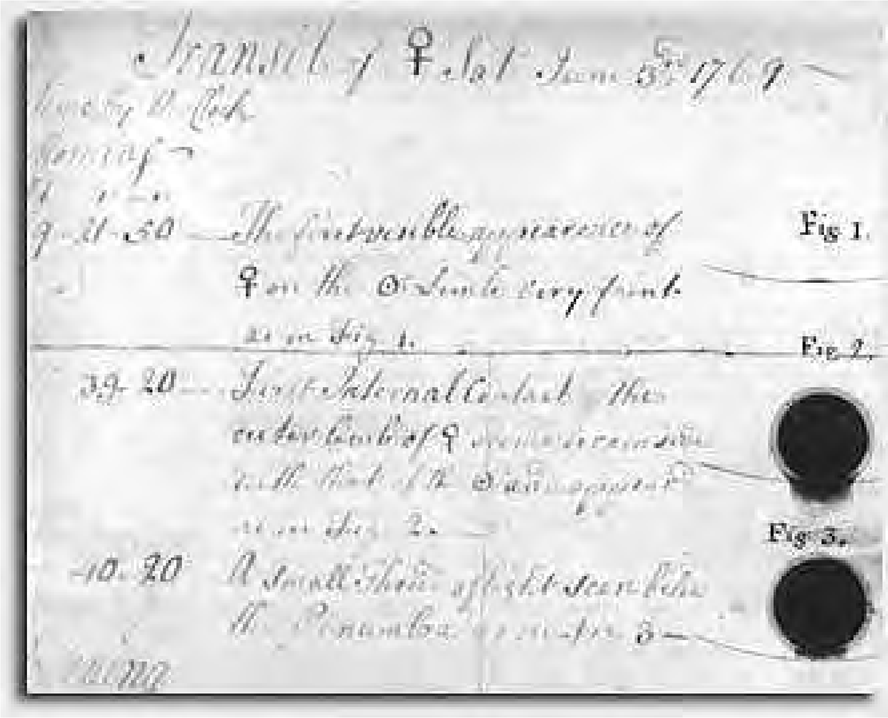


Figure 3. — Excerpt from Cook's journal showing the "black drop" effect. Copyright James Cook University.

After three months on open water the mountains of Tahiti were sighted and the *Endeavour* landed at Matavia Bay on April 13, 1769. Before going ashore, Cook issued a set of rules to his men in order to promote the best relations with the island's inhabitants. Foremost on the list was cultivating a friendship with the locals, while other rules regulated trade and responsibility. The last rule prohibited the exchange of "Iron, or anything that is made of Iron…for anything but provisions."[32]

This last rule was necessary to literally keep the ship together. The Tahitians were a metal-less culture and thus held metal objects, such as nails, scientific instruments, and tools, in extraordinarily high regard. According to sailors on the *Dolphin,* which had landed in Britain just before the *Endeavour* sailed, Tahitian women were beautiful and uninhibited. They would trade sexual favours for a simple iron nail — the very things that held wooden ships together. For men at sea months on end, such a price was so beguiling that they nearly pulled the ship apart to procure the costs of love. Cook wasn't about to jeopardize the rest of his expedition over these dalliances and thus took the necessary steps to protect his ship.

Soon after arrival, Cook and Green observed the moons of Jupiter to establish the longitude of Tahiti. Then, they set about building their observatory, which they located at the northernmost end of the bay. As the transit was the ostensible *raison d'être* for the expedition, Cook didn't want to take any chances with instruments going missing, or worse, an uprising, and thus had a fort built around the observatory.

However, on May 2, a month before the transit, when the instruments were brought into the finished observatory, the sturdy case for the astronomical quadrant was opened and found to be empty. Where was it? Because it had only been brought ashore on the previous day and placed in Cook's tent, no one could figure out how it could have gone missing. Normally diplomatic, Cook became livid because the instrument was crucial to the transit observations. He immediately sealed the bay so that no one could escape by canoe.

Meanwhile, Green and Banks, who had already developed some rapport with the Tahitians, made some discrete inquiries and were soon hot on the trail. They recovered one piece of it and this time it was Banks who became livid because the thief had clearly taken apart the quadrant and the likelihood of damage, or of not recovering all the pieces, was great. In front of a gathered, chattering crowd, he took out his two pistols to show his firepower. The demonstration had the desired results and the quadrant was returned piece by piece. Green confirmed that only minor pieces were now missing, and that it could be made operable again. Upon return, the two scientists found in the confusion of suspicion and search parties, a chief had been taken into custody. Cook immediately released the man and days later made amends by presenting him with an axe.

As the transit day drew near, Green and Cook made final preparations while keeping an eye on the weather. They'd had a mix of sunny and cloudy days and were understandably concerned. Cook dispatched a small party to a nearby island to improve their chances of success.

Luckily, on June 3, the Sun broke through the dawn haze and, according to Cook, "[the] day proved as favourable to our purpose as we could wish. Not a cloud was to be seen the whole day…."[33]

When the transit began, the team made an important discovery: "We very distinctly saw an Atmosphere or Dusky shade round the body of the planet, which very much disturbed the times of the contact, particularly the two internal ones."[34] Side by side and using telescopes

---

[32] Peter Aughton, *Endeavour,* p. 65.

[33] W.J.L. Wharton, *Captain Cook's Journal,* p. 76.

[34] Ibid. In fact, the atmosphere of Venus was first discovered by the Russian astronomer Lomonosov during the 1761 transit, though his priority wasn't established until 150 years later when one of his papers was translated into German.

of the same power, Cook and Green "differed from one another in observing the times of the contact much more than could be expected."[35]

This became known as the "black drop effect" (see Figure 3) and despite all the 1761 observations, neither Cook nor Green seems to have expected it. Due to Venus' atmosphere, contact with the Sun's disk was not distinct — it appeared like an oil drop that wouldn't fully detach from its source — making it difficult to obtain precise timings. Consequently, they knew their results were suspect. After such a long voyage, Cook was inevitably disappointed in the outcome of its primary purpose.

There was further intrigue that day. During the observations, the ship's storeroom was broken into and a large quantity of nails was stolen. Evidently, the transit provided enough distraction for other sorts of pursuits. Cook turned a blind eye to the fraternization between his crew and the local women for the sake of morale but he couldn't ignore thievery. When one sailor was caught with some nails on him that day, he suffered two dozen lashes as punishment.

Now it was time to complete the expedition. After three months on Tahiti, the *Endeavour* raised anchor and set sail on July 13, 1769. Though Cook nearly lost two men to desertion (and took extreme measures to have them returned), he gained one, a local chief and priest named Tupia. The wealthy Banks agreed to take responsibility for him in England, reasoning, in his most aristocratic way, that he could keep him as a curiosity in the same way his neighbours kept lions and tigers. Tupia proved useful as an ambassador while the *Endeavour* explored nearby islands.

At sea again, the *Endeavour* was now to continue its search for the unknown continent — there were even sealed secret instructions from the Admiralty, which Cook now opened. From Tahiti, he was to sail south to 40° latitude and then westward until he either hit the unknown continent or New Zealand.

Like William Wales and Joseph Dymond on their journey home, they observed the great comet of 1769; Cook claimed its tail was an astonishing 42°! Tupia saw it as a harbinger of war and feared his people would be invaded by those of a nearby island.

After days and weeks on the open seas, a stir of excitement was caused when land was sighted. Could it be the unknown continent? No, it was New Zealand. The *Endeavour* had removed the unknown continent from another large chunk of uncharted ocean.

On November 9, Green and Cook observed a transit of Mercury from New Zealand and used it to calculate their longitude. The *Endeavour* spent four months charting New Zealand then Cook ventured west to the coast of Australia where he had not one but two harrowing run-ins with the Great Barrier Reef. The ship limped all the way to the nearest large port, Batavia (modern Jakarta, Indonesia) for repairs.

By insisting on fresh food and water for his crew whenever possible, Cook had done more than any commander before him to keep his crew healthy and to keep scurvy at bay. However, he couldn't combat the diseases contracted at Batavia: malaria and dysentery. Seven crew members died during the month-long stay and another 23 died in the voyage across the Indian Ocean to Cape Town, South Africa, where the ship landed on March 14, 1771. Included in the unfortunate death toll was Charles Green, who had been battling health problems over the many months at sea.

On April 29, Cook recorded the longitude in his log with the comment, "[have] now Circumnavigated the Globe in a West direction."[36] Two months later, on July 13, 1771, three years after beginning its voyage, the *Endeavour* returned to England. Upon return, Banks began his own grand tour of the salons of London, telling all and sundry of his numerous botanical discoveries. Consequently, newspaper reports wrote about the voyage as Banks' own expedition, barely mentioning Cook and his many navigational triumphs.

Table 2
A Range of Solar Parallax Values and the Corresponding Earth-Sun Distance

Solar Parallax (arcsec)	Earth-Sun distance (km)	Earth-Sun distance (miles)
8.3	158,500,000	98,500,000
8.4	156,600,000	97,300,000
8.5	154,800,000	96,200,000
8.6	153,000,000	95,000,000
8.7	151,200,000	94,000,000
8.8	149,500,000	92,900,000
8.9	147,800,000	91,800,000
9.0	146,200,000	90,800,000
9.1	144,500,000	89,800,000
9.2	143,000,000	88,800,000
9.3	141,500,000	87,900,000

Tallying Up I

The 18th-century transit expeditions were truly an impressive effort. More than 120 observers from 62 separate stations around the world observed the 1761 transit, while the 1769 transit was recorded by 138 observers from 63 stations (Woolf 1953). Once the data from the transits was published, it was analyzed time and again by astronomers as they tried to find the best value. For the 1761 expeditions, the range of the solar parallax was 8.3″ to 10.6″ (Dick *et al.* 1998; and see Tables 2 and 3), considerably larger than expected. The range was marginally reduced for the 1769 transits, in which values ran from 8.43″ to 8.80″. The French astronomer Lalande combined data from the two transits to obtain a range of 8.55″ to 8.63″, corresponding to a distance of 153 ± 1 million kilometres (Pogge 2003). Halley had thought the method would produce a precision of 1 part in 500, so this error, a factor of three larger than expected, was cause for disappointment.

Many papers were published with mean values determined from different pairs of stations. But it wasn't until the mathematician Karl Friedrich Gauss came

---

[35] W.J.L. Wharton, *Captain Cook's Journal,*

[36] Ibid.

Table 3
Some Transit of Venus Observations

Observer	Date	Parallax Error (arcsec)	Mean Earth-Sun Distance Error (km)	Mean Earth-Sun Distance Error (miles)
Lalande 1769 transit	1771	8.55 to 8.63	153,900,000 to 152,400,000	95,600,000 to 94,700,000
Pingré 1769 transit	1772	8.80	149,500,000	92,885,000
Encke 1761 and 1769 transits	1824	8.5776	153,400,000	95,250,000
Harkness 1882 transit, American photos	1891	8.842 (0.0118)	148,788,000 (199,600)	92,455,000 (123,400)
Newcomb 1761 and 1769 transits	1891	8.79 (0.051)	149,700,000 (868,000)	93,000,000 (540,000)
Stone 1882 transit, British and Canadian results		8.832	148,957,000	92,560,000
Newcomb, system of constants	1895	8.800 (0.0038)	149,500,000	92,898,000
Modern IAU system of constants	1976	8.794148 (0.000007)	149,597,870.691 (0.030)	92,955,859

Adapted from Dick *et al.* (1998). Except for the final value, errors are "probable errors," which are 74% of the "mean error" or "standard error" used today.

up with the method of least squares early in the 19th century that the heaps of data could be reliably analyzed (Fernie 1976). In 1824, Encke used this method to obtain a value of 8.5776″ for the two transits (Dick *et al.* 1998), equivalent to 153.4 million kilometres. This value stood for a quarter century when new lunar motion measurements indicated that it was too large. The solar parallax would have to be measured again.

The 1874 and 1882 Transits

Mid-century, Astronomer Royal G.B. Airy called the measurement of the Earth-Sun distance "the noblest problem in astronomy"[37] and immediately set out a plan for observing the next transit of Venus in 1874. Soon, transit fever caught on around the world and it became a matter of national pride to participate in the observations. According to Agnes Clerke, in her book *A Popular History of Astronomy in the Nineteenth Century,* "Every country which had a reputation to keep or to gain for scientific zeal was forward to cooperate in the great cosmopolitan enterprise of the transit." Consequently, Russia led the way with twenty-six expeditions, Britain twelve, the United States eight, France and Germany six each, Italy three, and Holland one (Dick *et al.* 1998). New this time around was an opportunity to use the nascent technique of photography.

In 1874, Father S.J. Perry led a British team of observers to Kerguelen Island, a damp, chilly, windswept, and altogether uninviting island that lies in the southern Indian Ocean, closer to Antarctica than to either South Africa or Australia. Discovered by the French explorer Yves de Kerguelen-Trémarec in 1772, it often goes by a nickname given it by Captain Cook, who stopped there on his third voyage around the world: Desolation Island. Until a scientific base was set up there in 1950, this remote, inhospitable island was home only to seals and penguins.

Perry was director of Stonyhurst Observatory, near Manchester, and gained respect from his contemporaries for his sunspot studies and his geodetic and magnetic work (Ashbrook 1966). His expedition left England in May 1874 in two ships, the V*olage* and the *Supply,* seven months before the December 9 transit.

The team gathered in Cape Town where the naval lieutenants, according to instructions by Airy, made a series of practice observations. In addition to visual timings, they were to make photographic observations, so the four assistants had their hands full with learning wet-plate and dry-plate photography. They rehearsed for two months before venturing on to Kerguelen Island on October 8, 1874.

In his journal, Perry recorded his first bleak impressions of the island: snow "as far as the eye could see." Because spring was still lingering in the Southern Hemisphere they had "pleasant prospects of rambles in snow-shoes over rugged hills and half-frozen marshes and bogs."[38]

Upon landing at Morbihan Bay, the party unloaded 600 crates of equipment and erected huts for living in and shelters for the instruments. Weather was a big concern — the average cloudiness was 75% in December — so Perry sent two teams to secondary sites around the bay to improve their chances of success. Lieutenant Cyril Corbet led one team and

---

[37] Steven J. Dick *et al.* 1998, p. 226.

[38] Joseph Ashbrook 1966, p. 341.

Lieutenant Goodridge another.

Like Chappe, Le Gentil, and Wales before him, Corbet kept a journal giving us a vivid and colourful glimpse of the drama of the event. After making longitude and latitude measurements of their station, Corbet recorded the conditions: "We got a few observations in the evening, but it was terrible work in the high winds — lamps flickering and blowing out, couldn't hear the ticks of the clock or anything."[39]

At a mere 24 years of age, Corbet was already a Fellow of the Royal Astronomical Society and keenly aware of the importance of the expedition. On December 6 he wrote: "Trying to keep calm and collected for the day after tomorrow."[40] In fact, it seems his youthful zeal nearly got the better of him because the night before the transit he recorded the following:

"Weather still bad and the barometer very low and still falling, but I shall keep hoping, hoping, hoping for tomorrow. Oh! to think it is so close — I feel funnier today than I have ever felt in my life, and I suppose really tomorrow morning will be about the most unpleasant time of my life up to 11 o'clock, when one will know one's fate...."[41]

It was a classic case of "butterflies in the stomach." Understandably, he was far too anxious to sleep that night and was up at 4:30 a.m. He waited until 6 o'clock before rousing his assistants and "got their fat heads shaken out of them" even though he described the weather as "dubious, very."

First contact was due at 6:30 a.m. and Corbet was not disappointed: "Oh! the happy moment, when from 6:00 am to 6:30 I had been watching intently the bottom of the Sun for an impression, and I saw it — really and truly the happiest moment of my life."[42] It was exactly the opposite of the "unpleasant time" that he had feared.

Corbet then kept a detailed observer's report. He and his assistant differed by as much as 15 seconds for their first contact (of Venus to the Sun's disk) timings due to the nefarious black drop effect. Soon, heavy clouds moved in and though Corbet caught a glimpse of Venus leaving the Sun's disk, he wasn't able to time it.

When the event was over, the team treated themselves to a breakfast of Oxford sausages and a bottle of champagne. Meanwhile, Perry's team had both a photographic and visual program. At their station, a single cloud obscured first contact but the sky cleared and they got good timings and photos of the end of the transit. Goodridge's team had similar, partial success.

After the transit, the teams re-gathered at the primary station and compared notes, though this took a few days due to stormy weather. There was more work to do yet — Airy had given instructions to make more than a hundred additional lunar observations to fine-tune the longitude determination. However, the weather turned for the worse and it took three months to collect the necessary observations — forcing the expedition to go on half rations (Ashbrook 1966). On February 27, 1875, the expedition set sail back to England. Upon leaving the island, Corbet recorded his wistful thoughts:

"We watched the dreary desolate island for ever so long till all the low land had sunk into the sea and we could see the snow mountains only.... We were clear of the land by night, and all with light hearts and full of happiness at getting away from Kerguelen at last after five months of it, which sometimes seems an age, and at other times as nothing but a mad whirling gap in one's existence."[43]

Unfortunately, both Corbet and Perry ultimately gave their lives to their work. A year after the transit, Corbet succumbed to a fever off the coast of Africa, cutting short a promising career. Like Hell before him, Perry gained a reputation as a lecturer. He continued to make expeditions: he observed the 1882 transit in Madagascar and later died at sea in 1889, after completing solar eclipse observations in French Guiana (Gerard 1911; Kilburn 2002).

The American effort was spearheaded by Simon Newcomb, who recommended the establishment of a government commission in 1870 and was an early proponent of recording the transit photographically. Newcomb's biggest concern was to accurately establish the photographic plate scale in order to minimize conversion errors (measurements on the photographic plate were linear while the parallax measurements were angular). Because Venus was to look like a small, circular sunspot, Newcomb recommended adopting a solar observation method perfected by Joseph Winlock at Harvard Observatory (Janiczek & Houchins 1974; Dick *et al.* 1998). The final design was a horizontal telescope with a 40-foot focal length in which the Sun's light was directed to the photographic plate by a tilted, slowly moving mirror (known as a heliostat).

Much of the instrument making became the task of Alvan Clark and his firm in Massachusetts. Clark had his hands full outfitting eight U.S. expeditions with identical equipment, including the five-inch refractors for the visual observations, the five-inch 40-foot photoheliograph lenses, and the heliostat mirrors for the photographic program as well as chronographs for accurate time measurement (Dick *et al.* 1998). This was on top of the 26-inch refractor he was already commissioned to build for the Naval Observatory.

Beginning in May 1873, the teams gathered on the grounds of the Naval Observatory for a series of practice observations with an artificial sun and Venus mounted on a building. Even Henry Draper, one of the pioneers of

---

[39] Maunder and Moore 2000, p. 66.

[40] Ibid.

[41] Ibid.

[42] Ibid., p. 68.

[43] Ibid., p. 69.

astrophotography, lent a hand for a few weeks.

In June 1874, the *USS Swatara* left New York Harbour on a "milk run" to the Southern Hemisphere destinations. A total of five parties were dropped off: Kerguelen Island, Tasmania (two parties), New Zealand, and Chatham Island (880 km east of New Zealand). The three Northern Hemisphere parties travelled to Nagasaki, Japan; Vladivostok, Siberia, and Beijing, China. If anything, the American expeditions were routine, with few mishaps. Though travel had become much more predictable, the weather had not and on transit day the Southern Hemisphere stations were cursed with poor weather much of the time. Like the British parties on Kerguelen Island, the American party stationed there viewed only a portion of the transit.

Things were slightly better in the Northern Hemisphere. Unlike Chappe in Siberia, who battled the spring thaw, Asaph Hall's party in Vladivostok was stuck fighting the Siberian winter. Gale winds continually threatened to blow the roof of their observatory off and lubricants for the sidereal clock and heliostat froze. The temperature difference between the inside of the photography house and outside was 30 degrees Celsius, plaguing the photography program with unsteady air.

In Beijing, James Watson caused a stir among Chinese officials during his preparations when he discovered an asteroid. He diplomatically asked Prince Kung, regent of the empire, to name the new minor planet. Today, the 139th asteroid, "China's auspicious star" or, *Shui Hua Hsing*, is known by its contracted form, Juewa (Ashbrook 1974).

Newcomb was optimistic about the results and thought the solar parallax could be determined with a probable error between 0.02″ and 0.03″ (Dick *et al.* 1998). Here he was sorely disappointed. Not only that, he was soon to be frustrated in his attempts to complete the data analysis — a task that had fallen to him as secretary of the commission.

Due to confusion about appropriation of funds earmarked for this work, Newcomb was shortchanged $3000 and had to discharge his computers in 1876. The next year, new money was held up in a legal dispute and Newcomb had to lay off his computers a second time. In 1879, an additional fiscal dispute caused a now predictable reaction: Newcomb let his computers go a third and final time. For Newcomb, this was the last straw and he turned the work over to William Harkness.

William Harkness had developed important equipment for the 1874 transit and led an expedition to observe it from Tasmania. Getting the transit data analyzed and published became part of his life's work. Meanwhile, the 1882 transit was fast approaching. With no data published by the Americans from their long-focus photographic method, European astronomers began to suspect whether it was superior, even though the British had already admitted that their short-focus photography method was a failure. And, because the range of values obtained from the visual contacts method for the 1874 transit was again intolerably wide (thanks in part to the black drop effect), astronomers approached the 1882 transit with considerably less enthusiasm than for the previous ones.

Other methods for determining the solar parallax contributed to the disillusionment in the transit method, but with the next one not occurring for another 122 years, at the 11th hour, a "now or never" attitude prevailed and many countries hastily prepared expeditions. For the Americans, partly through the efforts of Harkness, Congress finally approved funding for expeditions four months before the transit.

It so happened that this transit was partially visible from North America, so there were many official and unofficial stations in Canada and the United States. If professional interest was lacking, public interest was at an all-time high. The *New York Times* reported that "A telescope was mounted on Broad Street, near the Stock Exchange, and the owner of this, too, had all the business he could attend to."[44] Elsewhere in the city, some enterprising amateur astronomers set up telescopes and made good money — the going rate was 10 cents a look! (DeVorkin 1982)

Though Newcomb doubted the usefulness of the transit observations in light of more recent methods, he led an expedition to Wellington, South Africa. He set up in a garden of a seminary and encouraged students and teachers alike to partake in the observations. The teachers were women and some claimed to have made better observations than the professional astronomers. Newcomb graciously wrote that "it was partly the result of good fortune and partly due to the quickening of the faculties which comes with intense interest,"[45] though the women preferred to interpret their success "as a tribute to the greater powers of their own sex."[46] Nevertheless, Newcomb gave them full credit for their observations in his report.

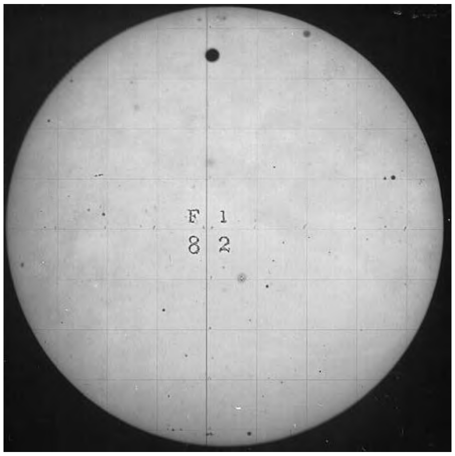


Figure 4. — Photo from the 1882 transit. Courtesy of the U.S. Naval Observatory Library

---

[44] DeVorkin 1982.

[45] W.P. Koorts, *The 1882 Transit of Venus: Observations from Wellington, South Africa,* www.saao.ac.za/~wpk/tov1882/tovwell.html

[46] Ibid.

For his part, Harkness observed the transit from Washington, D.C. where he had the good fortune to view all four contacts. Three other American parties had similar success so that in terms of weather, the 1882 transit was much better observed, yielding better data and more photographs than the 1874 transit. One of the 11 surviving photographic plates from the 1882 transit is shown in Figure 4. In total, Harkness collected 1380 measurable photographs from the various American stations for the 1882 transit, compared to only 221 measurable photographs for the 1874 transit.

The wealth of data swamped Harkness. He directed the measurement of the photographs, the time and latitude determination of each station and the various subsidiary calculations that today are done instantaneously by computer programs. In 1888, six years after the 1882 transit, he finally published the results in the *Astronomical Journal*. He calculated the solar parallax to be 8.847 ± 0.012″ (Harkness 1888), a value that corresponded to a distance of 148,675,000 km (92,385,000 miles), with a probable error of 201,000 km (125,000 miles). He later revised this to 8.842 ± 0.0118″ (Harkness 1891), corresponding to 148,788,000 km (92,455,000 miles), with a probable error of 199,600 km (123,400 miles).

Harkness must have been pleased to come up with a result when Newcomb couldn't and then equally annoyed to see Newcomb summarize results from a variety of methods and give his results low weight. It was Newcomb's new value for the solar parallax from a variety of methods, 8.800″, that was widely adopted by astronomers. In fact, this was very close to the modern value.

In Canada, Charles Carpmael, Director of the Toronto Observatory, was in charge of coordinating the 1882 Canadian transit observations. He received a federal grant of $5000, which was mostly directed toward acquiring good medium-sized telescopes (Sawyer Hogg 1982). These instruments no doubt greatly influenced local interest in astronomy. Thirteen stations were set up from Winnipeg to Halifax and five of them enjoyed at least partial success — not bad for December in Canada. The results were communicated to E.J. Stone, of Oxford, who used them to derive a solar parallax of 8.832″, corresponding to an Earth-Sun distance of 148,957,000 kilometres (92,560,000 miles) (Fernie 1979).

Tallying Up II

Why weren't better results obtained? Precise timing of the contacts of Venus with the disk of the Sun was fraught with difficulties. Firsthand reports indicated three major problems in the timings: (i) boiling of the image, (ii) a fuzzy ring surrounding Venus (too thick to be due to its atmosphere) and (iii) the notorious black drop effect (Bray 1980). Given these difficulties, one wit remarked to Sir George Airy, "You might as well try to measure the zodiacal light."[47]

The first two effects were due to heating of the ground and parts of the telescope by the Sun's rays. Such heating produces turbulent air currents that act to change the telescope's focus. Modern solar telescopes are designed in such a way as to eliminate these problems; 18th- and 19th-century astronomers found out about the complications the hard way. The "black drop" was first properly described by Lalande in 1770 as a blurring of the image due to normal terrestrial atmospheric smearing such that a meniscus appears (Schaefer 2000). Diffraction within the telescope is also a contributing factor, explaining why the 19th-century observers who used larger aperture telescopes had less of a problem with the black drop than the 18th-century observers. A similar effect, due to the finite size of the eye's pupil, can be seen by looking at your thumb and index finger held very close together near your eye. So, part of the problem with the results was the initial, overly optimistic expectations in the method itself.

Modern methods to calibrate the Earth-Sun distance are almost embarassingly straightforward. Giant radio telescopes are used to fire a radar beam towards Venus and the signal's return is timed by atomic clocks. Combining half the round-trip time with the speed of light gives the Earth-Venus distance at that moment; this is transformed to the Earth-Sun distance via Kepler's laws. Based on these measurements, in 1976, the International Astronomical Union adopted the value of 8.794148″ ± 0.000007″ for the solar constant, though the Earth-Sun distance, or the astronomical unit, is known to even greater precision: 149,597,870.691 km ± 0.030 km. With a precision of 1 part in 5 billion — like knowing the distance between Vancouver and Toronto to within 0.7 millimetres (Fernie 2002)! — this latest result has surely exceeded Halley's wildest dreams.

