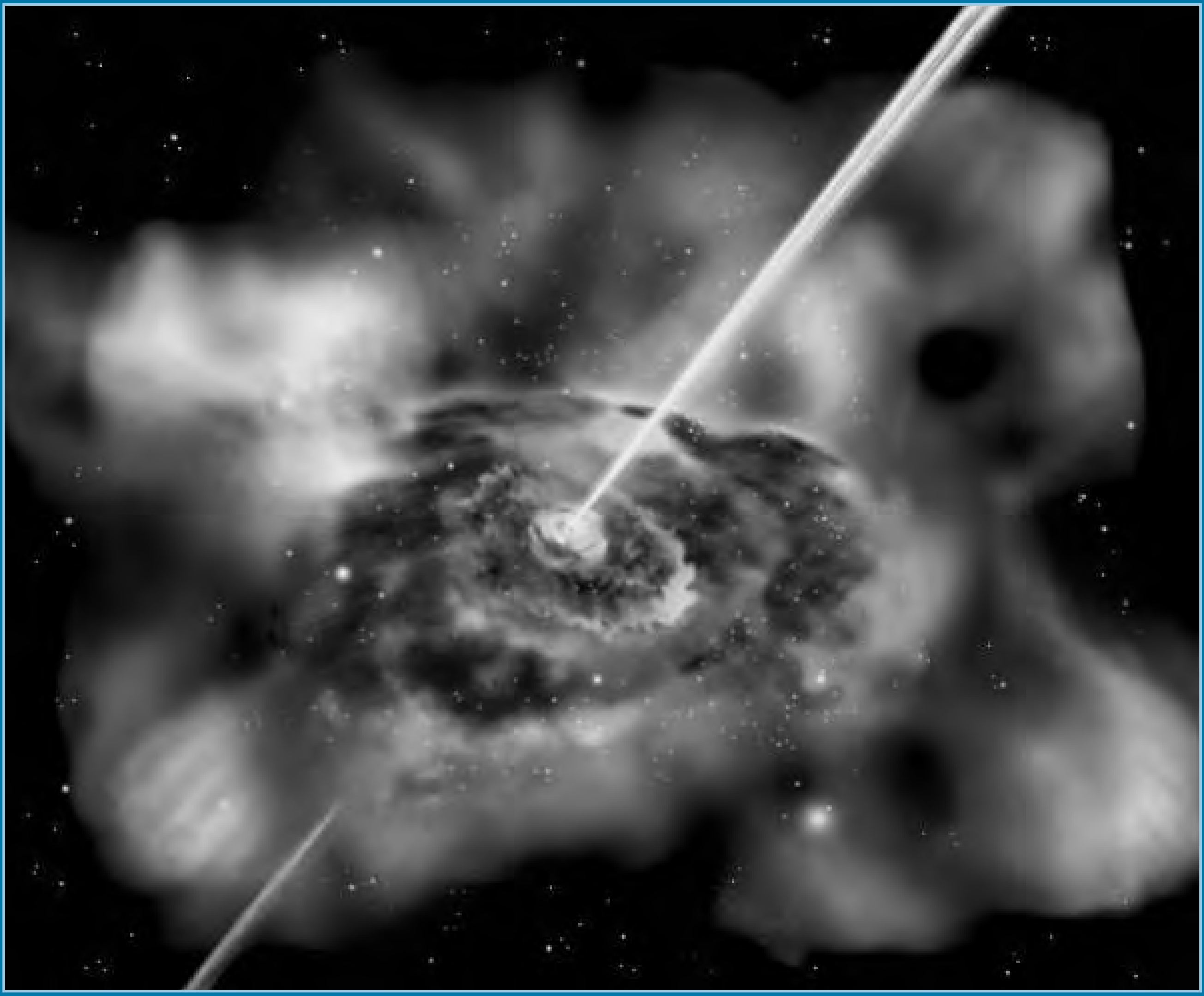
June/juin 2003 Volume/volume 97 Number/numéro 3 [700]

Journal

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



INSIDE THIS ISSUE

Nineteenth Century American Astronomy • The Discovery of Charon
Magnetically Powered Gamma-Ray Bursts • Martian Motion
Canadian Thesis Abstracts