Thanks to their rarity, the transits of Venus provide a sort of "passing of the baton" through the generations. No one observed the 1631 transit and only two people saw the next one, in 1639. The 1769 and 1769 transits were observed by perhaps a few hundred amateur and professional astronomers. The next pair, in 1874 and 1882, was likely seen by thousands. Now, with television and the Internet, the next transit in June 2004 could have an armchair audience of millions.

In an address to the American Association for the Advancement of Science in 1882, William Harkness gave the following poignant words:

"We are now on the eve of the second transit of a pair, after which there will be no other till the 21st century of our era has dawned upon the earth, and the June flowers are blooming in 2004. When the last transit season occurred [1761 and 1769] the intellectual world was awakening from the slumber of ages, and that wondrous scientific activity which has led to our present advanced knowledge was just beginning. What will be the state of science when the next transit season arrives, God only knows. Not even our children's children will live to take part

---

[47] Agnes Clerke 1902, p. 236.

in the astronomy of that day. As for ourselves, we have to do with the present…."[48]

Bibliographic Notes

Part of the reason for this essay, on the eve of the next transit pair, was to bring together some of the colourful tales and journal excerpts that are scattered widely in books, magazines, and journals. The best sources are Don Fernie's two books, which describe the 18th-century transits in warm detail. Interested members and readers with access to back issues of the *JRASC* (that is, back issues that go way back), are also encouraged to look up Helen Sawyer Hogg's *Out of Old Books* series for extensive and illuminating journal excerpts from Wales and Le Gentil.

References

Armitage, A. 1953, Annals of Science, 9, 47

Ashbrook, J. 1966, Sky & Telescope, 31, 340

Aughton, P. 1999, Endeavour: The Story of Captain Cook's First Great Epic Voyage (Windrush Press: Moreton-in-Marsh)

Beaglehole, J.C., ed. 1963, The Endeavour Journal of Joseph Banks (Angus and Robertson: London)

Bray, R.J. 1980, Proceedings of the Astronomical Society of Australia, 4, 114

Chappe d'Auteroche, J.B. 1970, Journey into Siberia (Arno Press: New York)

Clerke, A.M. 1902, A Popular History of Astronomy During the 19th Century (Adam and Charles Black: London)

DeVorkin, D.H. 1982, Sky & Telescope, 64, 524

Dick, S.J., Orchiston, W., & Love, T. 1998, Journal for the History of Astronomy, 29, 221

Fernie, D. 1979, *JRASC*, 73, 121

Fernie, D. 1976, The Whisper and the Vision: The Voyages of the Astronomers (Clarke, Irwin and Company Ltd.: Toronto)

Fernie, D. 2002, Setting Sail for the Universe: Astronomers and Their Discoveries (Rutgers University Press: New Brunswick, NJ)

Gerard, J. 1911, in The Catholic Encyclopedia, Vol. 11, www.newadvent.org/cathen/p.htm

Gillespie, C.C., ed. 1970, Dictionary of Scientific Biography, Vol. 6 (Charles Scribner and Sons: New York), 233

Harkness, W. 1888, AJ, 8, 108

Harkness, W. 1891, PASP, 3, 46

Janiczek, P.M., & Houchins, L. 1974, Sky & Telescope, December, 366

Kilburn, K. 2002, Fr. Walter Sidgreaves (1837-1919), www.u-net.com/ph/astro-history/sidgreaves.htm

Koorts, W.P. 1999, The 1882 Transit of Venus: Observations from Wellington, South Africa, www.saao.ac.za/~wpk/tov1882/tovwell.html

Lamb, C. 1822, Recollections of Christ's Hospital, Essays by Charles Lamb, www.pinkmonkey.com/dl/library1/essays.pdf

MacDonnell, J.F., Maximillian Hell and His Mesmerizing Adventures, www.faculty.fairfield.edu/jmac/sj/scientists/hell.htm

Maor, E. 2000, June 8, 2004: Venus in Transit (Princeton University Press: Princeton)

Maunder, M., & Moore, P. 1999, Transit: When Planets Cross the Sun (Springer-Verlag: London)

Nunis, D.B. ed. 1982, The 1769 Transits of Venus: The Baja California Observations of Jean-Baptiste Chappe d'Auteroche, Vicente de Doz, and Joaquin Velazquez Cardenas de Leon (National History Museum of Los Angeles County: Los Angeles)

Pogge, R.W. 2000, Lecture 26: How Far to the Sun? The Venus Transits of 1761 and 1769, www-astronomy.mps.ohio-state.edu/~pogge/Ast161/Unit4/venussun.html

Proctor, R., 1874, Transits of Venus: A Popular Account of Past and Coming Transits.

Longmans Green, London.

Sawyer Hogg H. 1948, *JRASC*, 42, 153-159, 189-193

Sawyer Hogg H. 1951, *JRASC*, 45, 37-44, 89-92, 127-134, 173-178, 1951

Sawyer Hogg H. 1982, *JRASC*, 76, 362

Schaefer, B.E. 2000, American Astronomical Society Meeting 197, December 2000, abstract

Smith, F.R., 2003, *JRASC*, in press.

Van Helden, A. 1995, in Planetary astronomy from the Renaissance to the rise of astrophysics, Part B: The eighteenth and nineteenth centuries, ed. R. Taton and C. Wilson (Cambridge University Press: Cambridge)

Woolf, H. 1953, Annals of Science, 9, 176

Daniel Hudon is an Assistant Editor with the JRASC. He teaches astronomy in the Core Curriculum at Boston University.

---

[48] Quoted in Dick *et al.* 1998.

Levers et couchers

par Raymond Auclair, membre indépendant et à vie, SRAC (auclair@cyberus.ca)

Voici un autre article qui nous invite à feuilleter l'*Observer's Handbook* et à utiliser les données qu'on y trouve. Pour bien profiter de cet article, il faut connaître le sens de certains mots. Nous encourageons le lecteur à consulter un dictionnaire illustré aux mots suivants: azimut, ascension, cosinus, déclinaison, écliptique, fuseau horaire, hauteur, latitude, longitude, pi, sphère, zénith.

Dans cet article nous utiliserons les équations pour la hauteur et l'azimut, pour le cas spécial où la hauteur de l'astre est de 0°. De là, nous trouverons l'intervalle durant lequel l'astre est au-dessus de l'horizon (pour le Soleil, c'est la durée du jour), puis nous déterminerons les heures théoriques de lever et de coucher. Enfin, nous verrons comment corriger les effets de la grandeur apparente du Soleil, de la réfraction atmosphérique et de l'altitude de l'observateur.

Rappel

Cet article fait suite à celui débutant en page 163 du numéro du mois d'août 2003 de ce *Journal* (JRASC, 97, 163). Nous avons alors exploré le triangle PZX qui permet à un observateur localisé (latitude, longitude) de passer du système équatorial (déclinaison, ascension droite) au système horizontal (hauteur, azimut).

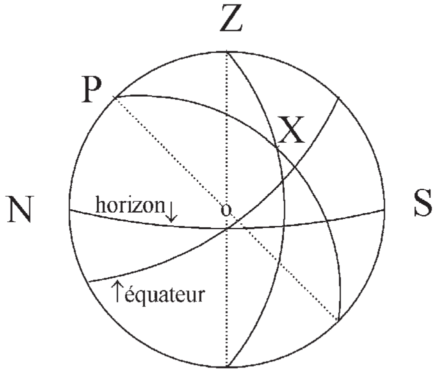


figure 1 — La sphère céleste

La sphère céleste utilisée pour nos calculs est centrée sur l'oeil de l'observateur. L'orientation est telle que nous pouvons imaginer l'observateur debout à la verticale sur la Terre (lettre **'o'** au centre de la figure 1). Nous imaginons l'observateur immobile; le mouvement apparent des astres est représenté par une rotation diurne de la sphère céleste. La période de rotation est de 86 400 secondes pour le Soleil (15° par heure) et de 86 164,1 secondes pour les étoiles (15,041° par heure).

Le rayon de la sphère céleste est tellement grand que celui de la Terre est négligeable en comparaison. Nous pouvons alors imaginer que le centre de la Terre coïncide avec celui de la sphère céleste, ce qui facilite les calculs et les projections.

Le triangle sphérique PZX est ancré aux points P (pôle), Z (zénith) et X (astre). Les angles et les côtés du triangle sont tous mesurés en degrés. Nous les identifions par ces symboles :

$\boldsymbol{h}$ pour l'angle **h**oraire (l'angle au point P)
ϕ pour la latitude de l'observateur (le côté PZ vaut $90° - \phi$)
$\boldsymbol{A}$ pour l'**A**zimut (l'angle au point Z)
$\boldsymbol{a}$ pour la hauteur (le côté ZX vaut $90° - \boldsymbol{a}$)
X pour l'angle au point X (nous l'utilisons)
δ pour la déclinaison de l'astre (le côté PX vaut $90° - \delta$)

Les équations utilisés pour résoudre le triangle PZX se trouvent à la page 32 de l'*Observer's Handbook 2003* :

$$\sin \boldsymbol{a} = \sin\delta \sin\phi + \cos \boldsymbol{h} \cos\delta \cos\phi$$
$$\sin\delta = \sin \boldsymbol{a} \sin\phi + \cos \boldsymbol{a} \cos \boldsymbol{A} \cos\phi$$

Durée du jour

En utilisant l'équation de la hauteur pour le cas spécial où $\boldsymbol{a} = 0°$, nous déterminons l'angle horaire de l'astre au moment du lever (ou du coucher). En utilisant la période de rotation appropriée (15°/h ou 15,041°/h), nous trouvons l'intervalle entre le lever et le passage au méridien ou, par symétrie, entre le passage au méridien et le coucher. Le double de l'intervalle donne directement la durée pendant laquelle l'astre est au-dessus de l'horizon. Dans le cas du Soleil, on parle de la « durée du jour.»

Généralement, nous supposons que la latitude ϕ et la déclinaison δ ne changent pas au cours de la période d'observation. Nous verrons, par un exemple, la différence entre un calcul utilisant la déclinaison du Soleil à midi et un calcul utilisant δ le matin et δ le soir.

Définitions

En navigation astronomique, l'horizon est défini comme l'ensemble de tous les points situés à exactement 90° du zénith de l'observateur. Le lever et le coucher sont définis comme étant les moments où l'astre est exactement sur l'horizon. Pour les astres qui ont une dimension apparente non-nulle (notamment le Soleil et la Lune), il s'agit de la position du centre du disque.

En théorie, au moment du lever, tout comme au moment du coucher, la hauteur de l'astre vaut 0° ($\boldsymbol{a} = 0$).

La simplification par zéro

Le zéro peut simplifier les calculs, tout comme il peut les compliquer. Une multiplication par zéro produit un zéro. Dans une somme, un zéro peut être ignoré. Par contre, il faut éviter de diviser par zéro.

Rappelons-nous que :

$\sin 0° = 0$, $\sin 180° = 0$, $\sin -180° = 0$...
$\cos 90° = 0$, $\cos -90° = 0$, $\cos 270° = 0$...

Attention, cos 0° vaut **1** (et non pas 0). De plus, si A + B = 0, alors on a que A = –B (et que B = –A).

Nous allons aussi utiliser la fonction trigonométrique appelée « tangente,» qui est le rapport entre le sinus et le cosinus, ainsi que la sécante qui est simplement l'inverse multiplicatif du cosinus (sec y = 1 / cos y).

tan y = sin y / cos y = sin y sec y

Alors, nous avons que :

tan 0° = 0, tan 180° = 0, tan –180° = 0...

mais nous devons éviter tan 90° et tan –90° qui donnent des divisions par zéro :

tan 90° = sin 90° / cos 90° = 1 / 0

La valeur de tan 90° n'est pas définie.

L'équation simplifiée pour *h*

Au moment du lever (ou du coucher), la hauteur ***a*** vaut 0°. En partant de la formule du cosinus pour ***a***, on peut isoler ***h*** puis déterminer sa valeur.

$\sin a = \sin \delta \sin \phi + \cos h \cos \delta \cos \phi$

Puisque $a = 0°$, alors $\sin a = 0$.

$0 = \sin \delta \sin \phi + \cos h \cos \delta \cos \phi$

Soustrayons les sin des deux côtés :

$- \sin \delta \sin \phi = \cos h \cos \delta \cos \phi$

Divisons par ($\cos \delta \cos \phi$) et utilisons le rapport des tangentes (tan y = sin y / cos y) :

$- \tan \delta \tan \phi = \cos h$.

Ainsi, nous trouvons une équation simplifiée qui détermine l'angle horaire d'un astre au moment de son lever (ou de son coucher). Il suffit de connaître la déclinaison de l'astre et la latitude de l'observateur.

Un exemple

L'équation nous donne une valeur théorique basée sur un horizon situé exactement à 90° du zénith et ne tient pas compte d'effets comme la réfraction et la dépression de l'horizon réel. Nous verrons plus loin comment corriger ces effets. Pour notre exemple, utilisons une position où, en général, il n'est pas nécessaire de tenir compte de ces différences, la géographie du lieu se prêtant bien à l'application de l'équation telle quelle.

Il y a probablement des milliers d'endroits plats, offrant peu ou pas d'obstructions à l'horizon et où l'observateur est à la même hauteur relative que l'horizon. Choisissons la ville de London (Ontario) et, plus précisément, la position 43°00´ N 81°15´ W.

Photo de l'intersection Grosvenor et Waterloo, London (Ontario)
photo prise par Dianne Kapitaniuk

London (Ontario)

London est une ville au relief peu prononcé, où les noms de rues et celui de la rivière (Thames) rappellent la topographie de la capitale du Royaume Uni. London est située dans le sud de l'Ontario, entre Toronto et Windsor, tout juste au nord de la route 401.

London abrite un centre très actif de la Société royale d'astronomie du Canada (réunions annuelles de la SRAC en 1979 et 2001). La ville compte plusieurs astronomes amateurs, dont un qui a su, au début des années 80, encourager l'auteur à s'impliquer dans les affaires de la SRAC et de l'astronomie au Canada en général. Indice: 5899.

Pour des renseignements sur le centre de London, voir la page Web `phobos.astro.uwo.ca/~rasc/`.

La photo, gracieuseté de Dianne Kapitaniuk de London, montre l'intersection des rues Grosvenor et Waterloo, à quelques mètres à peine du point choisi. La photo nous fait regarder vers l'ouest, dans l'axe de la rue Grosvenor. La direction vers laquelle se dirige la rue Grosvenor est entre 245° et 250°, c'est à dire la direction que les marins appelaient WSW (Ouest-Sud-Ouest), à mi-chemin entre l'Ouest et le Sud-Ouest.

La latitude de London (43°) est assez basse pour permettre d'utiliser des raccourcis faciles pour les corrections. De plus, la ville de London est nommée dans la liste de la page 107 de l'*Observer's Handbook 2003,* qui sert à corriger le tableau des levers et couchers de Soleil ; il nous sera facile de comparer nos réponses avec celles du livre.

Enfin, le calcul

Pour calculer la durée du jour, il nous faut la latitude de l'observateur (43°N) et la déclinaison du Soleil. Cette dernière change constamment. Choisissons une date à partir de laquelle nous pourrons déterminer la déclinaison d.

Le 5 novembre 2003 à 0h UT, selon le tableau à la page 101 de l'*Observer's Handbook*, la déclinaison du Soleil est de 15°29´ S. En interpolant, on peut calculer que vers midi, heure normale de l'est (vers 17h UT), le 5 novembre, la déclinaison du Soleil est d'environ 15°42´ S ($\delta = -15{,}7°$). Utilisons l'équation $\cos h = - \tan \delta \tan \phi$

$\cos \boldsymbol{h} = -\tan(-15,7°) \tan(43°)$
$\cos \boldsymbol{h} = -(-0{,}262118) = 0{,}262118$
$\boldsymbol{h} = 74{,}8042° \equiv 4^h\,59^m\,13^s$

On peut lire le symbole ≡ ainsi : « ce qui correspond à». Ce n'est pas une égalité à proprement parler, car si le même calcul avait impliqué une étoile, l'angle de 74,839° correspondrait à $4^h\,58^m\,32^s$ (en utilisant 15,041° par heure).

Puisque nous supposons qu'il y a symétrie, la durée du jour à London (Ontario) le 5 novembre 2003, est de $9^h\,58^m\,26^s$ ($4^h\,59^m\,13^s + 4^h\,59^m\,13^s$).

Y a-t-il symétrie?

Faut-il tenir compte du fait que la déclinaison du Soleil au moment du lever n'est pas la même qu'au moment de son coucher? L'analyse du tableau de la page 101 de l'*Observer's Handbook* révèle que la déclinaison du Soleil, le 5 novembre, varie de 0,766′ par heure. Sur une période de cinq heures, elle change donc d'environ 3,8′ et, au moment du lever, δ vaut environ 15°38,2′ S alors qu'au coucher, δ = 15°45,8′ S.

Pour calculer l'intervalle entre le lever et le passage au méridien :

$\cos \boldsymbol{h} = -\tan(-15{,}6367°) \tan(43°)$
$\boldsymbol{h} = 74{,}8702° \equiv 4^h\,59^m\,29^s$

Pour calculer l'intervalle entre le passage au méridien et le coucher :

$\cos \boldsymbol{h} = -\tan(-15{,}7633°) \tan(43°)$
$\boldsymbol{h} = 74{,}7382° \equiv 4^h\,58^m\,57^s$

La somme des deux intervalles donne $9^h\,58^m\,26^s$, la même valeur que celle obtenue avec la déclinaison moyenne. En théorie, il pourrait exister des dates et des lieux où nous trouverions une différence, mais en général, la différence sera infime.

L'azimut au lever ou au coucher

L'autre élément important du calcul est l'azimut de l'astre au moment de son lever ou de son coucher. Pour les marins, le lever et le coucher des astres les plus brillants (Soleil, Lune, planètes) sont des événements facilement reconnaissables et donnent l'occasion de vérifier la précision du compas.

Bien que les navigateurs arrivent à prendre l'azimut des astres à tout moment (à l'aide de miroirs ou de prismes), il faut admettre que les alidades, même modernes, se prêtent mieux à l'observation de relèvements à l'horizontale. Ainsi, il est plus facile de prendre un relèvement du Soleil au moment de son coucher. Le navigateur compare la valeur observée avec l'azimut calculé afin de déterminer l'erreur du compas.

En partant de la formule pour l'azimut, isolons ***A***.

$\sin \delta = \sin \boldsymbol{a} \sin \phi + \cos \boldsymbol{a} \cos \boldsymbol{A} \cos \phi$
Puisque $\boldsymbol{a} = 0°$, alors $\sin \boldsymbol{a} = 0$ et $\cos \boldsymbol{a} = 1$.
$\sin \delta = 0 + 1 \times \cos \boldsymbol{A} \cos \phi = \cos \boldsymbol{A} \cos \phi$

On peut intervertir :

$\cos \boldsymbol{A} \cos \phi = \sin \delta$

Divisons par cos φ des deux côtés :

$\cos \boldsymbol{A} = {}^{\sin \delta}/_{\cos \phi} = \sin \delta \sec \phi.$

Pour nous, l'azimut est calculé à partir du pôle élevé. Un observateur en hémisphère Nord mesure l'angle ***A*** à partir du Nord, vers l'est au lever, vers l'ouest au coucher.

Sur une calculatrice où n'apparaît pas la sécante, il faut diviser par le cosinus, ce qui équivaut à multiplier par la sécante. Dans notre exemple :

$\cos \boldsymbol{A} = \sin(-15{,}7°) \sec(43°) = -0{,}37$
$\boldsymbol{A} = 111°43′$

Donc, l'azimut du Soleil levant, de London le 5 novembre, est de 111°43′ tandis que l'azimut du Soleil couchant, le même jour, est de 248°17′ c'est-à-dire WSW (l'orientation de la rue Grosvenor, dans la photo de Dianne Kapitaniuk).

Les heures de lever et de coucher du Soleil

Le calcul de la durée du jour est une étape importante dans le calcul du lever et du coucher du Soleil. L'autre étape est la détermination du passage au méridien du Soleil, dont il a déjà été question dans l'article précédent (JRASC 97, 163).

Le transit du Soleil

Retournons à la page 101 de l'*Observer's Handbook 2003*. Pour le 5 novembre 2003, le transit (passage au méridien) est prévu pour 11:43:35 (heure solaire moyenne), heure à laquelle on ajoute la longitude Ouest de notre observateur (81°15′ ≡ $5^h\,25^m\,00^s$) puis on soustrait le décalage de 5 h du fuseau (en novembre, London utilise l'heure normale de l'est HNE).

Par excès de précision, ajoutons la petite correction (qui, dans ce cas, vaut 2 secondes) due au fait que le tableau donne le transit en heure solaire moyenne à 0h UT le 5 novembre, alors que nous le voulons pour 17h UT le 5 novembre.

Ainsi, le passage au méridien du Soleil le 5 novembre 2003, pour un observateur situé à 43°00′ N 80°15′ W, a lieu à 12:08:37 HNE.

À partir de là, nous pouvons calculer l'heure du lever du Soleil en soustrayant l'intervalle calculé plus haut. Puisque nous avons fait le calcul de deux façons, prenons la valeur plus précise de $4^h\,59^m\,29^s$ qui tient compte de la déclinaison du matin (au lieu de la moyenne). Nous trouvons que le lever du Soleil a lieu, en théorie, à 7:09:08 HNE.

L'intervalle entre le passage au méridien et le coucher étant de $4^h\,58^m\,57^s$, l'heure théorique du coucher est 17:07:34 HNE.

Avec la méthode plus facile où nous utilisons la déclinaison moyenne, nous trouvons respectivement 7:09:24 et 17:07:50 HNE. Il y a donc, dans notre exemple, un décalage de 16 secondes entre les deux méthodes.

Pour le lever, notre observateur n'aura pas vraiment le loisir de s'en rendre compte puisque des résidences du côté sud de la rue Grosvenor, à l'est de la rue Waterloo, l'empêcheront de voir le lever du Soleil.

Cependant, au moment du coucher, le Soleil sera sur l'horizon (en novembre, les arbres visibles sur la photo auront perdu leurs feuilles) et directement dans l'axe de la rue Grosvenor. Les automobilistes pourraient être aveuglés au moment où ils se décident à traverser l'intersection. Peut-être que pour l'un d'eux, une différence de 16 secondes aura été importante.

Mais l'astronome moyen n'installe pas son télescope au milieu de la rue Grosvenor. Dans ce cas, aussi bien utiliser la méthode facile.

Les corrections

Tout au long de l'article, nous avons fait état de durées théoriques. En pratique, certains effets viennent modifier notre perception des levers et couchers, donc la durée du jour.

Le diamètre apparent du Soleil

Pour la plupart des gens, la nuit commence lorsque le Soleil est complètement sous l'horizon. Nos calculs tiennent compte du centre du Soleil et non du limbe supérieur.

Le diamètre apparent du Soleil varie au cours de l'année. En juillet (apogée) il est à son minimum de 31,5´ tandis qu'en janvier (périgée) il atteint 32,6´. Au début novembre, il est d'environ 32,3´.

Le rayon (du centre au limbe supérieur) est donc d'environ 0,27°. Lorsque le centre du Soleil est directement sur l'horizon, le Soleil doit descendre de 0,27° pour disparaître complètement. Pour la plupart des gens, ce n'est qu'à ce moment que commence la nuit.

Par symétrie, la nuit se termine dès que le limbe supérieur passe l'horizon, alors que le centre est encore à 0,27° sous l'horizon.

La réfraction

Partout sur la Terre où il y a de l'air, il y a de la réfraction. La lumière du Soleil levant (ou couchant) traverse les couches de l'atmosphère à des angles assez aigus. L'effet normal de la réfraction atmosphérique est de faire paraître un astre plus haut qu'il ne l'est vraiment.

Les navigateurs utilisent des recueils de tableaux utiles, notamment sur les corrections à apporter aux observations astronomiques. Un de ces ouvrages découle des travaux du Capitaine Norie. Le titre « pratique » du bouquin est, en anglais, « Norie's Tables », que les francophones d'ici ont traduit par « les tables de Norie's » prononcé *norize* ou *norisse* selon la région. L'auteur de cet article préfère *norize*. Le titre complet est donné à la bibliographie. C'est du Norie's que nous vient le diamètre apparent du Soleil.

Norie's indique que la réfraction moyenne pour un astre à l'horizon est de 33´ c'est-à-dire que l'astre observé directement sur l'horizon (en mer) est en réalité à un peu plus d'un demi-degré sous l'horizon. En analysant le tableau du Norie's, on note qu'un astre dont la hauteur calculée est de 0° serait soulevé de 29´ par la réfraction. Au moment du coucher théorique de l'astre, le centre de l'astre semble être à 29´ au-dessus de l'horizon.

La table de réfraction de Norie's tient compte de conditions normales de 50°F (10°C) et de « 29,6 pouces de mercure » (100,24 kPa). Dans des conditions extrêmes, par exemple par temps froid (–20°C) sous un anticyclone important (104,6 kPa), il faudrait ajouter jusqu'à trois ou quatre minutes d'arc à l'angle de réfraction.

Donc, par une journée fraîche et claire de novembre, au moment où le centre du Soleil est directement sur l'horizon théorique, nous le verrons plus élevé d'environ 0,5°.

La dépression de l'horizon (dip)

Dans les endroits où il y a des pics élevés ou des édifices qui dépassent les autres, nous voyons que les endroits plus élevés restent éclairés par le Soleil alors qu'en bas, il nous paraît couché. Plus l'observateur est haut (par rapport à son horizon), plus la distance entre le zénith et l'horizon est grande.

Les équations pour résoudre le triangle PZX supposent que l'observateur est directement sur la sphère terrestre (d'où son horizon serait à 90° du zénith). En pratique, il est très rare que l'oeil de l'observateur soit exactement au niveau de la mer. De plus, sur terre il est rare que l'horizon lui-même soit au niveau de la mer. En général, les astronomes se cherchent des sites un peu surélevés par rapport à la géographie environnante.

Si ***r*** représente l'élévation relative de l'observateur par rapport à son horizon, alors la correction (en minutes d'arc) correspond à environ 1,78 fois la racine carrée de l'élévation en mètres (Norie's donne 0,98 fois la racine carrée de l'élévation en pieds) :

dip = $1{,}78' \times \sqrt{r}$ (pour ***r*** en mètres)
dip = $0{,}98' \times \sqrt{r}$ (pour ***r*** en pieds)

Ainsi, pour un observateur élevé de 60 m (197 pieds), le « dip » de 13,8´ indique la différence entre l'horizon vrai et l'horizon théorique. Dans ce cas, il faudra que le Soleil baisse de 13,8´ (= 0,23°) pour passer de l'horizon calculé à l'horizon vrai (le jour paraît plus long). Même chose le matin (le soleil est visible en haut avant de l'être au niveau du sol).

En revanche, il est possible que l'observateur soit plus bas que son horizon. Ainsi, au port de Chicoutimi (JRASC 97, 166), nous serions plus bas que l'horizon ouest et le Soleil disparaîtrait de notre vue bien avant l'heure calculée.

Corrections pour London

En général, à cause du peu de relief des résidences et de la végétation présente à London, un observateur debout sur le sol devrait observer peu de différence entre les valeurs théoriques et pratiques pour les levers et couchers.