June/juin 2003

Journal

Vol. 97, No.3 Whole Number 700

contents
table des matières

FEATURE ARTICLES/ARTICLES DE FOND

120 Nineteenth-Century American Astronomy and the Sublime
by Brett Zimmerman

RESEARCH PAPERS/ARTICLES DE RECHERCHE

128 A Leonid Meteor
by Roy Bishop

132 Canadian Thesis Abstracts
by Melvin Blake

EDUCATION NOTES
RUBRIQUES PÉDAGOGIQUES

133 Mars in Motion: Keplerian Earth Centred Orbits?
by David Orenstein

145 Web Site Reviews
by William Dodd

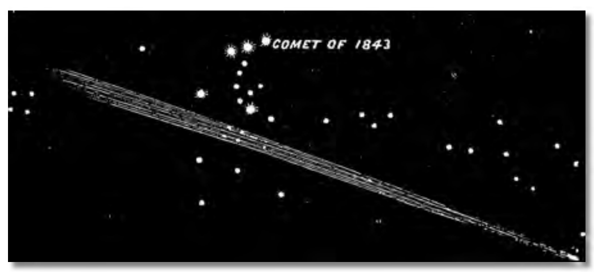
COLUMNS/RUBRIQUES

124 Second Light: Magnetically Powered Gamma-ray Bursts
by Leslie J. Sage

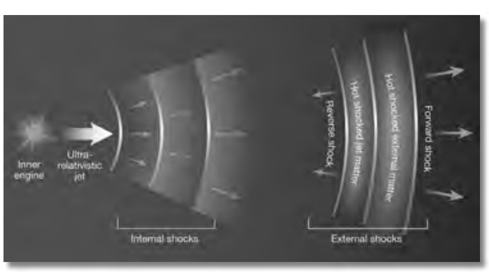
126 Reflections: J.W. Christy and the Discovery of Charon, Pluto's Satellite
by David M.F. Chapman

137 Orbital Oddities: Martian Motion II: Zig Zag
by Bruce McCurdy

141 Scenic Vistas; Cyg-nice!
by Mark Bratton

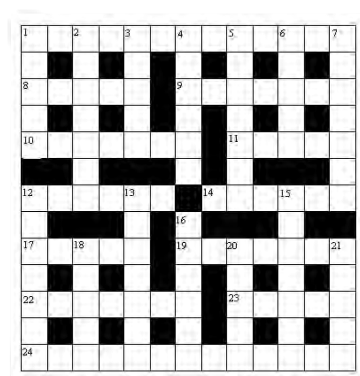


Nineteenth-Century Astronomy and the Sublime
p. 120



Magnetically Powered Gamma-Ray Bursts
p. 124

The Discovery of Charon
p.126



AstroCryptic
p.148

DEPARTMENTS/DÉPARTEMENTS

114 President's Corner
by Rajiv Gupta

116 Editorial
by Wayne A. Barkhouse

117 Correspondence / Correspondance

118 News Notes / En manchettes
Weighing the Invisible at the Edge of the Universe; Plaskett Medal; Northrop Frye Award; Royal Award; Gusty Winds in Molecular Clouds

127 From the Past / Au fil des ans
Notes From Observatories

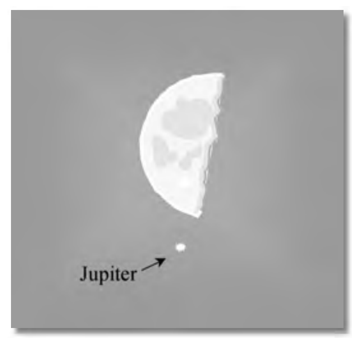
146 Reviews / Critiques
Misfortunes as Blessings in Disguise: The Story of My Life, by Dorrit Hoffleit; Star Testing Astronomical Telescopes: A Manual for Optical Evaluation and Adjustment by Harold Richard Suiter

Editorial
p. 116

ACROSS THE RASC
DU NOUVEAU DANS LES CENTRES

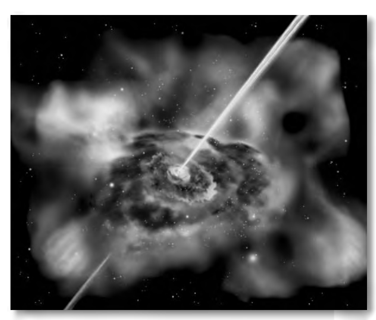
136 Society News / Nouvelles de la société
by Kim Hay
National Council Meetings; Upcoming Events

144 The Visibility of Jupiter During the Day
by Russell D. Sampson



The Visibility of Jupiter During the Day
p. 144

Reviews
p. 146



Cover:
The Heart of a Quasar
News Notes
p. 118

President's Corner

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

As I near the midway point of my term as President, I must admit that even though overall I am enjoying holding this office, there are elements of the "job" that are either tedious or downright unpleasant. As a member of every committee of Council, the President can participate in the discussion of all of these important working groups; while that allows him or her to influence the direction of the Society in a unique manner, it does at times lead to an overwhelming number of email messages to read and absorb. Also, as his been the case at least twice so far during my term, when a decision is made by the Executive that has an adverse impact on an individual member, it is the President's unpleasant task to communicate the decision to the member. There are also always little operational fires to fight, including trying to ensure that important tasks within the Society are completed on time. Despite the influence that being part of every committee provides, the President, as the chair of all meetings of Council, must refrain from expressing opinions during Council meetings. Presidents tend to have strong opinions on Society matters, and often find being so muzzled to be the most difficult aspect of the office!