Mais, supposons un observateur situé à 60 m au dessus de son environnement et qui profite d'un horizon rectiligne.

Pour cet observateur, la différence entre le coucher théorique et le coucher réel se calcule directement à partir de la distance qu'il reste à parcourir avant que l'astre, à l'horizon théorique, disparaisse sous horizon réel.

Dans le cas du Soleil, il y a le rayon apparent du disque (environ 0,27°). Dans tous les cas (Soleil ou étoiles), il y a la réfraction (environ 0,5°). Enfin, il faut tenir compte du dip; nous utilisons un dip de 0,23° qui correspond à une hauteur relative de 60 m. Au total, un degré.

À quelle vitesse descend le Soleil?

La course du Soleil est perpendiculaire au côté PX. L'horizon est perpendiculaire au côté ZX. Donc, l'angle entre la course du Soleil et le vertical est égal à l'angle X.

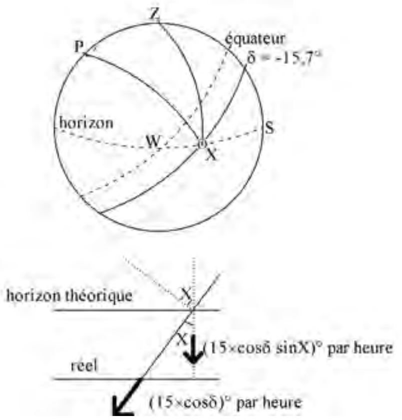


figure 2 — Mouvement apparent du Soleil couchant

L'angle au pôle du Soleil augmente de 15° par heure. Puisque la course du Soleil suit un cercle de déclinaison (qui n'est pas un grand cercle), il se déplace donc à 15° × cos δ par heure. Enfin, le taux de changement de la hauteur est fonction du sinus de l'angle **X**.

Alors, l'altitude du Soleil couchant baisse de 15°× cos δ × sin **X** par heure. Pour une étoile, il faudrait utiliser 15,041° au lieu de 15°.

L'angle X

Mais il est tellement rare que nous ayons à trouver l'angle X que les bouquins (y compris l'*Observer's Handbook*) ne donnent pas l'équation. Nous allons la construire.

Dans l'article du mois d'août 2003, nous avons vu une version de la formule du sinus, qui se résume ainsi : le rapport entre le sinus de deux angles est le même que celui entre le sinus des deux côtés correspondants.

$\sin \mathbf{X} / \sin(90-\phi) = \sin \boldsymbol{h} / \sin(90-\boldsymbol{a})$

Puisque $\boldsymbol{a} = 0$, nous avons que $\sin(90-\boldsymbol{a}) = \sin(90°) = 1$.
Puisque $\sin(90-\phi) = \cos\phi$ et que nous pouvons multiplier des deux côtés par $\cos\phi$, nous avons maintenant :

$\sin \mathbf{X} = \sin \boldsymbol{h} \cos\phi$.

L'application des corrections

En remplaçant sin **X** dans l'équation obtenue plus haut, nous obtenons une équation valide pour des petites valeurs de changement de hauteur, avec laquelle nous calculons l'intervalle de temps **T** qui s'écoule entre le coucher théorique du Soleil et le moment où il disparaît complètement de notre vue :

$\mathbf{T}$ (en heure) = Correction / $(15°\times \cos\delta \sin \boldsymbol{h} \cos\phi)$

Pour construire le tableau des corrections, nous utilisons les résultats « faciles » où $\delta = -15{,}7°$, $\boldsymbol{h} = 74{,}8042°$ et $\phi = 43°$ et les heures « précises » de lever et coucher théoriques, qui sont respectivement 7:09:08 et 17:07:34 HNE.

T est donné en minutes et secondes, chaque valeur étant strictement pour l'effet indiqué. L'intervalle de2m 57s (réfraction) ne tient compte que du 0,5°, mais l'heure du lever tient compte des deux premiers éléments (rayon et réfraction). Les heures indiquées sur la troisième ligne (élévation) tiennent compte des trois intervalles.
L'équation pour trouver **T** est un raccourci. Elle suppose que le taux de changement est linéaire, c'est-à-dire que le taux lui-même ne change pas au cours de l'intervalle entre le coucher théorique et le coucher pratique. Puisque nous ne recherchons qu'une précision d'une minute, l'équation est valide pour plusieurs degrés de corrections à basse latitude (comme à London). Mais la même équation pourrait être moins précise si l'angle **X** change beaucoup durant l'intervalle. Notamment, plus la somme $|\delta + \phi|$ est élevée, moins l'équation est précise. Quand la somme est proche de 90°, il se peut qu'il n'y ait pas de lever ou pas de coucher.

Le Tableau dans l'*Observer's Handbook*

Aux pages 107 à 110 de l'*Observer's Handbook 2003*, nous trouvons des tableaux pour déterminer les levers et couchers de Soleil. Le premier tableau, à la page 107, donne des renseignements pour différentes villes au Canada et aux États-Unis. Par exemple, pour London, on lit : **43° +25E.**

Le **43°** indique qu'il faut utiliser une latitude de 43° pour interpréter les valeurs du deuxième tableau. L'indication **+25E** est la correction en minutes de temps (25) qu'il faut ajouter (+) aux valeurs trouvées dans le deuxième tableau lorsqu'on utilise l'heure normale de l'Est (E). Il ne faut pas oublier d'ajouter une heure lorsque nous utilisons, en été, l'heure avancée de l'Est.

Pour trouver les valeurs pour une position qui n'est pas inscrite, il faut avoir la latitude et la longitude. Des valeurs approximatives (au degré près) peuvent suffire, selon la précision souhaitée. Pour la correction, il suffit de déterminer la différence entre notre longitude et celle du centre du fuseau. Pour l'heure normale de l'est HNE, le centre du fuseau est la longitude 75° W, la longitude de Montebello au Québec. Pour chaque degré de différence en longitude, on compte 4 minutes de correction. Puisqu'il y a 15° par fuseau, 15 fois 4 minutes donnent une heure

Correction	Intervalle **T**	Lever	Coucher	Durée
rayon = 0,27°	$1^m 35^s$	7:07:33	17:09:09	$10^h 01^m 36^s$
réfraction = 0,5°	$2^m 57^s$	7:04:36	17:12:06	$10^h 07^m 30^s$
élévation = 0,23°	$1^m 21^s$	7:03:15	17:13:27	$10^h 10^m 12^s$

Tableau des corrections
London (Ontario), le 5 novembre 2003
Une correction de 1° correspond à $5^m 53^s$
L'intervalle est donné séparément pour chacun des éléments

d'écart entre chaque fuseau horaire (voir la carte des fuseaux horaires à la page 43 de l'*Observer's Handbook*.

Si nous sommes à l'ouest de la longitude du fuseau, les événements surviennent plus tard. Alors la correction est additive. Si nous sommes à l'est de la longitude du fuseau, la correction doit être soustraite. Par exemple, un observateur à Québec doit soustraire 15 minutes aux valeurs tirées du tableau.

L'heure normale de Terre-Neuve (N) est retardée de 3h 30m par rapport au temps universel. Le centre du « demi-fuseau » est la longitude 52°30´ W. Le point le plus oriental du Canada est le cap Spear. La longitude du phare du cap Spear est de 52° 37´ 20,2″ W selon la liste des phares de la Garde côtière canadienne. Le phare est à moins de cent mètres de la mer. Donc, toute l'île de Terre-Neuve est à l'ouest de la longitude du fuseau et nous pouvons conclure que la correction y sera partout additive (+).

Vous voulez un devoir?

Pour ceux qui veulent calculer les levers de Soleil au cap Spear, sachez que la position du phare est 47° 31´ 16,2″ N 52° 37´ 20,3″ et que le sol, au pied du phare, est à 57,3 m au dessus du niveau de la mer. Le point focal du phare est à 71 m au dessus du niveau de la mer.

Revenons aux tableaux

Nous voulons trouver les heures de lever et coucher de Soleil à London (Ontario) le 5 novembre 2003. Nous remarquons que le tableau donne des valeurs pour les latitudes 40° et 45° ainsi que pour les dates du 2 novembre et du 6 novembre.

Commençons par interpoler des valeurs pour la date visée.

Lever à 40°: 6:30 (2 nov.) et 6:34 (6 nov.). L'interpolation donne facilement la valeur de 6:33 pour le 5 novembre.

Lever à 45°: 6:39 (2 nov.) et 6:45 (6 nov.). L'interpolation donne 6 :43,5 (5 nov.)

Maintenant nous interpolons pour la latitude 43° en prenant trois cinquième de la différence de 10,5 minutes. Nous trouvons 6:39,3 (5 nov. à 43° N). Les navigateurs utilisent des fractions de minutes (et non des secondes) lors de l'interpolation, pour se rappeler que la précision du tableau est de l'ordre d'une minute.

Enfin nous appliquons la correction de +25 pour trouver que le lever de Soleil du 5 novembre à London devrait avoir lieu à 7:04,3 HNE.

Pour le **coucher**, nous avons à 40° N, 16:57 (2 nov.) et 16:53 (6 nov.). Nous utiliserons 16:54 (5 nov. à 40° N). Nous avons, à 45° N, 16:47 (2 nov.) et 16:42 (6 nov.). Nous utiliserons 16:43,2 (5 nov. à 45° N).

Maintenant nous interpolons pour la latitude 43° en prenant trois cinquième de la différence de 10,8 minutes. Nous trouvons 16:47,5 (5 nov. à 43° N).

Enfin nous appliquons la correction de +25 pour trouver que le coucher de Soleil du 5 novembre à London devrait avoir lieu à 17:12,5 HNE.

Le 5 novembre 2003, à London, le lever du Soleil à lieu 7:04,2 et le coucher à 17:12,5. La différence (17:12,5 7:04,2) donne la « durée du jour » tirée du tableau: $10^h\ 0^8$m.

Nous pouvons comparer ces valeurs tirées de l'*Observer's Handbook* avec celles de la ligne centrale du tableau plus haut (la ligne intitulée *réfraction*). Le tableau des levers et couchers du Soleil aux pages 108 à 110 de l'*Observer's Handbook* semble donner, à une minute près, des valeurs qui tiennent compte du rayon apparent du Soleil et de l'effet de la réfraction atmosphérique, mais pas du dip (qui dépend de la hauteur de l'observateur).

Autre cas spécial: l'équinoxe

À l'équinoxe, l'équation de la durée du jour promet une journée où la durée du jour est égale à la durée de la nuit (d'où on tire, du latin, *æqui* = égal, *nox* = nuit).

$$\cos \boldsymbol{h} = -\tan\delta \tan\phi = -\tan \mathbf{0}° \tan\phi$$
$$\cos \boldsymbol{h} = 0 \Rightarrow \boldsymbol{h} = 90°$$
$$2 \times \boldsymbol{h} = 180° \equiv 12^h$$

C'est d'ailleurs de cette application théorique que nous vient le nom du phénomène astronomique qui marque le début du printemps et le début de l'automne.

Mais cette durée du jour est calculée pour le centre du Soleil, sur l'horizon théorique. En pratique, il faut attendre que le limbe supérieur descende jusqu'à l'horizon théorique, puis ajouter l'intervalle pour qu'il passe de l'horizon théorique à l'horizon réel. Utilisons l'équation pour la correction :

$$\mathbf{T}\ \text{(en heure)} = \text{Correction} / (15° \times \cos\delta \sin \boldsymbol{h} \cos\phi)$$

où, cette fois, $\delta = 0°$, $\boldsymbol{h} = 90°$ et $\phi = 43°$, pour une correction de 0,75° (tenant compte du rayon apparent du Soleil et de la réfraction). Nous trouvons ainsi un intervalle de $4^m\ 06^s$ qui s'ajoute aux deux extrémités de la journée (matin et soir).

Ainsi, le jour de l'équinoxe, la durée du jour à London, corrigée pour les deux effets, est de $12^h\ 08^m\ 12^s$. Si, en plus, l'observateur est à 60 m au-dessus du sol, nous ajouterons deux fois $1^m\ 24^s$. Alors, cet observateur pourrait se demander pourquoi nous parlons d'équinoxe alors qu'il observe une journée plus longue ($12^h\ 11^m$) que la nuit ($11^h\ 49^m$).

Bibliographie

Gupta, R., ed. 2003, Observer's Handbook 2003 (University of Toronto Press: Toronto)

Hopkins, F.N., ed. 1968, Norie's Nautical Tables (Imray Laurie Norie and Wilson Ltd: Huntingdon, UK)

Le petit Larousse *2003* (Larousse/VUEF: Paris) `www.mapquest.com/maps/latlong.adp` pour localiser (sur une carte) une position donnée en latitude et longitude (précision non garantie)

Summary

This article follows on from a general article on the PZX triangle published in August 2003 (JRASC, 97, 163). This time, we solve the PZX triangle for the special case where the altitude of the Sun is 0° (*i.e.,* sunrise or sunset). This calculation

yields the hour angle at sunrise, which, by symmetry, is assumed to be equal to the hour angle at sunset. Using a rate of 15° per hour, we calculate the "Length of Day" (for stars, the hourly rate is 15.041°). Some calculations are also done using more accurate values (*i.e.,* by not accepting the assumption of symmetry) in order to show that the difference is minor.

Our example is set in London, Ontario, at the corner of Grosvenor and Waterloo streets. This intersection corresponds to the position 43° 00´ N 81° 15´ W. This is the position inferred from the data given for London in the table on page 107 of the *Observer's Handbook 2003* (London 43° +25E). That part of London is relatively flat and has relatively straight streets; therefore, we can compare theoretical calculations with practical observations.

We calculate theoretical sunrise and sunset for November 5, 2003, using transit times found on page 101 of the *Observer's Handbook,* then apply corrections for the apparent radius of the Sun's disc, for atmospheric refraction and for the "dip of the horizon" for an observer located well above the ground. The height of eye was chosen to create a total correction of exactly one degree.

We then use the *Observer's Handbook* tables to find the corresponding times of sunrise and sunset. We conclude that the *Observer's Handbook* data includes a correction for atmospheric refraction and for the Sun's apparent radius (*i.e.,* times are determined for upper limb rising and setting).

One important objective is to guide non-English-speakers through various pages of the *Observer's Handbook*.

Since you will not read this article in time to verify if London drivers are blinded by the setting sun on November 5, 2003, at the corner of Grosvenor and Waterloo, check around February 7, 2004 (using the *Observer's Handbook 2004,* of course). ◉

L'auteur est membre de la Société royale d'astronomie du Canada (SRAC) depuis 1969. Il a été officier de navigation maritime à bord des navires de la Garde côtière canadienne, professeur à l'Institut de formation de Transports Canada puis doyen des sciences nautiques au Collège de la Garde côtière. Il a enseigné la navigation astronomique, c'est-à-dire l'utilisation de l'astronomie pour déterminer la position du navire. Toujours à l'emploi de Transports Canada (loi et règlement sur le transport des marchandises dangereuses), il dit se préparer pour une retraite prochaine. En plus de son diplôme en sciences nautiques du collège de la Garde côtière, il détient un Baccalauréat ès Arts général (littérature française) et un B.A. avec concentration en mathématiques. Il va bientôt compléter un B.A. avec spécialisation en mathématiques. En 1989, il a reçu la médaille du service (Service Award) de la SRAC et a été Secrétaire national de la SRAC de 1997 à 1999. Il est aussi membre de la Société d'astronomie de Montréal où il a été conseiller au début des années quatre-vingt.

The author has been a member of the RASC since 1969. After working as a marine navigation officer, he has taught nautical astronomy (the use of astronomy in marine navigation) and was a dean of Nautical Science. In addition to his Coast Guard College degree in Nautical Science, he holds a B.A. (French Literature) and a B.A. with concentration (mathematics); he is completing a B.A. with Honours (mathematics). He received the RASC Service Award in 1989 and served as National Secretary of the RASC in the late nineties. He still works for Transport Canada (Transportation of Dangerous Goods) and claims to be preparing for retirement.

Not Much Water on the Moon

by Leslie J. Sage (l.sage@naturedc.com)

The past eight years there have been multiple claims — based on data from two different spacecraft — about the presence of fairly significant quantities of water ice on the Moon, in craters that are permanently shadowed from the Sun. Other evidence — from Earth-based radar — has suggested that the amount of ice is negligible. A new study by Bruce Campbell of the Smithsonian Institution and his collaborators, using radar from the Arecibo Observatory in Puerto Rico, has failed to find the signature of thick ice deposits (see November 13, 2003 issue of *Nature*). What's going on here?

First of all — and somewhat surprisingly — it is physically reasonable that some water ice exists on the Moon. Even Mercury has ice at its poles, and that ice seems to exist in thick layers (see the May 19, 1994 issue of *Nature*).

Ice is carried on comets and other bodies that periodically hit the inner planets, and some quantity of that ice could survive in regions that are permanently in shadow. These regions occur inside craters near the lunar north and south poles (because of the topography, there is more shadowed area near the Moon's south pole). Lest you think that it is not possible for comets to carry much water to a planet, I should point out that there are reasons to believe that a good fraction of Earth's water — and we have a lot of it — was delivered through cometary impacts. The complication with the Moon's situation is that its orbit shifted considerably about two billion years ago, and that exposed what were previously the poles to sunlight — this would have eliminated any ice that had accumulated up to that point. Most of the water delivered to the Earth came in more than 3.6 billion years ago, when impacts were much more frequent than they are now.

Estimates of the amount of ice that could still be on the Moon have ranged to more than a hundred million metric tons (though the higher amounts were always "optimistic") — about the amount of a small-ish lake in northern Ontario. But less than a tenth of that seems more realistic.

This brings us to the earlier claims supporting the presence of ice. The first such arose from the *Clementine* mission (in 1994) — a low-budget defense rocket mainly designed to show off new technologies — which used their telemetry radar to look for the signature of ice (the reflected radar was picked up by the Goldstone Deep Space Network antenna). That signature was seen only near the Moon's south pole, but on the other hand the permanently shadowed part of the south pole was studied on only one orbit. The claim of evidence for ice — which first was made public in 1996 — was never definite. The scientists involved in the mission were excited, but conceded that the signal was only strongly suggestive that there was permafrost-like soil. The data implied the presence of layers of ice at least several tens of centimetres thick not too far below the surface. They subsequently concluded that the ice was about 1% by weight of the soil.

But a year later a radar study — using Arecibo — found no evidence for water. This study used relatively short wavelength radar, so it did not probe more than about 10 cm deep, and therefore was judged to be not at all definitive.

In 1998 the *Lunar Prospector* mission reported more evidence for ice in the lunar soil (technically, it's a regolith, since there are no organic materials in it). This time, the spacecraft had on it a "neutron spectrometer," which measures the energies of neutrons coming from the lunar surface. They originate when energetic cosmic rays hit the surface of the Moon, shaking loose some neutrons from the atomic nuclei in the soil. If those neutrons encounter hydrogen atoms — with which they interact strongly — the effect of the encounter is firmly established in the energy spectrum of the neutrons. This happens similarly to the way colours of objects on Earth are established by the light that is reflected off them. While the *Lunar Prospector* therefore did not directly find water — it simply found the signature of hydrogen — it was a reasonable assumption that the hydrogen was in water ice, given the earlier *Clementine* data. The two results were seen as supporting each other.

As the *Lunar Prospector* mission was reaching its end, NASA decided to crash it into one of the permanently shadowed craters, permitting Earth-based telescopes (including the *Hubble Space Telescope*) to analyze the puff of material that would be blown out by the collision. It was reasoned that the energy of the collision should dissociate some of the water molecules, which could be traced by ultraviolet emission from the OH fragments of those molecules. Although it was estimated that the chances of seeing the emission were somewhat low (about 10%) due to numerous technical issues, it was clear that a positive detection would be very important, so the attempt was made. No emission was seen, but of course with all the technical reasons originally cited as making that the likely outcome it was not regarded as in any way definitive.

Why should we care if there's some ice near the Moon's south pole? For anyone interested in a permanent lunar base, the presence of water is crucial. As every backpacker knows, water is heavy. It would cost a lot to boost water from the Earth to the Moon. Each person in North America uses on average about 400 litres of water per day, and each litre has a mass of 1 kilogram. It costs about $5,000 US to put a kilogram of material into low Earth orbit on the shuttle, and going to the Moon costs more. In addition to personal human uses, the water could be separated into hydrogen and oxygen for use as fuel for spacecraft going further out in the Solar System. (The energy for the separation would come from sunlight.) Therefore, anyone who is keenly interested in the Moon or in sending humans further out in the Solar System would be very enthusiastic about the presence of water there. The optimistic estimates of the abundance of water on the Moon must be viewed in that light.

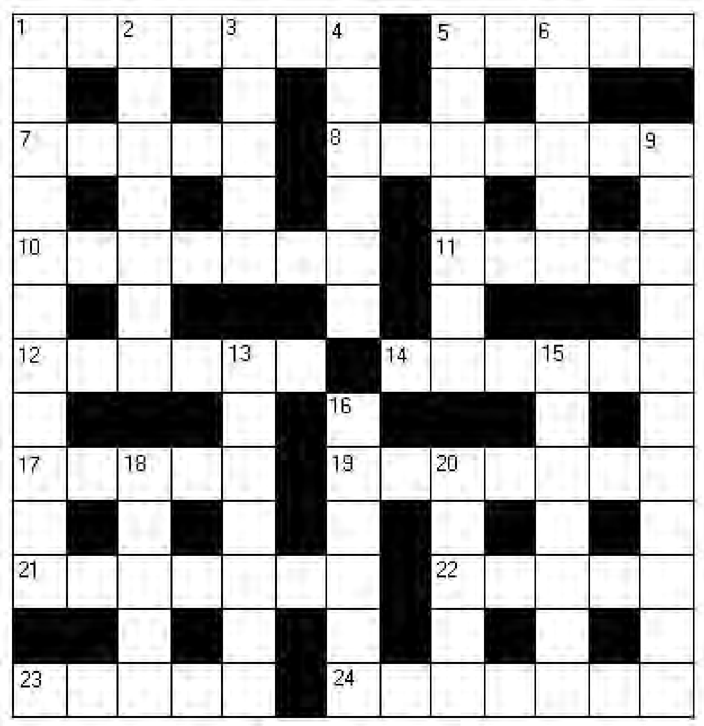
But science is self-correcting. The more important a claim is, the more it will be scrutinized, and this has happened with the water on the Moon. Campbell and his colleagues have now used long-wavelength radar, which penetrates several metres deep into the lunar soil, and therefore is much more definitive than the earlier Earth-based radar study. Campbell showed that there are no thick layers of ice on the Moon — any ice that does exist must be in scattered grains or very thin layers. This changes the outlook for mining the ice, because it is hard to see how it could be recovered in a useful way.

Is this the last, best answer? Almost certainly not. I believe that — for various reasons (some political) the question of ice on the Moon (and on Mars) will not be definitively answered until humans have visited the sites and seen for themselves. Sometimes science as it is practiced in real life is not pretty or elegant — it often consists of the kind of back and forth arguments seen in this case.

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

Astrocryptic

by Curt Nason, Moncton Centre



ACROSS

1. Her lips parted for his radial velocity work (7)
5. His electron theory described air exchange in direct current (5)
7. Stagger around Polaris like charges do (5)
8. Vengeful goddess perhaps perturbs the Oort cloud (7)
10. Such stars are powerful where campers sleep soundly (7)
11. Cinematic clash participant outside the rings (5)
12. Reduced aperture for Hallowe'en observing? (6)
14. Capella first rises over the lunar sea (6)
17. James at first was oddly sane with his radiation theory of stellar energy (5)
19. Variable observing factor is often discussed (7)
21. Henry slues around in the Roche lobe (7)
22. When old, it's routine to figure a mirror (5)
23. Element seen back in cabin or observatory construction (5)
24. Loony mare rut was but a typo (7)

DOWN

1. Trim soy jars around the prominent Martian feature (6,5)
2. Variable moon uses ape suit disguise (7)
3. Spartan queen went to Paris believing the stars belong to everyone (5)
4. Messier is one in NY lunar mission (6)
5. Met deer around Ceres in Greece (7)
6. X-ray mapper ruined the roast (5)
9. Unusual Sirius mud in lunar bay (5,6)
13. Poetic e'en star misplaced morning star in this sky (7)
15. CD Smith made a fast camera for astrophotography (7)
16. Herculean tasks counted at noon (6)
18. Goose stars in the fox's mouth (5)
20. Cosmic ray pioneer may be a bit boring (5)

Bohemian Astronomy

by David M.F. Chapman (dave.chapman@ns.sympatico.ca)

Last Autumn, a work trip took me to the Central European cities of Budapest and Prague, in countries I once thought I would never visit, owing to their location behind the Iron Curtain. However, since the thawing of the Cold War, Hungary and the Czech Republic have become more open to the West, and in fact both have recently joined NATO. Both cities — but especially Prague — are steeped in history and culture, and I was surprised to learn how little I knew about this city and the famous people that have lived there. In particular, it turns out that there is a significant amount of astronomical history in Prague, some of which I would like to share.

In preparing for the visit, I learned that both Tycho Brahe and Johannes Kepler lived and worked in Prague during the reign of Emperor Rudolph II of the Holy Roman Empire. In 1597, Brahe had lost his patronage post in Denmark, and he moved to Prague at Rudolph's invitation. Very soon, Kepler arrived from Austria (partly for religious reasons) to become Brahe's assistant. Tycho died in 1601, but Kepler stayed on, working with Brahe's astronomical data. He published *Astronomia Nova* in 1609, in which he revealed two of his laws of planetary motion concerning elliptical orbits. Kepler eventually became the Imperial Mathematician, and he named his published tables of planetary positions the Rudolphine Tables in honor of his patron. The day I arrived in Prague, I actually walked right by one of Kepler's former residences without knowing it. It is situated at 4 Karlova, a busy shopping street. Later, I went looking for it, and finally succeeded: it is now a hair salon!

The following day, Sunday, was an "off" day for me, as my symposium did not start until Monday. I walked from my hotel to Prague Castle, later discovering that I had walked along Tychonova Street. At the castle, I entered through the Summer Garden near the Belvedere, or Summer Palace. Brahe and Kepler are said to have made planetary observations from here, although I believe that most of Brahe's observing nights were behind him at this time.

Later the same day I went to the National Technical Museum in another part of the city, hoping to find out more about Brahe and Kepler. As luck would have it, the museum had mounted a special exhibit

Figure 1. — Number 4 Karlova, a former Prague residence of Johannes Kepler. (all photos by David Chapman).

Figure 2. — The plaque above 4 Karlova, Old Town, Prague.

(August–November 2003) entitled "Kepler and Prague" and I spent a good hour touring the displays. There were plenty of sextants and other instruments, and a pretty detailed history of Kepler's time in Bohemia. (He was not a happy camper!) I was disappointed that the museum bookstore did not have any material on the exhibition.

The Kepler exhibit is just one part of a larger European Union project called "The World View Network" that celebrates the accomplishments of Copernicus, Brahe, Kepler, Galileo, and Newton. The Web site for this project is `www.landskrona.astronomy.museum`.

Another day I attempted to visit the location of Brahe's tomb, inside the Tyn Church in the Old Town Square, but the church is not open to tourists, only for scheduled masses. Nearby is the Old Town Hall with its Astronomical Clock, which dates from the fifteenth century. Every hour, visitors congregate to watch the mechanical apostle-puppets parade past the windows as the clock chimes; the clock has other animated figures such as Death and Vanity. I had a hard time reading the clock, but my guidebook claims that it tells three kinds of time and demonstrates the motion of the Sun and the Moon through the Zodiac. I tried to find a book or brochure about this device, with no success; however there is a Web site: `koti.mbnet.fi/oddball/aiheet/astro/praha2003/orloj.en.shtml`. I did find a T-shirt, but it said "Astrological" Clock. My guidebook also called Brahe and Kepler "astrologers." (It is true that Kepler had his mystical side, and even cast horoscopes.)

On the last full day of my Prague visit, I walked from the hotel past the Prague Castle to another district in the city in which both Brahe and Kepler once lived. Here on Keplerova Street I found a large double statue of Brahe and Kepler, erected in 1984. This was at the edge of a popular city park called Petrin Hill. In the park itself, there is an observatory that is open to the public six days (and nights) a week. The observatory is named for Milan Stefanik, a Slovak astronomer,

Figure 3. — A double statue of Tycho Brahe and Johannes Kepler on Keplerova Street, Prague.

superb. (Warning: I had my wallet lifted in the subway, but I won't let that spoil my memories.)

David (Dave XVII) Chapman is a Life Member of the RASC and a past President of the Halifax Centre. By day, he is a Defence Scientist at Defence R&D Canada–Atlantic. Visit his astronomy page at `www3.ns.sympatico.ca/dave.chapman/astronomy_page.`

Figure 4. — The three domes of Stefanik Observatory, Petrin Hill, Prague.

military general, and politician. In front of the observatory is a complex multi-dial sundial/sculpture, including an Equation of Time component. The Czech-only Web page for the observatory is: `www.observatory.cz.`

After I returned home, I discovered that others have made the astronomical pilgrimage too. In fact, a fellow from Finland toured the city in March 2003 and it almost seems that I followed in his footsteps; his Web site is `koti.mbnet.fi/oddball/aiheet/astro/praha2003/index.en.shtml.`

Reading his travelogue, I found out that I had totally missed the Klementinum, the former Jesuit College that now houses the National Library. The college Observatory Tower was used for astronomy, long after Kepler's time. I also missed the Planetarium, which is in another city park near the train station. Oh well, next time...

Sometimes the most enjoyable parts of a trip are those "found" opportunities that are not planned. Such is the case with my visit to Prague. I criss-crossed the city several times seeking astronomical sites, and I thoroughly enjoyed getting lost and finding spots I had no idea existed. I will definitely go back, and I would recommend the city to anyone traveling in that part of the world. I did not find it expensive, and one can manage tolerably well in English. The transit system is

Figure 5. — The multi-dial sundial at Stefanik Observatory, Prague.

STAR NIGHT

On the grounds of Lower Canada College, the Montreal Centre held its first public "Star Night" — the most ambitious undertaking of the Centre to date. Well advertised by newspaper and radio, the event was planned originally for Wednesday but due to unfavourable weather conditions had to be postponed each evening until Saturday when the sky finally cleared. This postponement undoubtedly affected the attendance but nevertheless several hundred people arrived on the Saturday from all parts of the city.

Long before dark the crowds began to gather and watched with interest while the telescopes, nine in number, were being assembled and set up in position. These included three reflectors and six refractors. The reflectors, two 5-inch and one 8-inch mirrors, were made by their owners, F. W. Henshaw, J. Naubert and Jacques Labrecque. The refractors ranged from a portable Zeiss to a 4-inch Zeiss and a 4-inch "Lancaster." The Centre's 6-inch refractor could not be transported to the college grounds, being permanently mounted now in the Ville Marie Observatory. Judging by the questions and comments, the different types of instruments and mountings aroused almost as much interest as the celestial objects viewed.

The program began officially at nine o'clock when Daniel P. Gillmor, President of the Montreal Centre, addressed a few words of welcome to the visitors. The microphone was then handed over to Mr. F. DeKinder who gave a short talk on the Moon, Jupiter and Saturn, while long queues of spectators formed at each telescope to view these objects. The Moon, considerably older and brighter than on the original date, tried to steal the show, but the two planets came in for their fair share of attention. Later, as the sky darkened, Mr. DeKinder proceeded to point out the main constellations, telling many interesting facts and legends about each.

Arrangements for "Star Night" were under the direction of DeLisle Garneau, Director of Observations of the Montreal Centre, assisted by his committee. Programs handed out at the gate to each visitor, gave information regarding the objects to be viewed. Separate enclosures, roped off for each telescope and bearing signs indicating the object on which the telescope was turned, facilitated the handling of the crowds, while the public address system, which carried Mr. DeKinder's talk on the constellations to all corners of the grounds, kept the people from becoming restless while waiting their turn at the telescopes.

"Star Night," the first event of its kind to be held in Montreal, was in the nature of an experiment, but judging by its success it is evident that it appealed to the public of Montreal, and the Montreal Centre will probably make it an annual event.

by Isabel K. Williamson,
from *Journal,* Vol. 39, p. 415-416, December, 1945.

Research Papers
Articles de recherche

THE MILLMAN FIREBALL ARCHIVE II: “SOUND REPORTS”

By Martin Beech

Campion College at the University of Regina, Saskatchewan
Electronic Mail: beechm@uregina.ca

(Received June 19, 2003; revised November 17, 2003)

Abstract. A total of 3878 report cards pertaining to 2131 fireball events observed from across Canada, in the time interval from 1912 to 1989, are contained within the Millman Fireball Archive. A further 410 report cards relate to 315 fireball events recorded by observers in the United States. Of these reports 153 mention the occurrence of sonic booms, 97 mention the presence of simultaneous (electrophonic) sounds, and 12 mention seismic effects. We find that the combined data suggest that sonic booms are most likely to be reported from fireballs observed in February and August, while simultaneous sounds are most often reported from fireballs observed in April and August. The generally enhanced number of sound-generating fireballs reported between the months of January and April is keyed, we suggest, to the meteorite fall rate, which is also enhanced over the same time interval. We find some evidence to suggest that bright August Perseid meteoroids might produce short duration (so-called burster) simultaneous sounds. The typical reported characteristics of sound producing fireballs are found to be as follows. Of the simultaneous sound-producing fireballs some two-thirds are brighter than magnitude -10; about half have durations lasting between $1 \leq D(\text{sec}) \leq 5$; about half constitute single non-fragmenting fireballs that show no obvious bursts or flares, and of those fireballs that do fragment some two-thirds break into four or more components. Of the sonic-boom-generating fireballs some seven-eighths of events are brighter than magnitude -10; about half have durations lasting between $1 \leq D(\text{sec}) \leq 5$; about half constitute single non-fragmenting fireballs that show no obvious bursts or flares, with some one-third of the remainder displaying just one observed burst or flare. If fragmentation does occur in a sonic-boom-generating fireball then some three-quarters of such events produce four or more observable fragments.

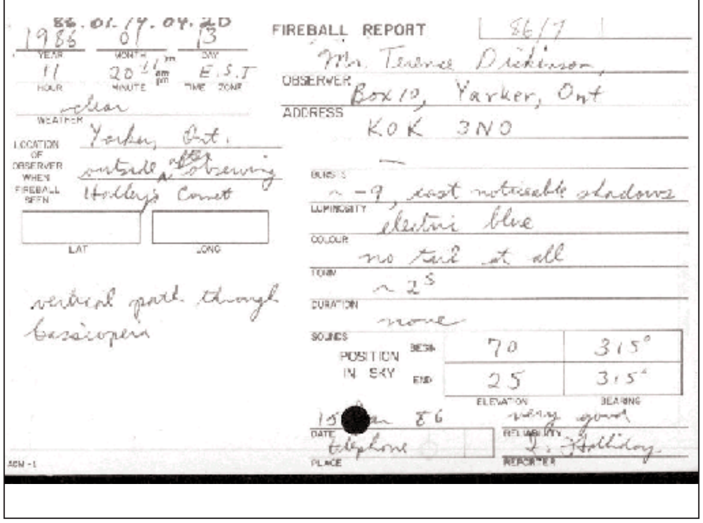
Résumé. Les archives Millman contiennent 3 878 rapports au sujet de 2 131 chutes de bolides observés à travers le Canada durant la période de 1912 à 1989. Quelques 410 comptes rendu additionnels concernent 315 chutes de bolides faits par des observateurs aux États-Unis. Parmi ces rapports, 153 mentionnent des circonstances de grondements soniques, 97 mentionnent la présence de grondements simultanés (électrophoniques) et 12 autres mentionnent des effets séismiques. Basé sur toutes ces données, nous trouvons que les rapports de grondements soniques sont plus probables durant les chutes de bolides ayant lieu aux mois de février et d’août, tandis que les grondements simultanés sont plus souvent mentionnés lors des chutes de bolides observés en avril et en août. Nous suggérons que le nombre croissant de mentions de bolides soniques durant les mois de janvier à avril est lié au taux aussi croissant de tombées de météorites durant cette période de l’année. Il nous paraît évident qu’une forte tombée des Perséides au mois d’août pourrait produire des grondements simultanés de courte durée (soit-disant éclat de son). Les caractéristiques typiques des bolides produisant des sons sont décrites comme suit : quelques deux-tiers des bolides produisant des grondements simultanés sont plus brillants que magnitude -10 ; environ la moitié de ces cas ont une durée d’entre $1 \geq D(\text{sec}) \geq 5$; aussi, près de la moitié sont des bolides non-fragmentés, indiquant aucun éclat ou flamboiement évident ; parmi les bolides qui se fragmentent, les deux-tiers se cassent en quatre morceaux ou plus. Quelques sept-huitièmes des chutes de bolides produisant des grondements soniques sont plus brillants que magnitude -10 ; environ la moitié de ces cas ont une durée d’entre $1 \geq D(\text{sec}) \geq 5$; près de la moitié sont des bolides non-fragmentés sans aucun éclat ou flamboiement évident, et un tier du reste produisent seulement un éclat ou flamboiement. Si la fragmentation de bolides produisant des grondements soniques a bien lieu, les trois-quarts de ces chutes produisent quatres morceaux ou plus.

> *What is this sound and rumour? What is this that all men hear,*
> *Like the wind in hollow valleys when the storm is drawing near?*
> — William Morris

1. Introduction

The Millman Fireball Archive (MFA) constitutes a series of fireball observation records mostly gathered from across Canada in the time interval from January 1962 to October 1989, although several historical reports date as far back as 1912. The archive is named in honour of Dr. Peter Millman who oversaw its initial organization in the early 1960s (Beech 2003; Halliday 1991). The Archive was originally maintained at the National Research Council (NRC) in Ottawa, Canada and was administered through the Associate Committee on Meteorites (ACOM), now the Meteorites and Impacts Advisory Committee (MIAC)[1] to the Canadian Space Agency.

The reasons for initiating a fireball archive in the early 1960s were to aid in the possible detection and recovery of new meteorites from within Canada, and, although not officially a part of the highly successful Meteorite Observation and Recovery Project (MORP;



86.01.14.04.20

FIREBALL REPORT 86/7

YEAR 1986 MONTH 01 DAY 13

HOUR 11 MINUTE 20 pm TIME ZONE E.S.T

OBSERVER Mr. Terence Dickinson,

ADDRESS Box 10, Yarker, Ont

K0K 3N0

WEATHER clear

LOCATION OF OBSERVER WHEN FIREBALL SEEN Yarker, Ont.

outside after observing Halley's Comet

LAT

LONG

vertical path through Cassiopeia

BURSTS —

LUMINOSITY ~ -9, cast noticeable shadows

COLOUR electric blue

TRAIN no tail at all

DURATION ~ 2^s

SOUNDS none

POSITION IN SKY	ELEVATION	BEARING
BEGIN	70	315°
END	25	315°

DATE 15 [illegible]an 86

RELIABILITY very good

PLACE telephone

REPORTER I. Halliday

ACM-1

Figure 1. — Scanned image of an MFA report card completed for a fireball witnessed (by a well-known astronomer) at 04:20 UT on January 14, 1986. The report was the seventh to be received in 1986 (see top right hand corner), and the observational details were recorded by Dr. Ian Halliday at the NRC. In this particular case no sounds were reported to accompany the fireball.

Halliday *et al.* 1996) the archive did, on occasion, provide additional eyewitness data on very bright, potentially meteorite dropping, fireball events. In particular, the eyewitness accounts could supplement the MORP camera data by providing information on occurrence time, trail duration, train colour, and sounds. Both sonic booms and simultaneous (also called electrophonic) sounds are described in the MFA, and in the sections below we discuss the general characteristics of the sound-generating fireballs. To give some idea of how the MFA is structured, Figure 1 shows a scanned copy of a report card (a so-called ACM-form 1 card). Reports on fireball events were received at the NRC via letter, telephone, telex, and through personal interviews with the observational details being transferred to a report card. The report cards were then archived according to the date and time of the event. Not every report card was fully completed and the various descriptions are often terse and occasionally rather cryptic. Many, but not all, of the cards within the MFA have complementary and detailed letters received from the eyewitness, and in our analysis it is both the letter and card information that we have examined.

2. Meteor Sounds

It is not our intention to review in detail here the mechanisms responsible for generating meteor sounds. Indeed, the mechanisms for sound generation are physically complex and in a number of aspects only poorly understood at the present time. The two main categories of fireball related sounds, however, are sonic and simultaneous (LaPaz 1958; Annett 1980; Ceplecha *et al.* 1998). The former are distinguished in that they are typically heard several minutes after the fireball has passed, while the latter are anomalous in that the fireball and sounds are witnessed concomitantly.

Sonic booms result from the generation of shock waves in the Earth's lower atmosphere. The essential picture is one of a fireball producing a cylindrical blast wave as it descends at hypersonic speeds through the Earth's atmosphere. The propagation of the shock waves and the distribution of the audibility zones, where the sonic booms might actually be heard, are determined by the local atmospheric conditions and prevailing winds (ReVelle 1975, 1997). Sustained simultaneous sounds, on the other hand, are believed to be generated via an interaction between the turbulent plasma column trailing behind an ablating meteoroid and the Earth's magnetic field (Keay 1980a, 1993; Bronshten 1983). This interaction, often described as a magnetic entanglement or "spaghetti" model, is believed capable of generating very low frequency (VLF) electromagnetic radiation. It is the transduction of the VLF electromagnetic radiation, by a suitable medium close to the observer, that ultimately results in the generation of audible, simultaneous sounds (Keay 1980b; Tatum & Stumpf 2000). In addition to the magnetic entanglement model, it has also been suggested that short duration, or "burster" simultaneous sounds (often described as sounding like "pops" and "vuts") might be generated as a consequence of shock waves propagating along the fireball's plasma column (Beech & Foschini 2001). It has become common practice, in recent years, to describe simultaneous sounds as being electrophonic. While the electrophonic label does express the apparent physical origin of such sounds, we shall continue to use the term simultaneous in this paper since it is the simultaneity between the sound and the passage of the fireball that is the key observable characteristic.

3. The MFA Sound-Generating Fireballs

Table 1 is a summary of the number of fireball accounts within the MFA relating to sound phenomenon. The Canadian data relate to fireball events witnessed in the time interval 1912 to 1989. The US data relates to fireball events observed between 1962 and 1989.

Table 1.

Summary of data records and event counts contained in the MFA.

Country	Reports	Events	Sound reports (%)	Sound events (%)
Canada	3878	2131	268 (6.9)	143 (6.7)
United States	410	315	20 (4.9)	19 (6.0)

We have distinguish in Table 1 between "reports" and "events," such that, by "events" we mean the observation of a specific fireball and by "reports" we refer to the total number of report cards engendered by a particular event. Most "events" generated just one "report," but some very well observed "events" produced hundreds of "reports." The April 26, 1966 event, for example, generated a total of 246 "reports" from across Ontario and Quebec.

The reported characteristics of the MFA sound-producing fireball events will not be given in tabulated form in this paper, but the data may be accessed from the MIAC Web page[2]. We have distinguished between "sonic booms" and "simultaneous" sounds, as best we can, according to the descriptions given in the reports. Comments such as "booms," "rumbling like thunder," "roaring like a jet aircraft," "explosions," and "bangs" are taken to be sonic booms, and especially so if there was a delay in hearing such retorts. In contrast, when comments like "crackling," "popping noise," "hissing," "screeching," "like a sky rocket," and "air rushing noise" are used we count the description as being simultaneous and especially so when the sound was stated as being heard concurrent to the passage of the fireball.

In our earlier, general analysis paper on the MFA (Beech 2003) it was noted that the average yearly percentage of fireball events generating some "sound" phenomenon was remarkably constant at 7.6 ± 3.5 percent. Further to this, we note here that Norton (2002), without supporting references, comments that "between 4 and 8%" of fireball events are accompanied by sound phenomena. The implications are, therefore, that of order one in thirteen fireball events has some associated "sound" characteristic. Sears (1978) presents data on the sound-generating characteristics of 20 fireballs associated with meteorite falls. Although only a small sample was considered, Sears finds that 17 (85%) of the events were accompanied by "explosions," presumably related to sonic booms. In addition, 9 (45%) of the fall events were accompanied by simultaneous sounds. During the time interval over which the MFA was actively maintained a total of four meteorite falls occurred in Canada[3]. Of these events, 3 (75%) produced MFA reports that specifically mention either sonic booms and/or simultaneous sounds. The one event that has no MFA reports signifying the occurrence of sounds was the Innisfree meteorite fall of February 5, 1977. Other eyewitness accounts not contained in the MFA do clearly indicate, however, that distinct simultaneous sounds did accompany the passage of the Innisfree fireball (Halliday *et al.* 1978). Indeed, with respect to organizing meteorite fall searches, McCall (1973) argues that only those "reports of falls which do include descriptions of sound effects are worth following up." While the general consensus appears to be that meteorite-dropping fireballs are highly likely to be accompanied by sound phenomena, it is not necessarily the case that every sound-generating fireball results in the delivery of a meteorite.

4. Seasonal variation of events

The monthly distribution of sound-generating fireball events is shown in Figure 2. Two reasonably distinctive peaks are discernible in the monthly data with one broad peak running from January through February, and the other occurring in August. A distinctive minimum is evident in June. The monthly distribution of sonic and simultaneous sound events is compared in Table 2 along with the simultaneous sound data reviewed by Kaznev (1994) who studied an extensive fireball data set gathered by Russian observers.

Given the high probability that a meteorite-preceding fireball will produce some accompanying sounds (Sears 1978; McCall 1973), one might expect a correlation between the monthly meteorite fall rate and the sound-generating fireball distribution shown in Figure 2. Hughes (1981) has analyzed the "observed" monthly meteorite fall rate and finds that it is maximized between April and mid-October and minimized between November and March. This result, however, does require careful interpretation with respect to numerous selection effects. Indeed, Halliday & Griffin (1982) show that the meteorite fall rate actually maximizes between November and March and is at a minimum between July and October (as indicated by the solid line in Figure 2). It appears, therefore, that while the longer nighttime hours in the winter months favour fireball observations, the harsher weather conditions hamper the recovery of meteorites even though the recovery conditions are perhaps at their best when the ground is frozen and vegetation is sparse. The enhanced numbers of sound-producing fireball events for January through April probably relate, therefore, to the relatively enhanced arrival rate of meteorites to the Earth in those months. The relative dearth of sound-producing fireball events in November and December, in turn, probably reflect the generally poor observing conditions prevalent in those months.

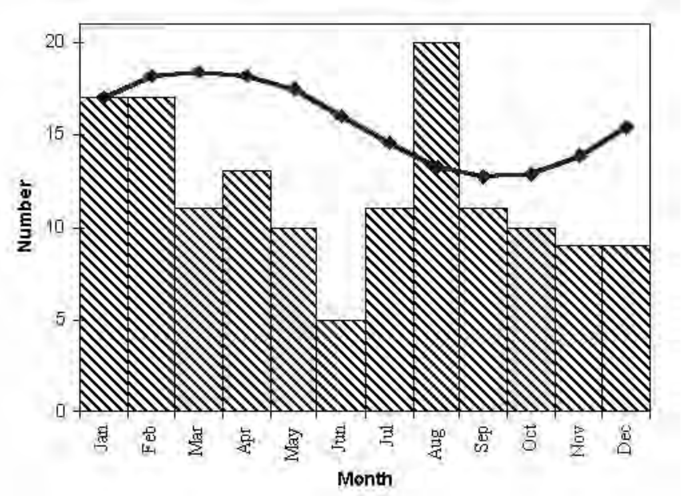


Figure 2. — The monthly distribution of "sound-" generating fireball events. The solid line shows the predicted variation in the relative meteorite fall rate, for latitude 52° N, as calculated by Halliday & Griffin (1982) and arbitrarily normalized to the January fireball count. The relative monthly variation in the histogram data would follow that of the curve derived by Halliday and Griffin if there were no seasonal selection effects in observing fireballs (and if all sound-generating fireballs were due to meteorite dropping events). As it is, the late fall and early spring observations suggest under sampling of sound-generating fireballs — this is presumably a "poor weather" related selection effect. The August observations are relatively "over" sampled but may also include a contribution related to sound-generating fireballs from the Perseid stream.

Judging from the Table 2 data it would appear that the August peak is related to enhanced rates of both sonic and simultaneous sound-generating fireballs. The August peak is also clearly represented in the simultaneous sound data gathered by Kaznev (1994). Since the well known, and well observed, Perseid meteor shower occurs in mid-August it might be suggested that it is responsible for the enhanced numbers of sound generating fireballs. We find, however, that this is unlikely. The collected data indicate that 7 out of the 28 sound generating fireball events observed in the month of August occurred within a seven day window centered on August 13, the time of the Perseid shower maximum. This "window" should capture events possible derived from the Perseid stream. Of the 7 events reported, 5 produced sonic booms and 2 were simultaneous. Since, however, Perseid meteoroids are cometary in origin (*i.e.,* derived from comet 109P/Swift-Tuttle) it is unlikely that they can penetrate deep enough into the Earth's atmosphere to produce sonic booms[4]. We suggest, therefore, that the August peak is probably the result of an observational selection effect. Essentially, we would argue, more people go out observing at the time of the Perseids, because the weather is typically fine and because it is known that a good "show" is likely to be seen. Since more people are out observing at the time of the Perseids, a greater number of non-Perseid fireball events will be observed and reported. In this respect, we note that the enhanced August reporting trend is also present in the overall fireball reporting rate (see column 9 of Table 3 in Beech 2003). The two simultaneous sound-producing fireballs in our seven day "Perseid window" are perhaps deserving of a little more attention since both occurred close to the time of the Perseid maximum. The events were observed on August 12, 1969 at

03:35 UT and August 12, 1979 at 09:30 UT. The first event was described as lasting for 3 seconds and was "brighter than Mars." The second event was described as lasting for a "few seconds" and being "very bright." We immediately run into difficulties with the duration times given for these two events since, we note, of the 27 MORP camera-detected Perseid fireballs not one lasted longer than one second. Hence, we are either dealing with exceptional Perseid fireballs (and the sound associations possibly support this supposition) or the duration estimates contain some considerable error (see below). With the above being said we note that the reported speed and direction of the 1969 event are consistent with it having been a Perseid shower member. The meteor apparently left a trail that lasted for some 10 seconds, and the report card indicates a "faint crack heard during mid-flight." The 1979 event was described as sounding "like [a] rocket taking off," but it is not clear from the report if it was truly a Perseid shower member. We note here, for comparison purposes, that the short duration, simultaneous sound event recorded by Beech *et al.* (1995) was observed at the time of the Perseid maximum on August 11, 1994. While large, tens of centimeter-sized Perseid meteoroids might conceivably produce simultaneous sounds, a survey by Beech & Nikolova (1999a) concluded that such large meteoroids must, at best, be a very rare commodity within the Perseid stream. Barabanov et al. (1996) have reported, however, upon the telescopic detection of multi-metre-sized objects within the Perseid stream (seen while they were passing Earth by outside of its atmosphere), but a similar telescopic survey by Beech *et al.* (2003), found no supporting evidence for the existence of such large meteoroids.

In addition to the August peak, a distinctive maximum in the number of simultaneous sound events is evident for April (see Table 2 and Figure 2). The April peak in the MFA data is not, however, apparent in Kaznev's study; this is possibly a result of the comparatively lower number statistics prevalent in the MFA data. Two of the April observed simultaneous sound-producing events were recorded on the night of the Lyrid meteor shower maximum (April 22/23). While there is some evidence to suggest that short-duration simultaneous sounds were heard during the 1803 Lyrid outburst (Beech & Nikolova, 1999b), neither of the events contained in the MFA can be sensibly linked to the shower. Hughes (1981) interestingly finds a distinct peak in the observed meteorite fall rate in April, which is close to the March maximum (see the solid line in Figure 2) predicted by the analysis of Halliday & Griffin (1982). The April peak is probably, therefore, related to the enhanced meteorite fall rate during the spring months and the generally improving weather conditions at that time.

A June minimum is present in all three of the data sets shown in Table 2, and it is clearly evident in Figure 2. Indeed, the minimum is also present in the over all MFA fireball data count (Beech 2003). The most likely explanation for the June minimum is the reduction of nighttime observing hours at the time of the Summer Solstice. That the June minimum is probably a short nighttime selection effect is further underscored by the fact that no similar minimum is seen in the observed meteorite fall data (Hughes 1981), and nor is it seen in the arrival rate of satellite-detected fireballs (Tagliaferri, *et al.* 1994).

Seismic phenomena were reported to accompany twelve of the sound-producing fireball events described in the MFA. These observations were presumably the result of sonic-boom related shock waves impinging upon the ground with the effect of producing surface-propagating seismic waves (see *e.g.,* Anglin & Haddon, 1987; Hildebrand *et al.* 1997). In principle the seismic data provides a valuable constraint upon the energy released during the fireball event (*e.g.,* Brown *et al.* 2003), and this, again in principle, can constrain the initial mass estimate of the incoming meteoroid. As far as can be gauged none of the MFA seismic-related fireball events were observed with sufficient detail to enable useful data on the parent meteoroid to be extracted.

Table 2.

Comparison of the monthly distribution of sound-generating fireball events. Columns 2 through 5 give the number and percentages (rounded to the nearest integer value) for the simultaneous and sonic-boom generating events catalogued in the MFA. The last two columns reproduce the data given by Kaznev (1994).

Month	Simultaneous	%	Sonic	%	Kaznev	%
January	9	12	8	12	56	10.5
February	5	7	12	18	47	8.8
March	7	9	4	6	32	6.0
April	10	13	3	5	33	6.2
May	4	5	6	9	44	8.2
June	4	5	1	2	40	7.5
July	8	10	3	5	49	9.2
August	10	13	10	15	74	13.9
September	9	12	2	3	42	7.9
October	7	9	3	5	39	7.3
November	1	1	8	12	41	7.7
December	3	4	6	9	37	6.9
	Σ = 77		Σ = 66		Σ = 534	

5. TYPICAL EVENT CHARACTERISTICS

There is probably no such thing as a typical sound-producing fireball event, but since the production of sonic and simultaneous sounds does require that certain physical conditions be satisfied we shall attempt to see what conditions favour the production of meteor sounds. We also derive the characteristics of a "control group" of 360 randomly selected, non-sound-generating fireballs. We note here that since many of the report cards were not fully completed the sample sizes being compared will vary according to the category under investigation.