There is however one aspect of being President of the RASC that every person who hold the office loves — travelling to the Centres. The Society has a tradition that the President visits as many Centres as possible during his or her term, and includes in its annual budget an allowance for that travel. The visit is multipurpose: the President gives a talk at a Centre meeting on his or her own area of interest in astronomy (the talk is often especially appreciated by smaller Centres that may have difficulty attracting out-of-town speakers), and more importantly the President learns about the Centre and meets with members of the Centre, learning of any difficulties or successes the Centre is having. The President's main duty here is not really to deliver the talk, but rather to act as a sounding board to keep an open ear, and to provide advice as needed.

After having now visited over half of the Centres (16 out of 26), I can only describe the visits as exhilarating. I have been able to share my passion for astrophotography, in the form of my talk on current methods in digital astroimaging, with a large number of enthusiastic (or perhaps captive) audiences. Members seem to appreciate learning about the techniques that were used to form many of the images appearing in the *Observer's Calendar* over the years. The real reason for the exhilaration is the opportunity to meet with scores of dedicated members across the country. As I learn more about the public outreach

Journal

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

The *Journal of The Royal Astronomical Society of Canada* is published at an annual subscription rate of $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 2003, $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: rasc@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

and observing activities Centres are actively engaged in, I feel increasingly proud to be the President of the diverse and committed ensemble of amateur astronomers of which the RASC uniquely consists.

I don't know when the tradition of Presidential visits to Centres started or what the specific reason for instituting these visits was, but I think they are a most wise investment of the President's time and the Society's resources. Some members perceive a disconnect between the Society's National Executive and themselves. While most members of the National Executive (the President, First Vice President, Second Vice President, Secretary, and Treasurer) were once active in a Centre, members of the National Executive may (as I did) become less involved in Centre affairs as their duties at the national level expand. The visits provide a healthy opportunity for dialogue between the Centres and the National Executive. They are a reminder to the President, in case the reminder is needed, that, in spite of the important astronomical tasks in which the Society engages (including the publication of the *Journal*, *Observer's Handbook*, *Beginner's Observing Guide*, and *Observer's Calendar*), the bulk of the astronomy within the Society is done *at the Centres*. The Centres are what define the Society, and that should never be forgotten.

The President's visits to the Centres can be burdensome for both the President and the Centres. My recent 10-day crisscrossing tour of southern Ontario, during which I visited the seven most southerly Centres of the Society (having previously visited its four most easterly Centres during an 8-day tour), was efficient but exhausting. For this tour, and for any tour that involves multiple Centres, some bending of regular meeting schedules is necessary, and I thank the Centres that altered their regular meeting dates to fit in my visit. Also, I thank the many members who helped arrange the visits or billeted me during my travels; there are too many to name all of them, but in particular I thank Roland Dechesne, Garry Dymond, and Dave Lane, who provided accommodation and wonderful company during multiple-night stays. Finally, I thank all the Centres for the tremendous hospitality extended to me during my travels. I eagerly look forward to my remaining Centre visits.

Editorial

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

In early April of this year, I embarked on my first trip to the Southern Hemisphere to undertake an observing run at the Cerro Tololo Inter-American Observatory (CTIO) in Chile. Having grown up in Nova Scotia, I was very excited about getting a chance to observe the southern skies for the first time (as well as having the opportunity to observe with the 4-metre Blanco telescope — the "monster of the hill").

After 13 hours of flying and seven hours of waiting in airports, I finally arrived at my first destination — the CTIO headquarters in La Serena, Chile. I had received permission to travel to the summit of Cerro Tololo a day before my observing run was to start, to familiarize myself with the area and the telescope I was to use. Having spent one night in La Serena for some much needed sleep, I caught the early morning shuttle to the observing site.

The weather in La Serena on the morning of my departure was a bit of a concern since we were buried in thick fog. After traveling for about half an hour, we left the clouds behind as we began our ascent of 2200 metres to the observing complex. Traveling through the mountainous terrain of the Andes was spectacular! My first thought was to compare the Chilean landscape to the Rocky Mountains of Western Canada (the mountains in Chile are more rounded and "rusty" in colour). I found the Chilean mountains to be more "friendly" than the jagged, rough-looking mountains of British Columbia.