Table 3 is a summary of the reported brightness estimates for those fireball events that were accompanied by sound phenomena. Given, however, that the majority of the reports in the MFA were produced by inexperienced observers we do encounter some difficulty in interpreting the comments relating to brightness. Observers, for example, commonly use expressions such as "bright," "very bright" and "extremely bright," "like lightning," or "like a welding arc," and the placement of a numerical magnitude upon such expressions is problematic. In the cases where observers used expressions such as "like Venus," or "like planets" we suggest that they are describing fireballs in the magnitude range −1 to −5. When observers use expressions such as "like the Moon" or "half as bright as the Moon" we have taken the magnitude to be in the range −5 to −10. It is our guess that expressions such as "bright," and "very bright" also fall somewhere in the magnitude range -5 to −10, but we have collated such accounts separately. When an expression such as "brighter than the Full Moon" has been used we ascribe to it a magnitude in the range −10 to −15. Events described as being "like daylight," or "the sky lit up like daytime" are given a magnitude in the range −20 to −25. We find that some 36% of simultaneous sound-producing fireballs have estimated magnitudes less than −10, while only 14% of sonic-boom-generating fireballs fall into the same brightness range. In general Table 3 appears to indicate that fireballs producing sonic booms tend to brighter than those fireballs that produce solely simultaneous sounds. Some 11% of the fireballs that produce sonic booms fall into the "like daylight" category (−20 ≤ mag ≤ −25), a value that is twice that derived for the fireballs producing simultaneous sounds. Likewise, column 4 of Table 3 indicates that in general fireballs that produce some accompanying sound phenomena tend to be brighter than those fireballs that apparently produce no sound.

TABLE 3.

Brightness estimates of "sound-generating" fireballs. The category "other" includes estimates such as "like lightning," "blinding," and "welding arc." Columns 2 and 3 give the number of reports and in brackets the percentage (rounded to the nearest integer value) of reports for each of the brightness categories. The last column is a control sample, picked at random, of non-sound-generating fireball events. The last row shows the sample size for each category.

Brightness	Simultaneous	Sonic Booms	Control
−1 to −5 (Venus)	20 (30)	9 (9)	109 (30.8)
−5 to −10	4 (6)	5 (5)	56 (15.8)
−10 to −15 (Moon)	13 (19)	20 (21)	40 (11.3)
−15 to −20	0 (0)	2 (2)	11 (3.1)
−20 to −25 (Daylight)	4 (6)	11 (11)	2 (0.6)
Bright (Brilliant)	6 (9)	10 (10)	41 (11.6)
Very Bright (Ext. Bright)	14 (21)	23 (24)	61 (17.2)
Other	6 (9)	16 (17)	34 (9.6)
	Σ = 67	Σ = 96	Σ = 354

One striking feature discernible in column 2 of Table 3 is the large percentage of simultaneous sound-producing fireballs having an estimated brightness less than magnitude −5. Drobnock (1992, 2002) has argued (although see Beech *et al.* 1995) that apparently "ordinary" meteors[5] can produce detectable "pulses" of VLF electromagnetic radiation, but it is not clear that simultaneous sounds can proceed from such events. It has been generally asserted on theoretical grounds that only fireballs brighter than magnitude −8 to −10 are likely to generate sufficient electromagnetic energy to produce simultaneous sounds (Keay 1980a; Beech & Foschini 2001). While we do not claim that the theory of simultaneous sound generation is fully described, it is none-the-less difficult to understand how apparently "ordinary" meteors can produce "sounds." Interestingly Vinkovic *et al.* (2002) report that some 37% of the reports received at the Global Electrophonic Fireball Survey[6] are attributable to fireballs less bright than magnitude −5. This observation certainly requires further study, but will only likely be verified as "real," as opposed to being some magnitude-estimation bias, through the careful and calibrated instrument study of sound-producing fireball events.

The distribution of duration estimates for sound-generating fireballs is shown in Table 4. Again, since most of the eyewitness reports are from inexperienced observers there is no doubt that some error in the duration estimates exists, however, the reported data suggests that ~55% of the fireballs that generate simultaneous sounds and/or sonic booms endure for between 1 and 5 seconds. In general, columns two and three of Table 4 suggest that with respect to duration there is no significant difference in the flight times of fireballs that generate simultaneous sounds and those that produce sonic booms. The sound-generating fireballs do apparently have slightly longer durations (in the 5 to 25 second duration ranges) than those fireballs that produce no sound (but see below).

Some measure of the observational error associated with fireball duration estimates can be gauged from the last two columns of Table 4. The data in these two columns is taken from MORP camera survey data presented in Table 3 and Table 4 of Halliday *et al.* (1996). The "fireball" data column indicates that only one MORP recorded fireball had a measured duration in excess of 10 seconds. Likewise the "meteorite" data column indicates that just one of the potential meteorite-dropping fireball events observed with the MORP cameras had a measured duration in excess of 30 seconds. We would suggest, therefore, that the large number of sound-generating fireballs with estimated durations in excess of 20 seconds is most probably due to the "tail" of the error distribution associated with eyewitness timing estimates.

TABLE 4.

Estimated duration of "sound-generating" fireballs. Events described as being a "flash" have been placed in the < 1 second category, while those events described as being "several," "few" and/or "brief" have been placed in the 1-5 second category. Columns 2 and 3 give the number of reports and in brackets the percentage (rounded to the nearest integer value) of reports for each of the duration categories. Column 4 is a control sample of non-sound-generating fireball events. Columns 5 and 6 are based upon MORP camera data (Halliday *et al.* 1996) — see text for details. The last row shows the sample size for each category.

Duration (sec)	Simultaneous	Sonic Booms	Control	MORP fireball	MORP meteorite
< 1 (Flash)	0 (0.0)	8 (7)	24 (6.7)	80 (37.6)	0 (0)
1 – 5	42 (57)	59 (53)	226 (63.3)	123 (57.7)	33 (72)
5 – 10	14 (19)	23 (21)	59 (16.5)	9 (4.2)	9 (20)
10 – 15	8 (11)	7 (6) 23	(6.4)	1 (0.5)	1 (2)
15 – 20	1 (1)	5 (5)	8 (2.2)	0 (0)	2 (4)
20 – 25	2 (3)	1 (1)	5 (1.4)	0 (0)	0 (0)
25 – 30	1 (1)	0 (0)	7 (2.0)	0 (0)	0 (0)
> 30	6 (8)	9 (8)	5 (1.4)	0 (0)	1 (2)
	Σ = 74	Σ = 112	Σ = 357	Σ = 213	Σ = 46

A summary of burst and flare-like events[7] for sound-generating fireballs is given in Table 5. About 50% of both the simultaneous and sonic-boom-generating fireballs are described as being single, continuous streaks of light with no apparent indication of flares, bursts and/or fragmentation events. Fireballs that generate sonic booms are about three times more likely to show a single burst or flare than those fireballs that generate simultaneous sounds, while simultaneous-sound-generating fireballs are some six times more likely than sonic-boom-generating fireballs to show "many" bursts.

Table 6 is a summary of the comments relating to fireball fragmentation. We distinguish between bursts and fragments on the basis that a burst need not result in multiple fireball components being produced[7]. It would appear that a fireball generating simultaneous sounds is about two times more likely to fragment into two or three components than a fireball that generates sonic booms. Also, a sound-generating fireball is some two times more likely to catastrophically break-up than a non-sound-generating fireball.

Table 5.

Burst observations for "sound-" generating fireballs. The row corresponding to "many" bursts was used to account for comments such as "bursting flames," "shower of sparks," "flares," and "pulsation." The last row shows the sample size for each category. The last column is a control sample of non-sound-generating fireball events.

No. of Burst	Simultaneous	Sonic Boom	Control
Single object	26 (49)	40 (47)	158 (53.4)
1	7 (13)	30 (35)	65 (21.9)
2	2 (4)	6 (7)	13 (4.4)
3	3 (6)	4 (5)	3 (1.0)
4	0 (0)	1 (1)	4 (1.4)
Many	15 (28)	4 (5)	29 (9.8)
	Σ = 53	Σ = 85	Σ = 272

Table 6.

Fragmentation observations for "sound-" generating fireballs. The numbers in columns 2, 3 and 4 give the number of reports and in brackets the percentage (rounded to the nearest integer) of reports for each of the fragmentation categories. The last column is a control sample of non-sound-generating fireball events. The row corresponding to "many" was used to account for comments such as "broke into many pieces," "breaking fragments," and "following fragments." The last row indicates the sample size of each category.

No. of Fragments	Simultaneous	Sonic Boom	Control
2	5 (23)	3 (13)	9 (41)
3	3 (14)	2 (8)	5 (23)
4	1 (5)	2 (8)	1 (5)
Many	13 (59)	17 (71)	7 (32)
	Σ = 22	Σ = 24	Σ = 22

6. Discussion

For the typical casual observer of the nighttime sky the probability of witnessing a sound-producing fireball is very small. Indeed, Keay & Ceplecha (1994) suggest that with respect to simultaneous sounds it is literally a once in a lifetime experience. Not only does one need to be fortunate to witness the fireball, but one also needs to be in an appropriate location for hearing sounds. In the case of simultaneous sounds a local transducting medium is required (Keay 1980b), while in the case of sonic booms placement in an audibility zone is necessitated (ReVelle 1975). Based upon those MFA fireball events that produced more than ten eyewitness reports, Beech (2003) found that on average if sonic booms do accompany a fireball event then 12.8 ± 9.0 percent of the observers actually "hear" the "booms" at a sufficiently distinctive level to comment upon them. Likewise, if simultaneous sounds are reported to accompany a fireball event then 5.7 ± 1.8 percent of the observers actually "hear" them in a distinctive fashion. For comparison, we note that following the recent fall of the Morávka meteorite in the Czech Republic on May 6, 2000 some 2.5% of eyewitnesses reported hearing distinct simultaneous sounds (Borovička *et al.* 2003).

Keay & Ceplecha (1994) suggest that the number of simultaneous sound-producing events N_E, occurring over an area A in the time interval n_y is

$$N_E = \frac{1}{2}\left(\frac{A}{A_E}\right) C\, n_y\, H,$$

where A_E is the Earth's surface area (5.1×10^8 km^2), C is a cloud obscuration term (taken here to be 0.5), H is the global frequency of simultaneous sound-producing events and the factor of $^1/_2$ accounts for predominant nighttime observing. Keay & Ceplecha (1994) argue that $H \sim 11{,}000$ events/year. Across the total land mass of Canada, where $A \approx 9.0 \times 10^6$ km^2, we might expect there to have been some 1300 simultaneous sound-generating events in the 27 years over which the MFA data was gathered. If one accepts this estimate as reasonable then just 7 % of the possible simultaneous sound-producing events were apparently witnessed and reported by Canadian observers. Since many of the simultaneous sound-producing events might also have produced sonic booms, then perhaps of order 10% of the possible sound-producing events were reported. It is likely that the actual percentage of events witnessed is much higher than the values just derived, since the area of Canada over which people physically reside is much smaller than nine million square kilometers. Indeed, the detection rate could easily be closer to one in three events after allowing for a not unreasonable 1/3 reduction factor in the area A.

It is a certainty that some of the sound reports in the MFA are illusory. Just how many reports might be mistaken, however, is difficult to determine. Odd sounds occur all around us, all of the time, even in remote locations, and observers can unwittingly associate such sounds with a chance fireball event. Romig & Lamar (1963) discussed the possibility of "psychological suggestion" for the origin of simultaneous sounds, but came to no conclusions as to how often "suggestion" might occur. A nice example of psychological "forces" at work is found in the report by Robert Leslie (1885), who described the obmutescence of the 1885 Andromedid meteor storm in the following terms, "the silence of the display was almost oppressive, as one expected each moment to hear the bang of fireworks." Leslie "held" his expectations at bay, but his sentiments underscore the tendency of human observers to "see and hear" what they expect to "see and hear." A detailed discussion of the "power" of "psychological suggestion," with respect to the phenomenon of lunar meteors, where observers "found" what they expect to "find," is given in Beech & Hughes (2000). While we do believe that simultaneous sounds constitute a real physical phenomenon, it is our belief that the next major development in this area must follow from carefully constructed instrument-based surveys.

There is a growing body of evidence, some instrumental but mostly anecdotal, that "sounds" can accompany annual meteor shower fireballs. A good number of cases exist for Perseid fireballs possibly producing "burster" simultaneous sounds, and there is some historical evidence to suggest that Lyrid meteor shower fireballs might also produce "burster" simultaneous sounds. In the case of the recent spectacular Leonid meteor storms, the reports relating to simultaneous sound production are of a very mixed quality. Indeed, it might very reasonably be argued that most of the recently reported Leonid events were simply "psychologically suggestive" in nature. This comment being made because the storms were well predicted, massively reported in the media, and viewed by countless multitudes of inexperienced observers. Furthermore, many media outlets and Web pages distinctly mentioned the possibility of sounds being associated with bright Leonid meteors, thereby instilling the expectation of hearing something in the minds of inexperienced observer. We note that the MFA contains no sound-producing fireball reports relating to the Leonid meteor storms of 1965 and 1966. All of the above being said, a few of the Leonid sound reports[4] gathered over the last several years (*e.g.*, Drummond, *et al.* 2000), along with the historical reports from the 1833 and 1866 Leonid storms (Beech 1998; Beech & Foschini 2001), are suggestive of a real physical phenomena.

Keay (1985) has argued that according to the magnetic entanglement model, sustained simultaneous (electrophonic) sounds should accompany the re-entry of large artificial satellites, and on this point, a number of the report cards in the MFA do relate to satellite re-entry observations. One event, the infamous *Cosmos 954* re-entry on January 24, 1978 generated five MFA reports and one report from the Hay River (N.W.T.) area interestingly notes a "hissing noise on first appearance in the west." Heaps (1978) further describes several additional eyewitness accounts of sustained simultaneous sounds being heard during the *Cosmos 954* re-entry. In more recent times, and also in apparent agreement with Keay's prediction, a distinct magnetic-field disturbance was detected during the re-entry of the *Molniya 1-67* satellite over Western Australia (Verveer *et al.* 2000).

That sound-producing fireball events are described in the MFA is not at all surprising. Indeed, it would have been surprising if they had not been reported. We find that of order one in thirteen of the fireball events documented within the MFA had some associated sound characteristic. In common with previous studies we find that it is predominantly the brightest, long-duration fireball events that produce associated sounds. We find some intriguing, but tentative, evidence to suggest that "burster" simultaneous sounds can proceed from Perseid meteor shower fireballs. We also find tentative (but as yet unclear) evidence supporting the claim that apparently "ordinary" meteors[5] can produce simultaneous sounds. It is, perhaps this latter topic that most clearly indicates where the next major thrust in the understanding of simultaneous sounds must come from; namely through the development of instrument based surveys.

ACKNOWLEDGMENTS

We extend our gratitude to Dr. Ian Halliday for his trenchant and insightful comments to the first draft of this paper. This work has been partially supported by a grant from the Natural Sciences and Engineering Research Council of Canada.

NOTES

[1] The MIAC Web page can be accessed via `miac.uquac.ca/MIAC/.`

[2] Data on the MFA and links to the tabulated data can be found directly at `hyperion.cc.uregina.ca/~astro/MIAC/MFA/Intro.html.`

[3] The meteorite events were the Peace River (AB) fall on March 31, 1963, the Revelstoke (BC) fall on March 31, 1965, the Vilna (AB) fall on February 5, 1967, and the Innisfree (AB) fall on February 5, 1977.

[4] The caveat to this statement is that sonic booms would not be expected unless an exceptionally large meteoroid encountered the Earth's atmosphere. Beech & Nikolova (1999a) estimate that an initial diameter in excess of 1-metre would be required before a Perseid meteoroid might produce sustained simultaneous sounds. A similar sized, or even larger, Perseid meteoroid would be required to produce a sonic boom. While sonic booms might not, in general, therefore, be expected to originate from fireballs in cometary streams, they can apparently produce infrasound waves. ReVelle & Whitaker (1999), for example, report on the infrasonic detection of a very bright Leonid fireball observed on November 17, 1998. A second very bright Leonid fireball (EN151101), recorded by the European Network of fireball cameras on November 15, 2001 was also found to generate a clear infrasound signal (P. Brown personal communication). Brief mention is made in Jenniskens *et al.* (2000) of a bright Leonid fireball, observed in 1998, that apparently generated a sonic boom, although the association is far from certain.

[5] By "ordinary" we mean meteors of peak visual brightness less than magnitude −5. The magnitude limit of −5 is somewhat arbitrary, but it is employed with respect to the standardized nomenclature adopted at the 1961 IAU General Assembly (Millman 1961). The IAU approved definition for the appellation of fireball corresponds to a meteor brighter than the brightest planet. In practical terms the planetary brightness limit is set by Venus, which can attain a maximum brightness of magnitude −4.7. Drobnock (1992) makes the extraordinary claim that meteors as faint as zero magnitude peak brightness can generate measurable VLF electromagnetic radiation transients. Based upon some 80 hours of VLF monitoring, however, Beech, Brown, & Jones (1995) found no evidence to support such a claim.

[6] The Web page of the Global Electrophonic Fireball Survey can be found at `www.gefsproject.org.`

[7] A burst or flare corresponds to a transient increase in a meteor's brightness. The occurrence of bursts need not indicate that the parent meteoroid has completely broken apart, but they do indicate that numerous small and hence rapidly ablating particles have been released from the meteoroid. We have distinguished between bursts and fragments in the following way; bursts are short-lived brightness enhancements of the parent fireball, while fragmentation corresponds to the appearance of distinct, relatively long-lived daughter trails that follow the parent fireball in its path.

Martin Beech
Campion College
The University of Regina
Regina SK S4S 0A2

REFERENCES

Anglin, F.M., & Haddon, R.A.W. 1987, Nature, 328, 607
Annett, C.H. 1980, IrAJ, 14, 199
Barabanov, S.I., Bolgova, G.T., Mikisha, A.M., & Smirnov, M.A. 1996, AstL, 22, 846
Beech, M. 1998, AJ, 116, 499
Beech, M. 2003, JRASC, 97, 71
Beech, M., Brown, P., & Jones, J. 1995, EM&P, 68, 181
Beech, M., & Hughes, D.W. 2000, JAHH, 3, 13
Beech, M., Illingworth, A., & Brown, P. 2003, in press
Beech, M., & Foschini, L. 2001, A&A, 367, 1056
Beech, M., & Nikolova, S. 1999a, M&PS, 34, 849
Beech, M., & Nikolova, S. 1999b, MNRAS, 305, 253

Borovička, J., Spurný, P., Kalenda, P., & Tagliaferri, E. 2003, M&SS, 38, 975
Bronshten, V.A. 1983, Solar Sys. Res., 17, 70
Brown, P., Kalenda, P., ReVelle, D., & Borovička, J. 2003, M&SS, 38, 989
Ceplecha, Z., Borovička, J., Elford, G., ReVelle, D.O., Hawkes, R.L., Porubcan, V., & Simek, V. 1998, SSRv, 84, 327
Drobnock, G.J. 1992, Sky & Telescope, 83, 329
Drobnock, G.J. 2002, JIMO, 30, 152
Drummond, J., Gardner, C., & Kelly, M. 2000, Sky & Telescope, 99, 48
Halliday, I. 1991, JRASC, 85, 67
Halliday, I., Blackwell, A.T., & Griffin, A.A. 1978, JRASC, 72, 15
Halliday, I., Blackwell, A.T., & Griffin, A.A. 1996, M&PS, 31, 185
Halliday, I., & Griffin, A.A. 1982, Meteoritics, 17, 31
Heaps, L. 1978, in Operation Morning Light: Terror in our skies, the true story of Cosmos 954 (Paddington Press: New York)
Hildebrand, A.R., Brown, P.G., Wacker, J.F., Wetmiller, R.R., Page, D., Green, W.E., Jacobs, C.F., ReVelle, D.O., Tagliafarri, E., & Kissin, S.A. 1997, JRASC, 91, 261.
Hughes, D.W. 1981, Meteoritics, 16, 269
Jenniskens, P., Nugent, D., & Plane, J.M.C. 2000, EM&P, 82, 471
Kaznev, V.Yu. 1994, SSRv, 28, 49
Keay, C.S.L. 1980a, Science, 210, 11
Keay, C.S.L. 1980b, JRASC, 74, 253
Keay, C.S.L. 1985, Sky & Telescope, 70, 623
Keay, C.S.L. 1993, J. Sci. Explor., 7, 337
Keay, C.S.L., & Ceplecha, Z. 1994, JGR, 99, 13163
LaPaz, L. 1958, Adv. Geophys, 4, 217
Leslie, R. 1885, Nature, 33, 103
McCall, G.J.H. 1973, Meteorites and their Origins (John Wiley and Sons: New York)
Millman, P.M. 1961, Sky & Telescope, 22, 254
Norton, O.R. 2002, The Cambridge Encyclopedia of Meteorites (Cambridge University Press: Cambridge, UK), 37
ReVelle, D.O. 1975, Sky & Telescope, 49, 87
ReVelle, D.O. 1997, Annals New York Acadm. Sci., 822, 284
ReVelle, D.O., & Whitaker, R.W. 1999, M&PS, 34, 995
Romig, M.F., & Lamar, D.L. 1963, Memorandum RM-3724-ARPA (The RAND Corporation: Santa Monica, CA), 7
Sears, D.W. 1978, in The Nature and Origin of Meteorites (Oxford University Press: New York)
Tagliaferri, E., Spalding, R., Jacobs, C., Worden, S.P., & Erlich, A. 1994, in Hazards due to Comets and Asteroids, ed. T. Gehrels (University of Arizona Press: Tucson), 199
Tatum, J.B., & Stumpf, L.L. 2000, PASP, 112, 1487
Verveer, P.A., Bland, P.A., & Bevan, A.W.R. 2000, M&PSA, 35, 163
Vinkovic, D., Garaj, S., Lim, P.L., Kovacic, D., Zgrablic, G., & Andreic, Z. 2002, JIMO, 30, 244

Martin Beech is a member of the RASC Regina Centre and Associate Professor of Astronomy at Campion College, The University of Regina. He is a member of the Meteorites and Impact Advisory Committee (MIAC) to the Canadian Space Agency and has recently been involved with the organization of the Prairie Meteorite Search. He is also coordinator for the Southern Saskatchewan Fireball Array: a system of three all-sky cameras designed and distributed to monitor bright fireball activity. His main research interests relate to the smaller objects in the Solar System.

The Michael Smith Award

by James Edgar, Regina Centre (jamesedgar@sasktel.net) and
John Percy, Toronto Centre and Department of Astronomy and Astrophysics, University of Toronto (jpercy@utm.utoronto.ca)

John Percy writes:

I have over 40 years of RASC membership and activity; I'm a former National President and *Observer's Handbook* editor, as well as a member for many years of the Council of the RASC Toronto Centre. I also have over 40 years of active interest in astronomy education and outreach at the local, provincial, national, and international level. I believe that science education and literacy are essential for the health of our society and have watched the issue of public-science literacy bounced back and forth from one organization (or government agency) to another. In the US, there is a major "umbrella organization" for science promotion (American Association for the Advancement of Science) and funding from organizations such as NASA and the National Science Foundation.

Therefore, I was delighted when the Natural Sciences and Engineering Research Council of Canada (NSERC) instituted the Michael Smith Award to recognize outstanding contributions to science promotion by individuals and by organizations. Terence Dickinson received a Michael Smith Award at the 1999 RASC General Assembly in Toronto, which I helped to organize. I was further delighted when NSERC developed the PromoScience program to provide modest grant support for science promotion projects. A year later, the Ontario government followed suit by developing the Youth Science and Technology Awareness Program. At this point, I had just become chair of the Education Committee of CASCA (Canadian Astronomical Society — Société Canadienne D'astronomie) — the society of professional astronomers in Canada. We were interested in starting a major new astronomy education initiative in Canada. We applied (successfully) to both NSERC and the Ontario program. One of the outcomes has been a new Canadian astronomy education Web site: `www.cascaeducation.ca`. Having thought seriously about astronomy education and outreach in Canada, I decided that the time was overdue for the RASC to be recognized for the remarkable work they have done in promoting public awareness and appreciation of astronomy — all voluntarily!

Figure 1. — Dr. Rajiv Gupta accepts the award from the Honourable Susan Whelan, M.P. and Minister for International Cooperation. (All photos courtesy of James Edgar)

In early 2002, I started doing serious research for the nomination; as chair of the Awards Committee of the University of Toronto's Department of Astronomy and Astrophysics, I have some experience with such nominations. I know that a very strong case must be made. So I went through *Looking Up* — Peter Broughton's wonderful history of the RASC — looking for examples of the RASC's outreach work through its history. I also re-read the RASC Annual Reports for the previous few years to create some statistical information about the Centres' activities and to find out about interesting and unique kinds of outreach activities. The RASC's programs reach hundreds of thousands of people each year! I was particularly impressed by the variety of partnerships that the Centres formed to make their activities more effective. Since the 2002 Annual Report had not yet appeared, I emailed all the Centres to get advance information about their outreach activities for 2001-2002.

Then I put the nomination together. I needed three letters of support. I turned to two previous Michael Smith Award winners — Terence Dickinson and Jim Hesser. Terry, of course, is a world-renowned astronomy writer. Jim is a professional astronomer in Victoria who has been deeply involved in and supportive of education and outreach. The third letter came from another professional astronomer, Michael De Robertis (York University), who had been President of the Canadian Astronomical Society and who is deeply involved in promoting better science education and literacy in Canada. Getting a letter of approval from the RASC President was easy — Bob Garrison (President at the time) has an office down the hall from mine.

Sadly, the 2002 nomination was not successful. I was not surprised. My previous experience told me that it was usually necessary to nominate for an award several times. No matter how deserving the nominee, there were probably other organizations "waiting in line." I was delighted that James Edgar initiated a nomination, which reminded me to re-submit my nomination in 2003. His work added double strength to the nomination. In my opinion, his not being a professional/expert placed him in a better position to communicate the impact of the RASC outside the narrow world of professional science. Plus, that 2003 is the RASC's Royal Centennial has to have made a difference!

I continue to believe that the RASC is a remarkable organization. One of its strengths is the balance between national activity and local activity. In other countries, there may be a national organization whose grass-roots impact is limited or a good assortment of local clubs with limited national co-ordination and clout. The RASC is "the best of both worlds."

Figure 2. — The 2003 Michael Smith Award winners (starred, left to right) Phil Eastman*, Rajiv Gupta*, Corinne Mount Pleasant-Jetté*, Scott Mair*, Hon. Susan Whelan, Angela Holmes*, Geoff Green*, Claude Benoit (President, Old Port of Montreal), and Nigel Lloyd (NSERC).

James Edgar continues with his side of the nomination story:

In March of last year, I happened upon an advertisement in the March/April issue of *Canadian Geographic* calling for nominations for the Michael Smith Awards (up to five of these are awarded each year). I had never heard of the awards before, but they exactly described the RASC mandate — for outstanding contribution in the promotion of science in Canada, outside the regular school system. That's what we do.

Instantly inspired, I thought to myself, "We could get that award!" — ten thousand dollars is a significant sum. I immediately e-mailed our President, Dr. Rajiv Gupta, suggesting that I could nominate the Society and requesting his support. That was on March 9. Nothing happened for quite some time, and the deadline of April 4 was rapidly approaching. On March 20, I couldn't stand the suspense any longer, and I wrote another e-mail to Rajiv. My first message hadn't gone through the way I thought it would, and he missed my question. This time, however, we connected, and he immediately gave me some suggestions about how I should proceed, particularly enlisting the help of Roland Dechesne, Chair of the RASC Membership and Promotion Committee. Roland guided me through some pitfalls of the application process, with which he was familiar since the Calgary Science Network (to which he belongs and is past President) had won the Michael Smith Award in 1994.

The sudden flurry of emails and urgent phone calls from my downstairs office would have seemed like a blizzard to someone looking in. I wrote and received 39 emails on this one subject in 11 days! It was all about the requirement to have three letters of recommendation accompanying the nomination, plus at least three pieces of supporting documentation, all with triplicate copies and all into the NSERC offices in Ottawa by April 4. Time was rapidly running out!

In the few days between March 20 and 31, I contacted Dr. James Hesser, Director of the Dominion Astrophysical Observatory, requesting a letter of recommendation from him. He was particularly helpful (and hopeful) since he too was a previous award winner in 1997. Not only did he write the letter, but he also made some very good suggestions as to how I should proceed and what to

Figure 3. — RASC members at the Gala Banquet — Bob Garrison, Rajiv Gupta, John Percy, and James Edgar.

include as supporting documentation.

In the meantime, Roland Dechesne was busy trying to get a letter from Dr. Russ Taylor, past-President of CASCA and one of the driving forces behind the Canadian Long Range Plan (LRP) for Astronomy and Astrophysics. In the end, Dr. Gretchen Harris graciously wrote the letter. She is the current President of CASCA and Professor of Physics at the University of Waterloo in Ontario. Dr. Harris also professes that astronomy is her main love in teaching, so it is particularly appropriate that she provided one of our supporting letters of recommendation. The date on her letter is April 1 — we were getting right down to the wire. Thank goodness for email, fax machines, and couriers!

During this period, I contacted Dr. John Percy by telephone. Many readers will recognize Dr. Percy as a past President of the RASC, but he has so many other professional associations there is just no room here to cite them all. If you want to read up on him, go to this Web site: `www.erin.utoronto.ca/%7Eastro/percy.htm`. His name came up in an e-mail conversation I had with Roland Dechesne because one of Dr. Percy's other hats (apart from teaching astronomy, that is) makes him Chair of the Education Committee of CASCA. The thought was that he could give us some advice about who should or could write the third letter of recommendation, one with an educational slant.

I found out from James Hesser that John Percy had nominated the RASC in 2002. The nomination didn't reach approval, but I discovered he had a wealth of information compiled for his previous nomination attempt, and more importantly, he was willing to share it with me for this year's nomination.

Dr. Percy also generously agreed, on very short notice, to write the third letter. I had already sent most of the documents to Bonnie Bird at the RASC National Office in Toronto, and he hand delivered his letter to her. Bonnie had to put Rajiv Gupta's signature on the application (he was away on an astrophotography trip to New Zealand and Australia through all this), and it had to be in quadruplicate — one original and three copies of all applications, recommendations, and supporting documents. This was April 2! Two days from deadline!!

Bonnie Bird accumulated all the required papers (Gretchen Harris thankfully mailed hers directly to NSERC) and sent them by courier to Ottawa on April 3 (see the application letter in Figure 3).

Eleven days after the deadline, I received a phone call from NSERC. They were looking for one final document that hadn't been included. What had I missed — I thought everything was in place and all was included?? It turned out that they were looking for a release from the Society saying that the RASC had no objections to the nomination and that the Society name and photos could be used, should we win. We had 48 hours to get the letter to the NSERC office in Ottawa. (I found out later that, of 44 applications, 42 failed to supply such a letter. After reading the *Canadian Geographic* ad again, I see where the instructions are, but completely overlooked them at the time. They aren't on the Web site at all.)

Bonnie Bird came through in the crunch. She drafted a letter, signed it herself as Executive Secretary of the Society, and got it to Ottawa right on

Michael Smi Awards for ience Promotion
Les prix Michae Smith pour la p omotion des sciences

Presented to:
Présenté à :

Royal Astronomical Society of Canada
2003

Dr. Thomas Brzustowski
President of NSERC
Président du CRSNG

Dr. Michael Smith
(1932-2000)
Nobel Laureate in Chemistry / Lauréat du prix Nobel de chimie

NSERC
CRSNG

Canada

Figure 4. — The Michael Smith Award certificate and medal.

time. President Rajiv Gupta was back in Vancouver by this time and could have faxed the required letter, but the people at NSERC agreed that Bonnie's signature would be just fine. Whew! It was finished, and all we could do was wait.

A couple of months later at the Vancouver General Assembly, Dr. Gupta took me aside and with a big smile asked, "Did you get your email?" I hadn't been near my computer for a couple of days and hadn't seen any emails from him, so my answer was "No." Another big smile and he said, "We got it! We got the Michael Smith Award!!" Then he quickly added that we had to keep the news quiet so that the responsible Federal Minister could make the announcement at the proper time. Only the RASC Executive, John Percy, and I would know, and we had to keep it that way.

As I write this in November 2003, the Awards Banquet is still a week away, scheduled for November 19. I haven't been able to tell anybody else, particularly my astronomy friends and associates, and I'm ready to burst. Dr. Gupta is going to accept the award on behalf of the Society, and he managed to get an invitation from NSERC for me to attend the Awards Banquet too — and I'll be there. And by the time you read this, we can all say, along with John Percy, Roland Dechesne, and me, "We got it! We got the Michael Smith Award!!"

As an afternote, I direct you to the President's Message from the December issue of the RASC *Journal*. There you'll find what the excitement is all about and why we think this is such a significant honour.

James Edgar is an RASC Life Member, attached to the Regina Centre. His serious love affair with astronomy began in Vancouver, B.C. in the early 1970s. His home in Melville, Saskatchewan provides many dark-sky nights.

John Percy is Professor of Astronomy and Astrophysics and of Education at the University of Toronto. He is currently Chair of the Education Committee of the Canadian Astronomical Society and Past President of the RASC.

A New Image for the RASC

by Denis Grey, Membership & Promotion Committee (denis.grey@sympatico.ca)

At the National Council meeting of October 25, 2003 the RASC decided to cap off a year of celebration and reflection on our Royal Centenary with the adoption of a new Seal for the Society. The new Seal will be officially launched on March 3, 2004, which marks the end of the RASC's Royal Centenary year. The new Seal will be quickly implemented on both RASC National and Centre Web sites followed by all Society publications and correspondence shortly thereafter.

Why change something as traditional as our official seal when we are celebrating our heritage and roots? Our original seal has been in use almost as long as the Society has been Royal. It was designed by Dr. Edmund Meredith and implemented by Professor Clarence A. Chant in 1905. This version of the Seal remained in use up in one form or another until 1992 when it was modernized by Toronto Centre member Paul Pfeld. Most recently in 1998, Niagara Centre member John H. VanOphem rendered the 1992 Seal from black and white into a colour version that has been used on the Society's Web site and other colour media where possible.

While minor changes were made in 1968 and 1992, the design did not reflect the application of such a graphical symbol to the modern requirements of our Society. In particular, the 1992 Seal is difficult to reproduce clearly and it does not scale very well to smaller sizes. This becomes an issue when we are seeking to represent the Society graphically in various media such as print, textiles, and computer screens.

There are basically three goals that are served by the new Seal:

1. The new design is demonstrably more Canadian. The Maple Leaf now surrounds Urania and forms her backdrop. The stars of Ursa Major are arrayed around her showing her northern declination in place of a random star pattern.

2. The new design is also more modern. The fonts and typefaces used are easier to work with graphically and the whole design is enabled for easier reproduction on our graphical and promotional materials.

3. Finally, the new design now lends itself to a "slimmed down" version that will allow the RASC to be more easily represented on merchandise and other materials. A "logo version" of the Seal will incorporate the key design elements of our official Seal. This graphically-streamlined logo will provide for a suitable image that can be used both as a logo for individual Centres as well as an appropriate graphical symbol for RASC promotional materials or other areas where only a low resolution image can be used.

In terms of other design changes, the *grande dame* of astronomy, Urania, figures more prominently. The Latin motto *"Quo ducit Urania"* or "Where Urania Leads" is prominently displayed in the surrounding area. The cross on the Tudor Crown now marks the approximate location of Polaris in relation to Ursa Major and the crown

Figure 1. — The evolution of the Seal of the Royal Astronomical Society of Canada, left to right 1903, 1992, and 2004. A full colour version of the new seal is available at the National Web site at `www.rasc.ca`.

itself has been revised and enhanced to enable clearer and more accurate reproduction.

RASC National President Rajiv Gupta, who assisted Dan Collier with implementing the design said: "The Society's previous seal has served us well through our first century of Royal designation; may the new seal, with its retention and improvement of the traditional elements and introduction of key new elements that make it even more appropriate as the face of the Society, remind us of our rich heritage and proudly lead us into our second Royal century."

We hope that you find the new Seal of the RASC to be inspirational and that it provides a focal point for your pride in being a member of one of the world's leading astronomical societies. As we move forward into our 2nd century as a Royal Society and 114th as an organization, we look forward to seeking what other wonders Urania has in store for us next!

New Promotional Materials

Speaking of "in store," the Membership and Promotion Committee of the RASC is planning to take advantage of this occasion to introduce new promotional materials for the Society. We hope that you will be the first in your Centre to sport the new Seal and support your Society. Our goal is to have the following materials available shortly after March 1, 2004 at the RASC eStore and at local Centres who wish to stock promotional merchandise. All materials will have a special introductory price of 20% off until the General Assembly in St. John's in July 2004.

- RASC Stainless Steel Travel Mug
- RASC Lapel Pin
- RASC Golf Shirts — Navy with the new RASC Seal, M, L, XL, XXL
- RASC Telescope & Bumper Stickers
- RASC License Plate Frame

Note that two versions of the RASC Golf Shirt will be available. The standard Seal of the Society is available from stock, however a special "Centre" version of the Golf Shirt is also available on a made-to-order basis. See the eStore for more details.

An Interview with Dan Collier

Q. When did you first come up with the idea to modernize the Seal of the Society?
A. My work started about 10 years ago when National Council announced intentions to update the RASC's original seal to produce a colour version. I lacked the time to delve into the subject, and a member in the Niagara Centre (John H. VanOphem) took up the project to produce the colour version in general use. The artist followed the previous version fairly closely, and in particular, applied considerable skill in rendering Urania.

Q. What got you started on the project again?
A. Around 1997 when I started updating Vancouver Centre's membership handling, I saw a need for both a separate crest for the Vancouver Centre, and more colour, particularly for electronic renderings. At this time I applied myself to learn more about the symbols in the crest. Peter Broughton was helpful, and sent me some background information that he used when preparing the Urania sidebar in *Looking Up*. He also sent me an image of a Wedgwood medallion showing Urania, which led me to research this topic in yet more detail. I was not able to answer a couple of key questions, (a) what was the source of the inspiration of this image, and (b) why Urania is depicted sitting without her staff and globe. Nevertheless, I pressed on to produce a prototype of a colour crest that Vancouver Centre has used unofficially in its publications (although not widely to date).

Q. Why is Urania so central to the design?
A. The Vancouver Centre has an extensive collection of old *JRASC* issues going back to the days of the forerunner Toronto Astronomical Society. Each issue after 1903 was affixed with a crest showing Urania sitting on a bench held up by pilasters and surrounded by some stars and the slogan, Quo Ducit Urania, and it was the primary source of inspiration for new version of the Seal adopted in 1968 and the colour version developed later. This old design has a lot of character and it seemed to me that latter-day evolutions

did not fully respect the symbols in it. This concern may seem trivial and backward to some. However, the 1903 depiction of Urania is significant to the RASC's history especially given the important role that women such as Helen Sawyer Hogg and Ruth Northcott have played in the Society over the years. It also reflects the thinking of C.A. Chant, and it is even thought that his daughter sat as a model for Urania. A better symbol for the RASC would be hard to find.

Q. How do you see the new Seal being used?
A. At this time (2002) it occurred to me that the Centre had not recently offered any quality "wearable" merchandise. The cost of multicolour machine embroidery had recently dropped, suggesting a new item that members might like to buy, an RASC "astronaut patch" that could be sewn directly onto jackets and shirts. I experimented with this idea on my computer. Along the way I substituted a small Canadian flag in place of the separator at the bottom, and this received such a favourable response from our Council that I expanded the leaf and placed it behind Urania. The seven stars were arranged into a Big Dipper at this time. I noticed later that these inclusions harmonized nicely with the Centennial crest design implemented at the 2003 Vancouver Centre General Assembly, which was successfully reduced to a sewn design. While some of the detail of the Royal Centenary design was lost in the stitched version it was still attractive and very popular. Coordination of these designs seemed natural as a gesture to the Royal Centenary.

Q. How did you develop your skills in graphic design?
A. The successful implementation of a graphic design depends on the skill of the artist/illustrator. While I do not represent myself as such, much of my career work with engineering firms and later with the Macmillan Space Centre involved graphic design and illustration. When combined with my interests in history and astronomy, it would seem these qualifications, limited as they were, did put me in a position to carry out this work.

Q. How was the final version developed?
A. Rajiv Gupta was made aware of my work, and offered to help me convert my prototype to vectorized form, in both colour and line-art versions. The appearance of these images owes much to his suggestions and assistance. While we did not agree on the suitability of every element we were very pleased with the overall design with respect to the added elements and the correction of existing ones.

Q. How do you feel about the finished product?
A. Arranging the stars around Urania into the Big Dipper seemed gratuitous and I worried that someone would object to my orienting the Pointers toward the crown. No one has, and this is good since the stars establish a proper astronomical symbol in our crest for the first time. But the deepest feeling of satisfaction came over me when I put the transparent maple leaf behind Urania and coloured it blue. It made me think of ice-cold observing nights and the glass in my telescopes. To me the maple leaf is the most beautiful of the world's national symbols. Placing it here is both historically appropriate and suggestive of Canada's natural heritage. Its colour and transparency should be taken as symbolic of the goals of our Society as a national instrument, although its position in the crest, with Urania prominent in front, was intended to emphasize our first love — astronomy.

Toronto Centre life member Denis Grey is part of the RASC's Membership and Promotion Committee and looks forward to sharing his pride in the RASC through the new Seal of the Society in 2004.

RASC INTERNET RESOURCES

Visit the RASC Web site
`www.rasc.ca`

Renew your Membership
`www.store.rasc.ca`

Contact the National Office
`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 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`

The Uranic Muse:

Astronomy and Major Nineteenth-Century U.S. Authors

by Brett Zimmerman, York University (bazimme@attglobal.net)

> *Descend from Heaven, Urania, by that*
> *name*
> *If rightly thou art called, whose voice*
> *divine*
> *Following, above th'Olympic hill I soar,*
> *Above the flight of Pegasean wing!*
>
> — John Milton, Paradise Lost

In *Star Names: Their Lore and Meaning*, Richard Hinckley Allen attests that "Longfellow and Lowell knew the stars well, and well showed this in their works" (Allen 1899), and in a recent issue of *Sky & Telescope* (Black 1999), Ted Black demonstrates that Oliver Wendell Holmes can be added to the list of 19th-century American writers who display an interest in astronomy in their poetry and prose. In my book *Herman Melville: Stargazer* (Zimmerman 1998), I show that references to astronomical themes abound in Melville's poetry and prose, ranging from his third novel, *Mardi* (1849), to his final masterpiece, *Billy Budd*, written in the five years before his death (1891) and published posthumously in 1924. Interestingly, however, references to the themes and subjects of the "uranic science" can also be found in *every other* major U.S. author of the nineteenth century: Edgar Allan Poe, Ralph Waldo Emerson, Nathaniel Hawthorne, Henry David Thoreau, Walt Whitman, Emily Dickinson, Mark Twain, and Henry James. The references range from the largely incidental to images and symbols that are thematically significant in the works in which they figure. We cannot substantiate that claim in detail *here,* but in order to appreciate further the impact of astronomy on American literary culture, we can provide a *brief* survey of those U.S. authors who now and then invoked Urania, the muse of astronomy.

That amateur astronomer Poe is perhaps best known for his interest in and literary employment of astronomy — no doubt because of his mystical-cosmological work *Eureka* (1848). As all Poe scholars know, however, the nebular hypothesis, the Moon, planets, constellations, comets, and stars figure in his essays, short stories, and poems also. Frequently Poe's astronomical allusions are quite esoteric, and only those readers whose understanding of the science is comparable to Poe's can make sense of his astronomical symbolism and imagery. A brief reference in his tale *Ligeia* (1838) is a case in point: there the narrator is wonderstruck as he contemplates the mysterious eyes of his beloved Ligeia. He is unable to express the ineffable meaning they may have; he can only suggest through symbols what the expression in her eyes may mean and the strange feeling he gets when he ponders them. He tells us that "there are one or two stars in heaven — (one especially, a star of the sixth magnitude, double and changeable, to be found near the large star in Lyra) in a telescopic scrutiny of which I have been made aware of the feeling" (Harrison 1965). Although the editors of the Mabbott edition of Poe's works suggest that this star is the double binary Epsilon Lyrae (Mabbott 1978), I think Poe is more likely referring to Beta Lyrae (Sheliak), which is "changeable" in brightness because it is really composed of two stars, one eclipsing the other regularly and bringing about periodic changes in the system's magnitude as seen from Earth. When we consider the events of *Ligeia*, the stellar symbolism becomes clear. At the tale's conclusion, the tormented narrator, who longs for his long-dead first wife (Ligeia), is watching over his dying second wife (Rowena). Then, to his astonishment, the "ghastly cerements" that have enwrapped Rowena suddenly fall off — to reveal the living body of the Lady Ligeia! Ligeia can be said to "eclipse" Rowena, as if they were the two stars of the Sheliak system. Thus, Poe's use of astronomy in the tale is not merely ornamental but is centrally relevant to the story's theme, which is metempsychosis, the passage of the soul from one body to another, thus usurping, *eclipsing,* that body's original soul.

Several studies, long and short, have been written on Poe and astronomy, including the unpublished dissertation of Elva Baer Kremenliev, *The Literary Uses of Astronomy in the Writings of Edgar Allan Poe* (Kremenliev 1963), and Frederick W. Conner's article *Poe and John Nichol: Notes on a Source of Eureka* (Conner 1965). In this essay, Conner suggests the influence that the well-known Scottish astronomer John Pringle Nichol had on Poe and other American authors such as Ralph Waldo Emerson.

In Emerson's *Angle of Vision,* Sherman Paul maintains that astronomy was "one of the imaginative constituents of Emerson's vision . . . " (Paul 1952). Certainly the science exerted a profound influence on his thinking both before and after he became a Transcendentalist philosopher. The topics of astronomy were a passion of his at least from the age of thirteen to the end of his life. In his early career, just before he left the Unitarian Church in the summer of 1832, Emerson even delivered a sermon on "Astronomy" in May of that year; and afterward, as America's foremost Transcendentalist, he wrote about celestial bodies, cosmic laws, and astronomers in his essays, journals, and poems. Astronomy was for Emerson something like a religion. In his 1836 essay *Nature,* he writes,

> "If a man would be alone, let him look at the stars. The rays that come from those heavenly worlds will separate between him and what he touches. One might think the atmosphere was made transparent with this design, to give man, in the heavenly bodies, the perpetual presence of the sublime. Seen in the streets of cities, how great they are! If the stars should appear one night in a thousand years, how would men believe and adore; and preserve for many generations the remembrance of the city of God which had been shown! But every night come out these envoys of beauty, and light the universe with their admonishing smile."
>
> The stars awaken a certain reverence, because though always present, they are inaccessible . . ." (Whicher 1960).

Of Emerson, Paul writes, the "lawful heavens promised him successful moral navigation, and he took nightly walks under the stars to take his spiritual bearings."

While Paul writes about how astronomy affected Emerson's thinking, Harry H. Clark discusses the philosopher's reading of ancient, modern, and contemporary scientists: "Copernicus, Galileo, Kepler, Laplace, Newton, Kant, the Herschels, and Mary Somerville attracted him especially toward astronomy" (Clark 1931). Clark informs us that Emerson was acquainted with Newton's *Principia* at the age of twenty and read *The Life of Galileo* and Somerville's *Mechanism of the Heavens* by 1832 and John F.W. Herschel's *Treatise on Astronomy* before 1834. He also perused Nichol's widely read *Views of the Architecture of the Heavens,* as he records in a journal entry for April, 1841 (Plumstead & Hayford 1969). But it was Newton who seems to have had the most influence on Emerson; indeed, "Emerson seems to have been possessed by a long-lived fascination involving Newton," says Carl M. Lindner. He was familiar with David Brewster's *The Life of Sir Isaac Newton,* and "as late as 1855 and 1864 . . . borrowed Brewster's two-volume *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton . . .*" (Lindner 1974). In "Newtonianism in Emerson's *Nature,*" Lindner explores, among other things, the idea of Newtonian (gravitational) astronomy in that famous essay of 1836.

Not only did Emerson know the literature by and about astronomers but he also knew some personally. At the beginning of November 1847, Nichol was getting ready to embark from Liverpool to America to give lectures on astronomy (which Melville may have attended during the New York winter of 1847-48). Emerson met the astronomer and forwarded letters to Henry Wadsworth Longfellow and Theodore Parker on Nichol's behalf. He wrote the former,

> "I find here just embarking for America, Dr. Nichol, who holds with so much reputation the astronomical chair at Glasgow, and, which is much more, stands very highly in the regard of excellent people whom I have seen here. In thinking of friends to whose kindness & courtesies I could commend him, I do not hesitate to give him your address, and with the request that you will introduce him to the gentlemen connected with the Observatory" (Rusk 1939).

Emerson was also an acquaintance of the amateur Nantucket astronomer William Mitchell and of his famous daughter, Maria. The biographer of Maria Mitchell, Helen Wright, tells us that Emerson visited the father and daughter several times: "That night, after his lecture, and again in later years when he came to the island, Emerson climbed 'up scuttle' to their little observatory. Maria never forgot those nights!" (Wright 1950). In a journal entry of 1847, Emerson himself records, "In Wm Mitchell's observatory I saw a nebula in Casseopeia[,] the double star at the Pole, the double star Zeta Ursi" (Sealts 1973).

Emerson was not the only American author who knew Miss Mitchell. While consul to Liverpool, Nathaniel Hawthorne noted in a journal entry of January 9, 1858,

> "This morning, Miss Mitchell, the celebrated astronomical lady of Nantucket, called [celebrated because she had discovered a comet at 10:30 p.m., October 1, 1847 — see O'Meara in *Sky & Telescope* (1999); also Zimmerman, *HM: Stargazer*]. She had brought a letter of introduction to me, while Consul; and her business now was, to see if we could take her as one of our party to Rome, whither she likewise is bound. We readily consented . . ." (Woodson 1980).

During the trip, the astronomer became so well liked that the Hawthorne children took to calling her "Aunt Maria" (Wright), and a much older Julian Hawthorne later remembered that Miss Mitchell "told us tales of the stars and gave us their names" (Hawthorne 1903). It is Wright's opinion that Hawthorne himself was influenced by his acquaintance with Maria, so much so that he apparently alludes to her in his novel *The Marble Faun:* "the woman's eye that has discovered a new star turns from its glory to send the polished little instrument [a sewing needle] gleaming along the hem of her kerchief . . ." (Hawthorne 1860). The other references in the novel to orbits, stars, and stargazing suggest that it was Maria's presence in Rome that put Hawthorne in mind of astronomy while composing *The Marble Faun*. But there are passages referring to celestial bodies in Hawthorne's earlier works, too, especially *The Blithedale Romance* (1852) — evidence that he was interested in things astronomical years before he met the Nantucket sky-watcher.

I do not know that Emerson's younger Transcendental friend, Henry David Thoreau, ever met any astronomers, but he did not need their company to be inspired by thoughts of the cosmos. His books, journals, and poems all show his familiarity with astronomy. He reminisces in *Walden* that one of his favourite pastimes was fishing in Walden Pond underneath the stars: "It was very queer, especially in dark nights, when your thoughts had wandered to vast and cosmogonal themes in other spheres, to feel this faint jerk, which came to interrupt your dreams . . ." (1854; Paul 1960). Thoreau liked to engage in such a nocturnal activity because to him the stars symbolized esoteric, but not ungraspable, transcendental knowledge. To be attuned to the cosmos is to be in communion with the Ubiquitous (the everywhere-in-space) and the Eternal (the everywhere-in-time), so what better symbols to represent transcendental awareness than the stars, which, like the pantheistic Oversoul (the Transcendentalists' idea of God), are scattered throughout the Universe and nearly contemporaneous with it? In his poetry, nature — frequently *celestial* nature — and the spiritual are linked; for instance, "'Walden' is one of the poems in which celestial bodies act as symbols of the transcendent in the natural world . . ." (Kaiser 1977). David Levy, in *More Things in Heaven and Earth: Poets and Astronomers Read the Night Sky* (Levy 1997), devotes an entire chapter to Thoreau.

That other Transcendentalist poet, Walt Whitman, seems to have had an even greater knowledge of and passion for astronomy than Thoreau. In his poem *A Clear Midnight* (1881; Bradley 1949), Whitman addresses his Soul and writes of "the themes thou lovest best, Night, sleep, death and the stars." Like Melville, Whitman is known to have attended astronomy lectures — but in one poem he documents his preference for first-hand over second-hand experience:

> "When I heard the learn'd astronomer,
> When the proofs, the figures, were ranged in columns before me,
> When I was shown the charts and diagrams, to add, divide, and measure them,
> When I sitting heard the astronomer where he lectured with much Applause in the lecture-room,
> How soon unaccountable I became tired and sick,
> Till rising and gliding out I wander'd off by myself,
> In the mystical moist night-air, and from time to time,
> Look'd up in perfect silence at the stars"
> (1865; Bradley 1949).

Whitman's love of the stars is that of the poet, not the mathematician or theoretician. He could not have written *Eureka,* as Poe did. Whitman prefers an *original* relation to the Universe.

Like Thoreau and Emerson, he had distaste for merely scientific men. Astronomers and other scientists deal only with what Emerson — borrowing the terms from Coleridge — called the "Understanding" (involving the empirical investigation of nature) and ignore "Reason," which enables us to see spirit and its laws behind, or through, the material Universe. If I may use a metaphor, Whitman and the other Transcendentalists looked at the natural world with "averted vision." While merely scientific men perceive only the material object by looking at it too closely, too intensely, by looking at that same object in a different way — with the "averted vision" of the poet or seer — the Transcendentalists see spiritual laws at work "behind" the object, as it were. They obtain more comprehensive insights about the workings of the cosmos in its physical *and* metaphysical dimensions — "higher laws." Scientists stop at empiricism; the Transcendentalists go beyond it to *intuition,* which is a necessary component of their epistemology.

Whitman's use of celestial imagery so pervades his poetry and prose that it has attracted the attention of several scholars, and so much work has been done on his use of astronomy that, rather than try to summarize what has been said, I shall only list some of the studies. Joseph Beaver devotes two chapters to the uranic science in *Walt Whitman — Poet of Science* (Beaver 1951); Alice Lovelace Cooke writes about the poet's "Use of Contemporary Revelations in Astronomy" in her article *Whitman's Indebtedness to the Scientific Thought of His Day* (Cooke 1934); this was complemented two years later by Clarence Dugdale's essay *Whitman's Knowledge of Astronomy* (Dugdale 1936); Stephen L. Tanner discusses the spiritual significance of the night sky for the poet in *Star-Gazing in Whitman's Specimen Days* (Tanner 1973); and a more recent study is Robert J. Scholnick's *The Password Primevel: Whitman's Use of Science in "Song of Myself"* (Scholnick 1986).