My first night on the mountain was free of any work-related duties and, since the skies were very clear, I laid back under the brilliance of the southern stars with my trusty old binoculars that I had dragged along. My first objective was to locate the

Large and Small Magellanic Clouds. The view was truly awesome — the clouds easily recognizable just off the Milky Way. The sight of these two neighboring galaxies was incredible through my 10×50 binoculars, with the LMC definitely looking like a "barred irregular."

Over the course of several minutes I quickly searched for Alpha Centauri (bright red in colour), Omega Centauri (a globular cluster that puts M13 to shame), and 47 Tucana. The Southern Cross was plainly visible overhead with the greatest visual impact being that of the nearby Coal Sack. Immediately obvious to the eye was the fact that all of the constellations I am familiar with, such as Orion, were upside down, with the constellation Scorpius directly overhead instead of hovering near the southern horizon.

The greatest awe-inspiring view was made late in the night when the centre of the Milky Way was at the zenith position. Being a "galaxy" person, I had appreciated the view of the Magellanic Clouds and the Milky Way. but what really caught my attention was the amount of interstellar material that one can see silhouetted against the Milky Way centre. From the Northern Hemisphere, the amount of dust in our galaxy can most easily be seen by looking at the Cygnus area of the sky, but the contrast afforded by the brilliance of the Milky Way centre and the large amount of extinction was breathtaking! Scientists are always being accused of "taking the romance out of nature" by explaining various phenomena. but to me, understanding the full implication of what I was looking at when I viewed the Milky Way centre was more emotional and inspirational (at a much deeper level) than I would have otherwise felt.

My trip to Chile was very successful — both in terms of experiencing the southern skies for the first time, and having very clear weather for my observing run. My only hope is that others will get an opportunity to venture south and experience the wonders of the southern skies.

Correspondence
Correspondance

Dear Sir,

I enjoyed Rogert Egler's well-written article *Astronomical Events Recorded in the Medieval Anglo-Saxon Chronicles* in last October's issue (*JRASC*, 96, 184). I'd like to add a few thoughts regarding events in the year 1106. Egler suggests that the star with a "beam so immense" was a comet, and that the only comet he could find was Comet Linear C/1999 S4, which was almost 500 astronomical units from the Sun and thus way too faint.

Egler's decision to confine his comet search to known periodic comets resulted in the paper's losing out on some pretty interesting old comet apparitions. It turns out that there was a great Comet of February 1106 that matches the description. In addition, this comet passed so close to the Sun that it split apart into several pieces and may have been the parent of at least part of the Kreutz family of Sun-grazing comets. At least two of these pieces have been seen to return; one as the Great Comet of 1882, the other as Comet Ikeya-Seki in 1965.

At the end of Donald Yeomans' book, *Comets: A Chronological History of Observation, Science, Myth, and Folklore* (John Wiley, 1991, pp.361-424), is a comprehensive list of comets that appeared in the ancient past. There a reader will find information about some of the other comets that Mr. Egler writes of in his article, including the two comets of 729, 891, 1097, 1106, and 1114.

I hope these comments add a little spice to an already interesting article.

Sincerely

David H. Levy
Jarnac Observatory, Inc.

News Notes
En Manchettes

WEIGHING THE INVISIBLE AT THE EDGE OF THE UNIVERSE

For the first time astronomers have weighed a black hole at the furthest reaches of the Universe. A team of astronomers from Canada and the United Kingdom has studied infrared light from the most distant quasar known and found that the quasar contains a black hole of mass some 10^{15} times greater than that of the Earth. The observations were made with the United Kingdom Infrared Telescope (UKIRT) in Hawaii, using the new UKIRT Imager Spectrometer, and are published in the March issue of *Astrophysical Journal Letters*.

Team leader Dr. Chris Willott, from the National Research Council's Herzberg Institute of Astrophysics in Victoria, Canada, comments that "we looked at the most distant known quasar, SDSS J1148+5251, with UKIRT. We're seeing this quasar as it looked when its light was emitted 13 billion years ago, back when the Universe was only 6% of its current age." The key spectroscopic feature that that team analyzed was due to ionized magnesium (Mg II). Willott explains that "the masses of the black holes in distant quasars can be determined by looking at the Mg II emission line and comparing it with the same emission line in closer quasars. The basic idea here is that the width of the line gives an indication of the speed of the gas close to the quasar. More massive black holes will have faster moving material."