It is appropriate that such a cosmos-embracing poet should expand his vision to the stars in order to enumerate and "enfold" all celestial phenomena, as he at other times catalogues and embraces all earthly phenomena. While we may often think of Whitman as the poet of macrocosmic vision, we may likely consider Emily Dickinson, his opposite in so many ways, as the poet of microcosmic vision. Whitman ponders the planets and comets, Dickinson ponders a snake; he thinks in terms of orbits and stellar motions, she of an inebriated bee; he describes the stars and constellations of the Universe, she a humming bird; he takes us on a voyage through space and time, permitting us to look back to the beginning of creation like a telescope — she is like a microscope. But when she wanted to, Dickinson could suspend her close scrutiny of her New England garden and, like Whitman, look toward the broad celestial heavens. Many brief references in her poems show that Dickinson occasionally invoked the uranic muse, too: God is "a Telescope" who "Perennial beholds us" (1929; Johnson 1970); fideists are "Harmless — as streaks of Meteor — Upon a Planet's Bond" (1891); the poet's secret is as secure "As Herschel's private interest/ Or Mercury's affair" (1894); the distance between the living and the dead is greater than "the Comet's chimney [tail]" (1945); our periods may lie "As Stars that drop anonymous/ From an abundant sky" (1896); the world's peaks hold "with Bird and Asteroid/ A bowing intercourse" (1945). And as two of her poems show, Dickinson even knew the truth about the so-called Seven Sisters — namely, that normally only six can be seen with the naked eye:

> "I had a star in heaven —
> One "Pleiad" was its name —
> And when I was not heeding,
> It wandered from the same" (1896).

> "How noteless Men, and Pleiads,
>   stand,
> Until a sudden sky
> Reveals the fact that One is rapt
> Forever from the Eye —" (1929).

As with Thoreau, sometimes, astronomy provided for Dickinson a source for her many metaphysical conceits. She turns conventional astronomy into her very personal astronomy.

Generally less idiosyncratic in his use of astronomy is Mark Twain (Samuel Clemens). In the autobiographical *Life on the Mississippi,* he speaks of a conversation in which he participated and that eventually, no doubt to his approval, "drifted into talk about astronomy" (Clemens 1883). I say "no doubt to his approval" because, according to Hyatt H. Waggoner, Clemens "had a keen and lasting interest in astronomy, and an imaginative grasp of its implications . . ." (Waggoner 1937). His biographer, Albert Bigelow Paine, tells us that astronomy was Clemens' "favorite science," in fact: "He talked astronomy a great deal — marvel astronomy. . . . He was always thrown into a sort of ecstasy by the unthinkable distances of space — the supreme drama of the universe" (Paine 1912). So enraptured was Clemens by the idea of cosmic vastness that he would sometimes engage in astronomical calculations about how far light travels in a year or the distance to Neptune or the nearest star. Says Paine, "Few things gave him more pleasure than the contemplation of such figures as these." Once, at the Museum of Natural History in New York, Clemens paused to look at the meteorites and the astronomical model in the entrance hall: "To him these were the most fascinating things in the world. He contemplated the meteorites . . . and lost himself in strange and marvelous imaginings concerning the far reaches of time and space whence they had come down to us."

Clemens' daughter, Clara Clemens Gabrilowitsch, in a letter to Waggoner, reports that her father read several books on astronomy: Bayne's *The Pith of Astronomy* (1896), which he carried along with him to Bermuda (Paine 1542); Guillemin's *The Heavens* (1871); Simon Newcomb's *Side Lights of Astronomy* (1906); and Serviss's *Curiosities of the Sky* (1889). She also attests to Clemens' fascination with astronomy, as does Sherwood Cummings, in Mark Twain's *Acceptance of Science* (Cummings 1962).

Some of Clemens' stories demonstrate his astronomical interests. In *Captain Stormfield's Visit to Heaven,* we find a discussion of stellar distances and the speed of light (1907-08; Ketterer 1984). In *A Connecticut Yankee at King Arthur's Court* (Clemens 1889), there is the scene of the solar eclipse, and let us not forget the wonderfully comical cosmogonal cogitations of Huck and Jim in *Huckleberry Finn:*

> "It's lovely to live on a raft. We had the sky, up there, all speckled with stars, and we used to lay on our backs and look up at them, and discuss about whether they was made, or only just happened. Jim he allowed they was made, but I allowed they happened; I judged it would have took too long to make so many. Jim said the moon could a *laid* them; well, that looked kind of reasonable, so I didn't say nothing against it, because I've seen a frog lay most as many, so of course it could be done. We used to watch the stars that fell, too, and see them streak down. Jim allowed they'd got spoiled and was hove out of the nest" (Clemens 1884).

Surrounded by fundamentalist Christians, Clemens was surely ahead of his time, and rather courageous, in having Huck consider the possibility that the cosmos has no creator. And how radically different an attitude from that displayed by his contemporaries, the Transcendentalists, who saw "God" when they beheld the starry sky.

Comets seem to have been Clemens' special interest, which is not surprising for a man whose life span was bracketed by successive returns of Halley's Comet and who in 1909 told Paine,

> "I came in with Halley's comet in 1835. It is coming again next year, and I expect to go out with it. It will be the greatest disappointment of my life if I don't go out with Halley's comet. The Almighty has said, no doubt: 'Now here are these two unaccountable freaks; they came in together, they must go out together.' Oh! I am looking forward to that" (Paine 1912).

(On April 20, 1910, Halley's was at its brightest — Clemens died the next day.) His fascination with comets also made its way into his books. In *Tom Sawyer,* a frantic dog is described with comic hyperbole as "a woolly comet moving in its orbit with the gleam and the speed of light" (Clemens 1876); in *Life on the Mississippi,* it is Clemens' opinion that attempts to control the river are as futile as trying to "bully the comets in their courses and undertake to make them behave . . ." (Clemens 1883). The short piece entitled *A Curious Pleasure Excursion* advertises a cosmic voyage for passengers on a comet (1874; Ketterer 1984). In *Captain Stormfield's Visit,* Stormfield describes what it is like to be a disembodied soul racing through space with the comets.

Even Henry James, who more than any author mentioned so far seems to have been concerned solely with the events of the sub-lunar realm — that is, with human society — even James made literary use of astronomy. Isabel Archer, in James' novel *The Portrait of a Lady,* contemplates her perception of Osmond: "she had seen only half his nature then [during courtship], as one saw the disk of the moon when it was partly masked by the shadow of the earth. She saw the full moon now [after marriage] — she saw the whole man" (James 1881). Later, Isabel, exasperated by Goodwood, "stares" at a proposal of his "as if it had been a comet in the sky." Finally, there is the "twinning" of Osmond and his sister, the Countess "*Gemini.*"

We find even more astronomical images in James' 1886 novel *The Bostonians.* In making fun of Olive Chancellor's inclinations to reform, Mrs. Luna tells Basil Ransom that Olive "would reform the solar system if she could get hold of it." Later, Ransom meets the autonomous Dr. Prance contemplating the constellations, "all of which he was sure she knew." (Is Prance modeled in some respects on Maria Mitchell, who was still alive in 1886 and who was, in many ways, as emancipated a woman as Dr. Prance?) Elsewhere in the novel, Olive and Verena Tarrant stand together shivering under the winter stars: "There was a splendid sky, all blue-black and silver — a sparkling wintry vault, where the stars were like a myriad points of ice." Does James here associate the coldness of distant starlight with the frigid sterility of Olive's homosexual passion? When Olive finally succeeds in drawing Verena under her wing, the two of them watch "the stellar points come out at last in a colder heaven, and then, shuddering a little, arm in arm, they turned away, with a sense that the winter night was even more cruel than the tyranny of men. . . ."

The above references to astronomical objects in Henry James' fiction are ornamental, but we may in no way infer from them that he was actually *interested* in the science, as Poe, Emerson, Melville, Whitman, and Mark Twain certainly were. In these writers astronomical references are frequently more than merely incidental or poetically ornamental; they often function as an integral part of their authors' creative, thematic, and philosophical visions.

Their fascination with the science seems to reflect a more general apparent concern with astronomy on the part of their fellow Americans, a concern which peaked during the middle decades of the last century. Lieutenant M.F. Maury of the U.S. navy, in a letter to John Quincy Adams (November 17, 1847), claims that "There never has been, in the history of Astronomy, a period of so much activity and energy as the present," and that "The people of America have caught up the spirit, and are beginning actively to engage in Astronomical pursuits." A note to this remark referring to a recently discovered comet says that the comet "is another evidence of the attention which the subject of Astronomy is exciting in this country" (Maury 1848). A review of Nichol's *Contemplations on the Solar System in the North American Review,* dated January, 1848, notes "the popular yearning for astronomical intelligence," and in August of 1847 a reviewer of Mitchell's *The Sidereal Messenger* in the *American Whig Review* informed his readers that recent discoveries in astronomy, particularly Neptune and asteroids, "have awakened a new interest in the science."

The flurry of activity centering on astronomy in mid-nineteenth-century America was manifested in part by a wave of observatory-building. The U.S. acquired something like thirty of these "light-houses of the skies" between 1830 and 1860. By 1882, Agnes Clerke informs us, the United States had "no less than one hundred and forty-four" (1885), some of which had become world-famous. Walt Whitman even wrote an editorial in the Brooklyn *Daily Eagle* arguing for an observatory near New York (Rodgers & Black 1920). But even as early as 1851, America was said by Elias Loomis to be as efficient astronomically as the European countries that had fostered the science for centuries. "...while the number of observers, and the taste for astronomical studies, has kept pace with the increase of our instruments. Astronomy may now claim to be the most popular of the sciences . . ." (Loomis 1851). Perhaps it is no surprise, then, that the imaginations of literary men and women were inspired!

References

Allen, R.H. 1899, Star Names: Their Lore and Meaning (Dover: New York)

Beaver, J. 1951, Walt Whitman — Poet of Science (Octagon: New York)

Black, T. 1999, Sky & Telescope, 97, 52

Bradley, S., ed. 1949, Walt Whitman: Leaves of Grass and Selected Prose (Rinehart: San Francisco)

Clark, H.H. 1931, Emerson and Science, Philological Quarterly, 10, 225

Clemens, S. 1884, The Adventures of Huckleberry Finn (Holt: Toronto)

Clemens, S. 1876, The Adventures of Tom Sawyer (NAL: New York)

Clemens, S. 1889, A Connecticut Yankee at King Arthur's Court (Penguin: New York)

Clemens, S. 1883, Life on the Mississippi (NAL: New York)

Clerke, A.M. 1885, A Popular History of Astronomy during the Nineteenth Century (Adam and Charles Black: Edinburgh)

Connor, F.W. 1965, Poe and John Nichol: Notes on a Source of Eureka in All These to Teach, ed. Robert A. Bryan *et al.* (University of Florida Press: Gainesville FL), 190

Cooke, A.L. 1934, Whitman's Indebtedness to the Scientific Thought of His Day, University of Texas Studies in English, 8, 89

Cummings, S. 1962, Mark Twain's Acceptance of Science, Centennial Review, 6, 245

Dugdale, C. 1936, Whitman's Knowledge of Astronomy, University of Texas Studies in English, 8, 125

Harrison, J.A. 1965, The Complete Works of Edgar Allan Poe (AMS: New York)

Hawthorne, J. 1903, Hawthorne and His Circle (Harper: New York)

Hawthorne, N. 1860, The Marble Faun (NAL: New York)

James, H. 1886, The Bostonians (Random House: New York)

James, H. 1881, The Portrait of a Lady (Penguin: New York)

Johnson, T. 1970, The Complete Poems of Emily Dickinson (Faber: London)

Kaiser, M.I. 1977, Conversing with the Sky: The Imagery of Celestial Bodies in Thoreau's Poetry, Thoreau Journal Quarterly, 9, 15

Ketterer, D., ed. 1984, The Science Fiction of Mark Twain (Archon: Hamden, Conn)

Kremenliev, E.B. 1963, The Literary Uses of Astronomy in the Writings of Edgar Allan Poe, Ph.D. thesis (University of California: Los Angeles)

Levy, D.H. 1997, More Things in Heaven and Earth: Poets and Astronomers Read the Night Sky (Wombat: Nova Scotia)

Lindner, C.M. 1974, Newtonianism in Emerson's Nature, Emerson Society Quarterly, 20, 260

Loomis, E. 1851, The Recent Progress of

Astronomy; Especially in the United States (Arno: New York)

Mabbott, T.O., *et al.*, eds. 1978, The Collected Works of Edgar Allan Poe (The Belknap Press of Harvard UP: Cambridge, MA)

Maury, M.F. 1848, Letter Addressed to the Hon. John Quincy Adams, Southern Literary Messenger, 14, 4

Mitchell, O.M., ed. 1847, Rev. of The Sidereal Messenger, The American Whig Review, 6, 218

Nichol, J.P. 1848, Rev. of Contemplations on the Solar System, The North American Review, 66, 253

O'Meara, S.J. 1999, Comet Awards and Their Social Impact, Sky and Telescope, 97, 86

Paine, A.B. 1912, Mark Twain, A Biography: The Personal and Literary Life of Samuel Langhorne Clemens (Harper: New York)

Paul, S. 1952, Emerson's Angle of Vision: Man and Nature in American Experience (Harvard UP: Cambridge, MA)

Paul, S., ed. 1960, Walden and Civil Disobedience by Henry David Thoreau (Houghton: Boston)

Plumstead, A.W. & Hayford, H., eds. 1969, The Journals and Miscellaneous Notebooks of Ralph Waldo Emerson, Vol. 7 (Belknap Press of Harvard UP: Cambridge, MA)

Rodgers, C. & Black, J., eds. 1920, That Observatory in Brooklyn Which We Must Have by Walt Whitman in The Gathering of the Forces (Putnam's: New York)

Rusk, R.L., ed. 1939, The Letters of Ralph Waldo Emerson, Vol. 3 (Columbia UP: New York)

Scholnick, R.J. 1986, The Password Primeval: Whitman's Use of Science in Song of Myself, in Studies in the American Renaissance, ed. Joel Myerson (University Press of Virginia: Charlottesville, VA), 385

Sealts, M.M., Jr., ed. 1973, The Journals and Miscellaneous Notebooks of Ralph Waldo Emerson, Vol. 10 (Belknap Press of Harvard UP: Cambridge, MA)

Tanner, S.L. 1973, Star-Gazing in Whitman's Specimen Days, Walt Whitman Review, 19, 158

Waggoner, H.H. 1937, Science in the Thought of Mark Twain, American Literature, 8, 357

Whicher, S.E. 1960, Nature in Selections from Ralph Waldo Emerson (Houghton: Boston)

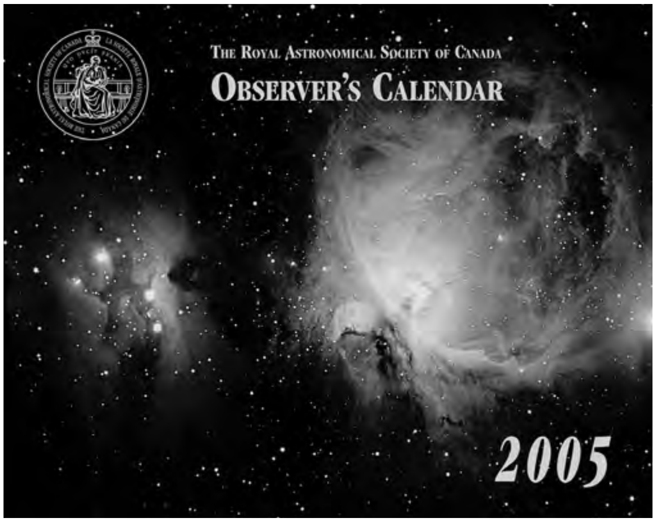
Woodson, T. 1980, The French and Italian Notebooks, Vol. 14 of The Centenary Edition of the Works of Nathaniel Hawthorne (Ohio State UP: Columbus)

Wright, H. 1950, Sweeper in the Sky: The Life of Maria Mitchell, First Woman Astronomer in America (Macmillan: New York)

Zimmerman, B. 1998, Herman Melville: Stargazer (McGill-Queen's UP: Montreal and Kingston)

An amateur astronomer and avid astrophotographer, Dr. Brett Zimmerman is the author of Herman Melville: Stargazer, *an examination of Melville's knowledge and literary uses of astronomy. With William Cole, he is currently working on a photographic guide to the northern constellations. Dr. Zimmerman teaches at York University in Toronto.*

CALL FOR PHOTOS — 2005 RASC OBSERVER'S CALENDAR



All members of the RASC are encouraged to submit astronomical photos for consideration for publication in the 2005 RASC Observer's Calendar. Images can be of any type – deep-sky or solar system; prime focus, piggy-back, or fixed-tripod; film or CCD-based.

Electronic images under 2 MB in size may be sent by email to rgupta@telus.net.
CDs, prints, negatives, or slides should be mailed to:

Rajiv Gupta
2363 18th Ave W
Vancouver BC V6L 1A7

The submission deadline is April 30, 2004.

For further information about submissions, please contact me by email at the above address.

Rajiv Gupta
Editor, RASC Observer's Calendar

Orbital Oddities

March of Planets

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

> *It looks like the moon is stuck up a tree*
> *And I am in the mood for a nice cup of tea*
> — Buck 65, Riverbed 7

To the dedicated observer of the solar system, the early years of the 21st century have been a wonderful time to be alive. The planets have grouped together in a series of conjunctions and massings, Jupiter and Saturn have had a series of excellent apparitions near the top of the ecliptic, while Mars set proximity records last year and Venus transits the Sun this. Although we are currently between those two major events, the spring of 2004 offers a cornucopia of delights not to be missed.

The best window of opportunity occurs just after the vernal equinox. *Observer's Handbook 2004* boldly proclaims, *"All five naked-eye planets (and the Moon) are visible by northern observers in the evening sky for approximately two weeks commencing Mar. 22"* (Lane 2003).

At first glance, the upcoming grouping of the five seems a pale imitation of that of April 2002, when all but Jupiter were tightly bunched in the western twilight, and all five closed to within 33° at one point in a true planetary massing. This year we will not experience the pleasing clusters and conjunctions but will actually have a much better opportunity to observe each planet.

For starters, the window of opportunity is a full month earlier, with the Sun just passing the celestial equator and the evening ecliptic tilted at its steepest angle. Each of the three outer planets is much higher in the sky offering a much better observing window. The two inner planets, meanwhile, both reach maximum elongation almost simultaneously, with Venus in particular in the midst of a glorious pre-transit apparition. Four of the five are situated well north of the ecliptic to further increase their accessibility; the fifth is as far north as it can possibly get (see Figure 1).

Although it is too imprecise to be labeled a periodicity, the interval of 23 months yields planetary layouts that are fairly similar. In 700 days:

Planet	Period (year)	No. Revolutions
Mercury	0.241	7.96
Venus	0.615	3.12
Earth	1.000	1.92
Mars	1.881	1.02
Jupiter	11.86	0.16
Saturn	29.63	0.07

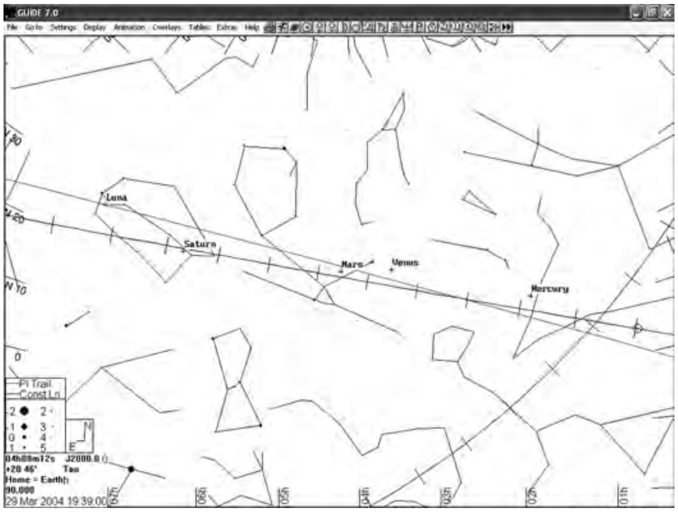


Figure 1. — The evening sky at the onset of nautical twilight, Sunday, March 28. The Sun is at the extreme right, 6° below the western horizon (the curving line at right). Gemini is transiting the meridian. Mercury and Venus are both at maximum eastern elongation. Saturn, Mars, and Venus are all above +22° declination; the Moon, situated to the upper left of Saturn, is near +28°. The ecliptic is the line with cross-ticks; the other line arching above it is the path of the Moon in March 2004. Note the favourable position of all but Saturn relative to the ecliptic. Jupiter is off the left edge of the diagram but is well placed in the ESE. The five planets will remain in the same order throughout this observing window.

Each of the six (or for that matter, the nine) has a near integer value of revolutions, with Jupiter displaying the greatest shift, slipping some two zodiacal constellations eastward, and Earth (or as seen *from* Earth, the Sun) one to the west. The quasi-periodicity is thus fairly short-lived, with two or three rough recurrences before Jupiter leaves the scene entirely. In the current sequence, 2002 featured the tightest massing. Perhaps the more-notorious grouping came some 46 months ago, the supposedly catastrophic "alignment" of May 5, 2000, which because it included the Sun was very difficult to observe. Of course that did not stop the doomsayers from selling their books,

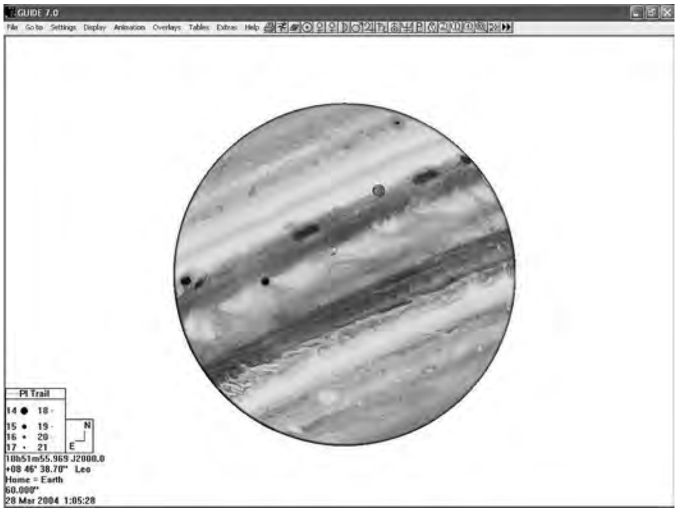


Figure 2. — The triple-shadow transit of Jupiter, 0805 UT, Sunday, March 28. The inner three moons have an orbital resonance of 4:2:1 and are co-aligned frequently, but with one of them 180° opposed to the other two. Triple-shadow transits therefore must involve the fourth moon, distant Callisto, which casts a small umbral shadow with a diffuse penumbra. In the current instance, the opportunity is brief and the observation challenging. The shadows of Ganymede and Callisto are on opposite limbs of the giant planet for only 19 minutes starting at 0800 UT. I recommend observing as much as possible the entire sequence of events, which begins with the ingress of Callisto's shadow at 0459. By 0800 when Ganymede's large, slightly oval-shaped umbra first appears on the trailing limb, Callisto's more diminutive shadow will have nearly completed its pass and will be difficult to pick out against the darkening limb. The apparent latitudes of the shadows are commensurate with their satellites' relative distances from Jupiter; by October the jovian system will have tilted sufficiently so that shadow transits of Callisto are no longer possible until 2008.

It may be possible to pick out Io and Ganymede themselves, which should just be straddling the North Equatorial Belt assuming this *Guide 7.0* simulation has placed the NEB accurately. Europa, meanwhile, is in eclipse, consistent with the co-alignment discussed above. Therefore, Jupiter will at first glance appear to have only one satellite, namely Callisto, which is off the upper right edge of the diagram a little over one jovian diameter from its shadow.

if not their souls. Ultimately and predictably, the only tidal influence in evidence was on the wallets of the gullible. (And to think I used to *like* science fiction.)

The March of Planets starts with the opposition of Jupiter on the 4th, when the big guy officially crosses over into the evening sky. While not as favourable as those of recent years, this apparition will be the last time in the current decade that Jupiter will be north of the celestial equator. I hope to spend a few mild spring evenings in the company of the King of Planets and his four attendants.

Just after opposition, begins an extended series of double-shadow transits involving Io and Europa, and a shorter one involving Io and Ganymede. The highlight occurs in the wee hours of Sunday, March 28, when a rare triple-shadow transit will be visible from anywhere in North America (see Figure 2). According to Meeus (1997) this is the only such event to occur between 1997 and 2013. As luck had it, the last occurred during a regularly scheduled meeting of the Edmonton Centre of the RASC, which therefore convened in the Observatory. Dozens of members viewed the event, a tricky observation in marginal conditions.

Moving west, Saturn will be transiting the meridian high in the south around sunset. The only planet of the five to currently be south of the ecliptic, the ringed wonder is nonetheless as far north as it ever gets, some 22° 49´ North declination as of April 2. This milestone occurs within a year of both perihelion and maximum ring tilt, a combination of favourable circumstances that has allowed northern observers a ring-side seat for viewing this unparalleled celestial jewel. Still shining around magnitude 0.0 even near quadrature, Saturn will remain well placed for observation deep into the evening hours.

Mars continues to hang around in the evening sky, soaring up the ecliptic as it exasperatingly recedes from Earth. No longer of much telescopic interest, the Red Planet nonetheless holds lingering memories of the summer that was and promise of what is yet to come. At its next opposition in November 2005 Mars will soar high above the celestial equator not too far from its current position. As you read this, the flotilla of spacecraft launched from Earth in the spring of 2003 will have completed its invasion of the Red Planet in a remarkable reversal of the scenario envisioned by H. G. Wells. How many of the five will have succeeded?

By this time much of the observational attention will have turned from Mars to nearby Venus. No war of the worlds here, as the Goddess of Love is famously unarmed.

In advance of her liaison with the Sun, Venus will put on a spectacular show. As I write this in late 2003, the brightest planet hugs the horizon deep in the south at −25° declination. But by March, it will have vaulted high into the evening sky. This is by far the most favourable variant of the five evening apparitions of Venus, which nearly repeat themselves every eight years (see Figure 3).

Venus achieves maximum eastern elongation of 46° on March 29. Days later, in the evening hours of Friday, April 2, Venus will pass only 0.6° south of the Pleiades. I remember well the spectacular sight of this distaff grouping on April 3, 1996, with the brilliant planet gleaming steadily against the backdrop of colourfully scintillating diamonds. On that occasion, there was an even rarer sight not far away, as the stunning Comet Hyakutake passed in front of the striking alpha Persei association. Unforgettably, two of the finest binocular fields in the entire sky each had a brilliant interloper simultaneously. I remember sweeping from one to the other in open-mouthed awe deep into the evening.

Certainly, Venus offers its best opportunity for deep-into-the-evening observation in this apparition. Even as it begins to be reeled back in by the Sun, it will continue to soar northward against the celestial sphere, its inclination exaggerated by foreshortening as it approaches Earth. Unlike the recent Mars opposition, this effect works to northerners' advantage this time. In late April Venus won't set until 1:30 a.m. MDT here in

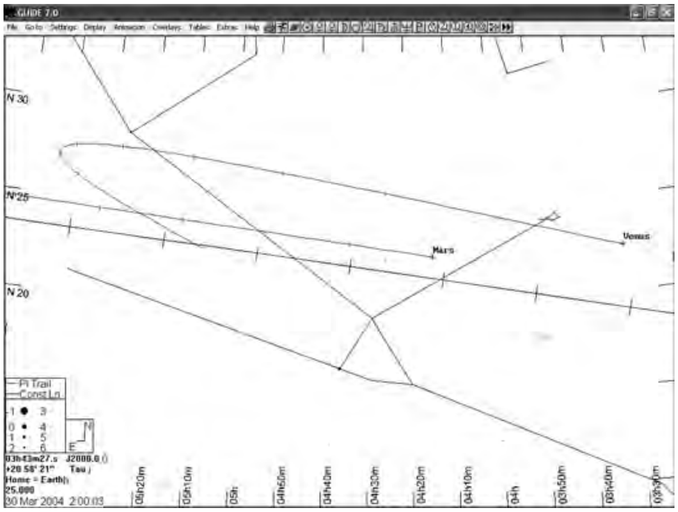


Figure 3. — The path of Venus through Taurus for the 70-day period beginning March 30 (plotted). Ticks are at 7-day intervals. The path of Mars is shown in similar fashion for much of the same period. Venus and Mars will have an extended dalliance, marching in lockstep between 5° and 10° apart from the starting point until Venus begins its retrograde motion in mid-May, but will never have a formal conjunction. Note that Venus reaches its descending node at the end of the path shown, just as the Sun (not shown) reaches that point on the ecliptic on June 8, 2004.

Edmonton, virtually local midnight!

On May 5, Venus will reach the maximum possible declination of +27° 49´. It will thus be some 2´ further north than at a similar point in 1996, which was the highest northern declination for any planet in the 20th century! This figure will be equalled (to the nearest arcminute) in 2012, leading up to the next transit. It will be equalled again, but not exceeded, in 2020, suggesting this must be very close to its northern limit. Interestingly, the extreme southerly declination for Venus recorded by Meeus (1983-95) in the coming centuries occurs on November 6, 2125, which, significantly, is 121.5 years from now and mere weeks before a transit of Venus at the other node. During the present epoch, it would seem that extreme declinations and transits are intimately associated.

Mercury chooses late March to put on its finest evening display (for northerners) of 2004. This is nothing new: the best evening apparition of Mercury of each year *always* occurs in spring or late winter — typically two and a half weeks earlier than the previous year — as the favourable angle of the evening ecliptic overwhelms all other factors. Indeed, Mercury's maximum elongation is only 19° from the Sun, near the minimum possible. Fortunately Mercury is well north of the ecliptic at this point in its orbit, further improving its angle to the horizon this spring.

Both Venus and Mercury will have achieved perihelion on March 21; while this is inconsequential for Venus and its near-circular orbit ($e = 0.007$), it is a very important factor for eccentric Mercury ($e = 0.206$). Not only does the Winged Messenger stay tight to the Sun but it is moving at its maximum speed, minimizing the period of visibility. The entire evening apparition from superior to inferior conjunction is just 44 days, compared to 68 days for the immediately preceding morning apparition. Watch for rapid changes of Mercury's position and brightness, as it fades by more than 0.1 magnitude per day.

Interestingly, Mercury and Venus both achieve maximum elongation within five hours of each other, on March 29. This is the first time since at least 1989 that the two have reached maximum elongation on the same side of the Sun within ten *days* of one another.

Overarching this superb array of planets throughout this time will be the waxing Moon. The lunar orbit is tilted some 5° to the ecliptic, and its changing orientation is such that the northern extreme of this tilt is currently approaching that of the ecliptic. The effect will max out in 2006 when the lunar nodes will briefly coincide with the equinoctial points and the two tilts will be piggybacked together. This is leading to ever more extreme declinations, characterized by extremely high full Moons in the winter months and exceptionally low ones in the summer. Around the vernal equinox it is the first-quarter Moon that soars high above the summer solstice point, some 90° ahead of the Sun.

The Moon's changing extremes of declination are noted to the nearest degree in the Sky Month-by-Month section of the *Handbook,* which states for March 2004: "The Moon reaches its greatest northern declination on Mar. 1 (+27°) and Mar. 28 (+28°) and its greatest southern declination on Mar. 14 (−27°)." March 28 is the first time Luna has been 28° from the celestial equator since 1989. On that date the first quarter moon will pass a full 5° north of Saturn — which you will recall is itself as far north as it can get (Percy 1988; Lane 2003).

One byproduct of a high-declination Moon is that it seems to hang around forever. Here in Edmonton the first-quarter Moon will not set until 4:16 a.m. MST on March 29, nearly four hours after local midnight when one might reasonably expect a first-quarter moon to exit stage west. While the lunar observer can enjoy extended observing sessions and favourable exposure of the southern libration zones, to the impatient deep-sky observer, the darn thing seems to be stuck up a tree. Might as well have that nice cup of tea and wait a fortnight, when the third-quarter moon will *rise* at a similarly late hour. There are many hours of dark, moonless skies relatively soon after the March and April Full Moons as our satellite dives down the ecliptic, in what I call the Reverse Harvest Moon Effect. This effect is accentuated during periods of high declinations.

So what's special about the planets in the spring of '04? In the single week March 28-April 3, there will be two maximum elongations, an extreme northern declination, a triple-shadow transit, an outstanding apparition of the waxing Moon, and a conjunction between the brightest planet and the brightest star cluster. Alas, the week comes to rather a sorry end with that annual April Fool's joke the human race insists on playing on itself, Daylight Saving Time.

I'll end with a fearless prediction of

my own: the planetary grouping of 2004 will cause neither earthquake nor volcano nor tsunami. At least, not here in Edmonton. Do you think anybody will buy my book?

References

Lane, D. 2003, in Observer's Handbook 2004, ed. R. Gupta (University of Toronto Press: Toronto), 82

Meeus, J. 1983-95, Astronomical Tables of the Sun, Moon and Planets (2ed: Willmann-Bell Inc.: Richmond), 36

Meeus, J. 1997, Mathematical Astronomy Morsels, (Willmann-Bell Inc.: Richmond), 279

Percy, J. 1988, in Observer's Handbook 1989, ed. R. Bishop (University of Toronto Press: Toronto), 52

Bruce McCurdy is active in astronomy education with the RASC Edmonton Centre, Odyssium, and Sky Scan Science Awareness Project. He currently serves National Council as Astronomy Day Coordinator. His grip on reality might most charitably be described as other-worldly.

Canada on Mars

by Philip Mozel, Toronto Centre (phil.n.mozel@attcanada.net)

Mars has beckoned for centuries. Now, Canada is responding. With the launch of Japan's *Nozomi* toward the red planet, Canada entered the interplanetary game, and there is nowhere to go but up.

Nozomi carries an instrument called the Thermal Plasma Analyzer. It is designed to study the composition density and temperature of the upper Martian atmosphere as well as its interaction with the solar wind. The intention is that this first-ever-Canadian inter-planetary instrument will provide clues as to the origin and fate of the Martian atmosphere.

Canadian Mars activity heated up in August 2003 with the announcement by NASA that it was selecting the *Phoenix* mission from a short list of proposals. To be built by the University of Arizona's Lunar and Planetary Laboratory, *Phoenix* will launch for Mars in 2007 and land in high northern latitudes the following year. Its two major goals will be to study the geologic history of water on Mars and to search for evidence of areas conducive to life. In the former case, it will be following up the lead provided by *Mars Odyssey,* which found evidence of near-surface water ice. The proposed landing site is suspected of containing as much as 80 percent ice by volume a mere half metre or less from the otherwise desert-like surface. Suspicions are that such an environment may also be a relatively benign one for organic molecules. This is more optimistic than the view from *Viking* days when no organics were definitely detected. A robot arm will be used to excavate samples and deliver them to an on board lab for both chemical and geological analysis. An onboard microscope will be capable of resolving at the ten nanometre level, more than enough to detect evidence of living or fossil cells preserved in the local geology.

While all this is happening, a Canadian instrument designed, built, and tested by Optech Inc. and MD Robotics will be looking upward. This LIDAR (Light Detection and Ranging) system uses a 100 Hz laser mounted on a pan and tilt platform to fire pulses of light into the atmosphere. Using the intensity versus time-of-flight signature of the reflected light, a determination of, for example, the velocity, density, and structure of Martian dust and ice clouds up to altitudes of several kilometres can be made. The structure and motion of dust devils will also be observed.

Measurements will be made of the boundary layer, a region dividing the atmosphere into upper and lower portions. Here is found much of the atmospheric dust, with the expanse above the layer being largely dust-free. The boundary layer is important as it has a bearing on general atmospheric circulation and the water cycle. Other instruments mounted near the laser will measure such aspects of the environment as atmospheric pressure and temperature.

Also in the works at Optech and MD Robotics is LAPS (LIDAR-based Autonomous Planetary-landing System) consisting of a 50,000 Hz scanning laser emitting nanosecond pulses. Software developed by the Université de Sherbrooke will analyse pulse time-of-flight to make accurate determinations of altitude and landing site topography so the spacecraft will avoid ground hazards. This has been called the "Neil Armstrong mode" in reference to how Armstrong took control of his Lunar Module's automated descent and steered it to a safe landing. LAPS will be the machine equivalent and may be in place for the *Phoenix* mission.

Plans are also afoot for a completely Canadian Mars package: *Northern Light.* Led by Thoth Technology, a consortium of twelve Canadian universities plus industrial partners aims to deliver a rover named *Beaver* to the surface of Mars by 2010. Using technology derived from the current *Beagle II* mission, the rover, with a range of one kilometre, will spend ninety Martian days (sols) exploring various aspects of the surface environment.

High-resolution cameras will make detailed panoramic images of the landing site and may even be able to capture Earth, as large as 50 arcseconds across, in the Martian sky.

Sunlight will be analysed to determine, for the first time, exactly what wavelengths reach the surface. Based, in part, on this information, other Canadian researchers will develop Mars-tolerant plants for possible seeding of the red planet.

The distribution of water has a bearing on whether life exists on Mars. A spectroscopic search will be conducted for water on the surface and in the atmosphere. Ground-penetrating radar, a Canadian speciality, and a seismometer will look for sub-surface ice and sedimentary deposits to a depth of about twenty metres.

A search will be made for biomarker gases, but the rover will look for living organisms directly as well. Using a grinding tool, *Beaver* will excavate up to ten millimetres into rocks and then engage a microscope in an attempt to image microorganisms. Life seeks such sheltered niches in hostile environments on Earth and may possibly do so on Mars. A point spectrometer will also look for the signature of chlorophyll. These investigations have been described as the "scratch and sniff" tests.

Beaver will be able not only to see but to hear, as well. A microphone will transmit ambient Martian sounds back to Earth.

An adult beaver may weigh over twenty kilograms, but its namesake on Mars will pack everything it needs to survive and study its new habitat into a svelte six kilograms. And like the real animal shaking its fur free of water, the Martian *Beaver* will also be able to shake . . . its solar panels, that is. Since the accumulation of dust on the panels, with the associated drop in power, is a limiting factor on mission duration, *Beaver* will have a certain capacity to clean itself.

Northern Light is exciting, not only for its potential science return, but also for the way in which its information will be handled. The intention is to have new data from Mars posted in near real time on the Internet. With any luck, we will be seeing, and hearing, Mars "live" in just a few years.

Acknowledgment

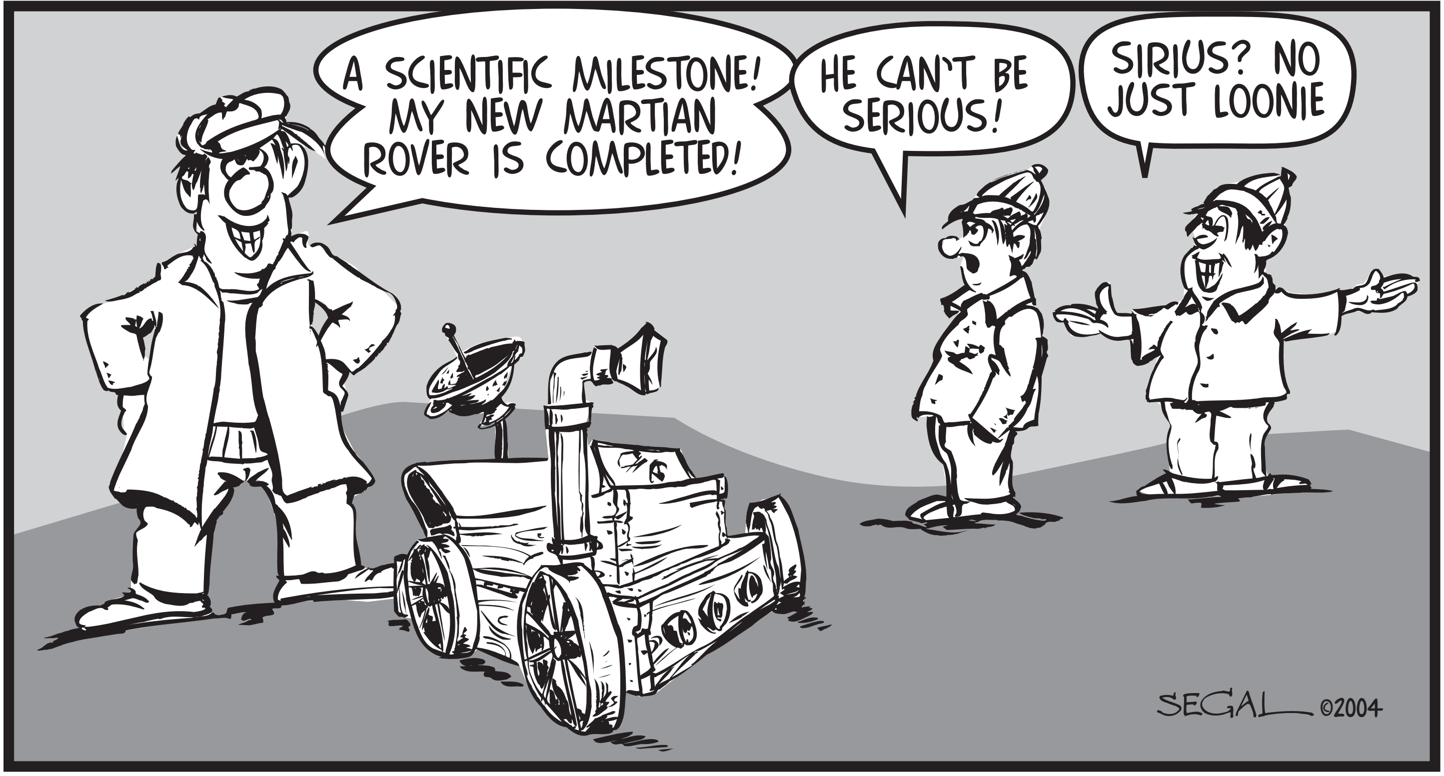
Thanks to Robert Richards and Arkady Ulitsky (Optech Inc.) and Brendan Quine (Thoth Technologies) for providing information for this article.

References

Canadian Space Agency, `www.space.gc.ca`
Optech Inc., `www.optech.on.ca`
Northern Light, `www.marsrocks.ca`
Thoth Technology, `www.thothtech.com`
MD Robotics, `www.mdrobotics.ca`

Phil Mozel is a past National Librarian of the Society and was the Producer/Educator at the McLaughlin Planetarium. He is currently an Educator at the Ontario Science Centre.

ANOTHER SIDE OF RELATIVITY



Reviews of Publications
Critiques d'ouvrages

Space, the Final Frontier?, by Giancarlo Genta and Michael Rycroft, pages 401 + xxvii, 16 cm× 23.5 cm. Cambridge University Press, 2003. Price $29 US hardcover (ISBN 0-521-81403-0).

On the eve of my 16th birthday, while I was watching the television in my Ottawa home, a man stepped on the Moon for the first time. I was a child of the space age, and that moment was a milestone in my life. I remember stepping outside and looking at the Moon, hardly believing that people could be up there. The event was the realization of a dream, and we thought it would open the door to the Universe. That has not come to pass. I find it remarkable that there are grownups today for whom the Apollo missions and Moon walks are simply history: something that happened before their time. The book *Space, the Final Frontier?* considers that topic and goes beyond.

This book is a learned, serious examination of the prospects for the exploration and colonization of outer space by humankind. The kinds of questions the book attempts to answer are: What are our motivations for going into space? Of the many possibilities for space travel, which is the most likely to succeed? Why and how should we strive to reach, if not for the stars, at least for the Moon and Mars? What and where are the greatest challenges and advantages of space to the human species?

One author, Genta, is a Mechanical Engineering Professor at the Technical University of Turin, Italy. His specialty is aeronautics and aerospace engineering. He has published both books and research articles. The other author, Rycroft, is a Visiting Professor at the International Space University in Strasbourg, France, and has a distinguished scientific career in Britain, including the editing of scientific journals and the *Cambridge Encyclopedia of Space*. There are forewords by both an Italian astronaut (Franco Malerba) and a UK astronaut (Michael Foale).

The book is reasonably up-to-date, having been published in 2003 and completed in 2002. Unfortunately, the book predates the tragic February 2003 accident involving the space shuttle *Columbia* and her crew, and the aftermath.

The authors first briefly review the progress already made in space exploration, but their treatment is far from being a comprehensive history of space travel. The controversies and crises of space exploration are included in the analysis. Their intent is to introduce past and current technologies for space vehicles and stations, including the effect on inhabitants. The pros and cons of robotic exploration are discussed in the context of our exploration of the nearby planets. The authors then turn to the possibility of a return to the Moon, the future colonization of Mars, and extensions beyond that. Exploitation of the resources provided by the planets of the solar system is considered. The final chapters address propulsion techniques needed to support exploration beyond the solar system, and related aspects of long-distance travel. Accordingly, the book gradually becomes more fantastic as one reads on, but the treatment is always realistic, based on correct scientific principles. There are several appendices on technical subjects: cosmic distances, astrodynamics, space propulsion, and acronyms.

The book is very well written and organized, neither too elementary nor too advanced. There are frequent footnotes directing the reader to specialized literature, but no bibliography. The authors deal with some controversial topics, but their vision is grand and optimistic.

For example, one interesting (and slightly disturbing) concept is the idea of engineering the atmosphere of Mars to support life (as we know it). The idea is to stimulate global warming by adding CFCs to the atmosphere, to raise the surface temperature and melt water ice to form water and water vapour. Mars, being smaller than Earth, could never have our dense atmosphere, but there is a view that in a regenerated atmosphere humans could live without space suits, using a version of SCUBA gear. Something tells me the environmentalists will not like the idea. The general concept is called "terraforming": altering the environment of a planet to make it more suitable for human life. To their credit, the authors discuss the ethics of the issue and give arguments both in favour and against.

One criticism I have about the book is the uneven quality of the illustrations, a surprising gaffe by a publisher of the calibre of Cambridge University Press. Some photos and images are clear: sharp with good contrast; others are poor: fuzzy and washed-out. Many appear to be low-resolution images downloaded from the Internet. That is unacceptable in a quality book.

Nevertheless, I would recommend the book to those interested in space technology and space exploration.

DAVID CHAPMAN

David Chapman is a Life Member of the RASC and a Past President of the Halifax Centre. As a Contributing Editor of JRASC, *he writes the Reflections column six times a year. He is also a member (Dave XVII) of the RASD: Royal Astronomical Society of Daves.*

A New Image for the RASC

> “ The Society’s previous seal has served us well through our first century of Royal designation; may the new seal, with its retention and improvement of the traditional elements and introduction of key new elements that make it even more appropriate as the face of the Society, remind us of our rich heritage and proudly lead us into our second Royal century.”
>
> — Rajiv Gupta, President, RASC

Design by Dan Collier

A Proud Moment

The RASC receives the Michael Smith Award

From Left: Dr. Rajiv Gupta with the Honourable Susan Whelan (Minister for International Cooperation), Madame Claude Benoit, and Dr. Nigel Lloyd at the Canadian Museum of Nature, Ottawa, November 19, 2003. (Photo courtesy of NSERC)

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

NATIONAL OFFICERS AND COUNCIL FOR 2003-2004/CONSEIL ET ADMINISTRATEURS NATIONAUX

Honorary President	Roy Bishop, Ph.D., Halifax
President	Rajiv Gupta, Ph.D., Vancouver
1st Vice-President	Peter Jedicke, London
2nd Vice-President	Scott Young, B.Sc., Winnipeg
Secretary	Kim Hay, Kingston
Treasurer	Michael S.F. Watson, Unattached member
Recorder	Heide Debond, Toronto
Librarian	Colin Haig, M.Sc., Hamilton
Past Presidents	Robert Garrison, Ph.D., Toronto and Randy Attwood, Toronto
Editor of *Journal*	Wayne Barkhouse, Ph.D., Halifax
Editor of *Observer's Handbook*	Rajiv Gupta, Ph.D., Vancouver
Editor of *Beginner's Observing Guide*	Leo Enright, Kingston
Editor of *Observer's Calendar*	Rajiv Gupta, Ph.D., Vancouver
Author of *SkyWays*	Mary Lou Whitehorne, AdPR, Halifax
Executive Secretary	Bonnie Bird, M.L.Sc., 136 Dupont Street, Toronto ON M5R 1V2 Telephone: (416) 924-7973

CENTRE ADDRESSES/ADRESSES DES CENTRES

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

Belleville Centre
9 South Park Street, Belleville ON K8P 2W9

Calgary Centre
C/O Calgary Science Centre, PO Box 2100 Station "M", Calgary AB T2P 2M5

Charlottetown Centre
C/O Clair Perry, 38 Mt Edward Road, Charlottetown PE C1A 5S2

Edmonton Centre
C/O Edmonton Space & Science Centre, 11211 – 142 Street
Edmonton AB T5M 4A1

Halifax Centre
PO Box 31011, Halifax NS B3K 5T9

Hamilton Centre
PO Box 1223, Waterdown ON L0R 2H0

Kingston Centre
PO Box 1793, Kingston ON K5L 5J6

Kitchener-Waterloo Centre
C/O John Beingessner, 479 Cabot Trail, Waterloo ON N2K 3Y3

London Centre
PO Box 842 Station B, London ON N6A 4Z3

Moncton Centre
C/O Dr. Francis LeBlanc, Département de physique et d'astronomie,
Université de Moncton, Moncton NB E1A 3E9

Centre francophone de Montréal
Casier postal 206 Station St-Michel, Montréal QC H2A 3L9

Montreal Centre
PO Box 1752 Station B, Montreal QC H3B 3L3

Niagara Centre
PO Box 4040, St Catharines ON L2R 7S3

Okanagan Centre
PO Box 20119 TCM, Kelowna BC V1Y 9H2

Ottawa Centre
PO Box 33012, 1363 Woodroffe Ave, Ottawa ON K2C 3Y9

Prince George Centre
7365 Tedford Road, Prince George BC V2N 6S2

Centre de Québec
2000 boul Montmorency, Québec QC G1J 5E7

Regina Centre
PO Box 20014 Cornwall Centre, Regina SK S4P 4J7

St. John's Centre
C/O Randy Dodge, 206 Frecker Dr, St. John's NL A1E 5H9

Sarnia Centre
C/O Jim Selinger, 160 George Street, Sarnia ON N7T 7V4

Saskatoon Centre
PO Box 317 RPO University, Saskatoon SK S7N 4J8

Thunder Bay Centre
286 Trinity Crescent, Thunder Bay ON P7C 5V6

Toronto Centre
C/O Ontario Science Centre, 770 Don Mills Road, Toronto ON M3C 1T3

Vancouver Centre
C/O The HR Macmillan Space Centre, 1100 Chestnut Street
Vancouver BC V6J 3J9

Victoria Centre
C/O Lauri Roche, 8581 Sentinel Place, Sidney BC V8L 4Z8

Windsor Centre
C/O Ken Garber, 2831 Alexandra Avenue, Windsor ON N9E 2J8

Winnipeg Centre
PO Box 2694, Winnipeg MB R3C 4B3

Publications and Products of

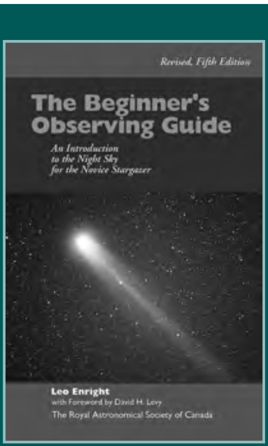
The Royal Astronomical Society of Canada

Observer's Calendar — 2004

This calendar was created by members of the RASC. All photographs were taken by amateur astronomers using ordinary camera lenses and small telescopes and represent a wide spectrum of objects. An informative caption accompanies every photograph.

It is designed with the observer in mind and contains comprehensive astronomical data such as daily Moon rise and set times, significant lunar and planetary conjunctions, eclipses, and meteor showers. The 1998, 1999, and 2000 editions each won the Best Calendar Award from the Ontario Printing and Imaging Association (designed and produced by Rajiv Gupta).

Individual Order Prices: $16.95 Cdn (members); $19.95 CDn (non-members)
$14.95 US (members); $17.95 US (non-members)
(includes postage and handling; add GST for Canadian orders)



The Beginner's Observing Guide

This guide is for anyone with little or no experience in observing the night sky. Large, easy-to-read star maps are provided to acquaint the reader with the constellations and bright stars. Basic information on observing the Moon, planets and eclipses is provided. There is also a special section to help Scouts, Cubs, Guides, and Brownies achieve their respective astronomy badges.

Written by Leo Enright (160 pages of information in a soft-cover book with otabinding that allows the book to lie flat).

Price : $19.95 Cdn (Add $3.00 Shipping & Handling; add GST for Canadian orders)

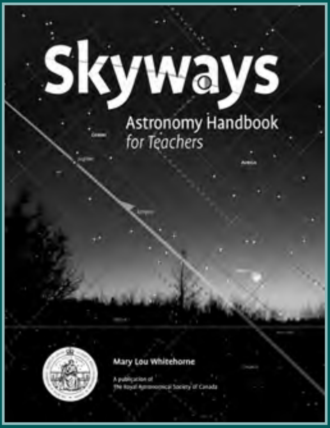
Skyways: Astronomy Handbook for Teachers

Teaching Astronomy? Skyways Makes it Easy!

Written by a Canadian for Canadian teachers and astronomy educators, Skyways is Canadian curriculum-specific; pre-tested by Canadian teachers; hands-on; interactive; geared for upper elementary, middle school, and junior-high grades; fun and easy to use; cost-effective.

Skyways is complete with conceptual background; teacher information; student worksheets; resource lists; Canadian contributions to astronomy section FAQ's, and more. Written by Canadian author and RASC member, Mary Lou Whitehorne.

Price: $16.95 Cdn (members); $19.95 Cdn (non-members)
(includes postage and handling; add GST for Canadian orders)



Shop On-Line at www.store.rasc.ca

Send cheque or money order to: RASC, 136 Dupont St, Toronto ON M5R 1V2 Canada
Please allow 6-8 weeks for delivery. Orders outside Canada please remit in U.S. Funds.
Major credit cards accepted. Call the National Office toll-free at 1-888-924-7272 to place your order.
(These products may also be available directly from your local Centre)