The team measured the width of the Mg II emission line, which allowed them to determine the mass of the black hole in SDSS J1148+5251 as 3×10^9 times the mass of the Sun. They also used the wavelength displacement of the emission line to determine a precise redshift of 6.41 for the quasar. The redshift measures the distance to the object, confirming it as the most distant quasar known, and placing it at some 1.3×10^{10} light-years from Earth.

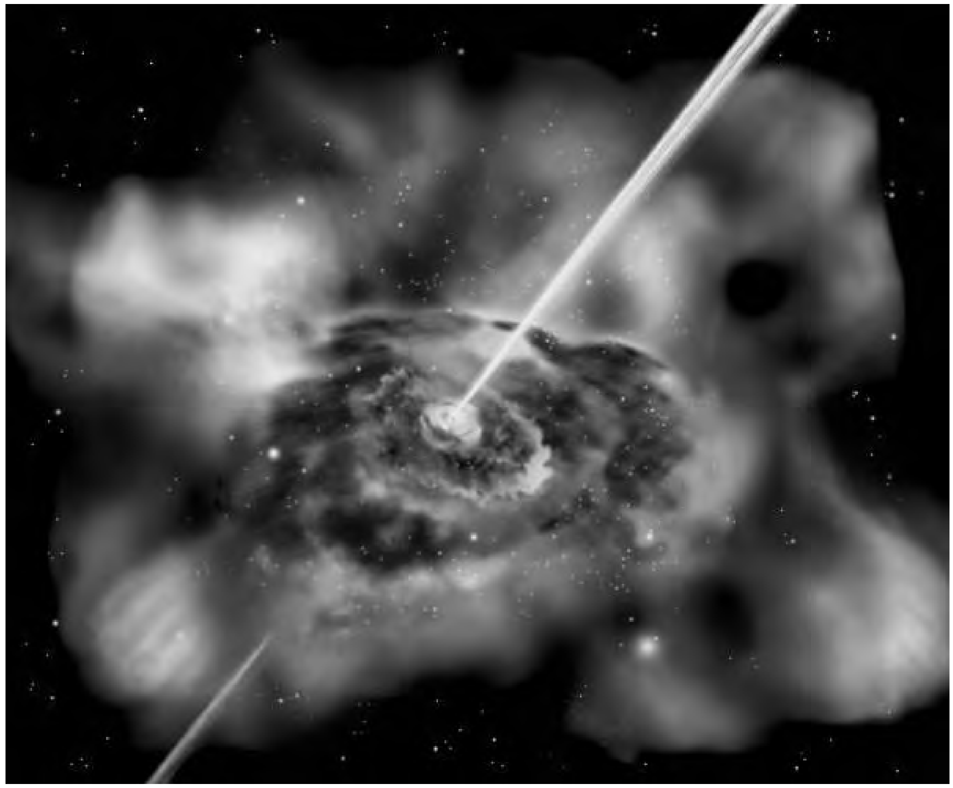


Figure 1— Artist's impression of the heart of a quasar, where a black hole is hidden in a disk of gas and dust. Image courtesy of NASA Education and Public Outreach at Sonoma State University — Aurore Simonnet, `epo.sonoma.edu`

Willott and co-workers also find that the extreme brightness of SDSS J1148+5251 indicates that the black hole in its core is accreting matter at its maximum possible rate, the so-called Eddington Limit. If the black hole were accreting matter any faster, it would shine even brighter, and the intense luminosity would actually exert enough pressure to stop any more material falling in. Dr. Ross McLure, a team member from the Institute for Astronomy in Edinburgh, also notes "this quasar pinpoints the first massive structures to have formed in the universe. It confirms predictions that such huge black holes do exist so early in the universe, but they are rare."

PLASKETT MEDAL

The J.S. Plaskett Medal for 2003 has been awarded to Dr. Tracy Webb of the University of Toronto. The Plaskett medal is awarded each year by the RASC and CASCA for the best doctoral thesis submitted to a Canadian university during the previous two calendar years. Webb's thesis is entitled "The Formation and Evolution of Galaxies: A Deep Submillimetre Survey." An award ceremony and public lecture by Dr. Webb will take place at the CASCA meeting in Waterloo in June, 2003.

NORTHROP FRYE AWARD

The prestigious Northrop Frye Award for "demonstrating exemplary and innovative ways of linking teaching and research" has been awarded this year to astronomer Dr. John Percy (Erindale Campus, The University of Toronto). The award is granted annually to a faculty member and is co-sponsored by the University of Toronto Alumni Association and the Provost of the University.

ROYAL AWARD

Dr. R.F. Garrison (David Dunlap Observatory, the University of Toronto) has been awarded the Queen's Golden Jubilee Medal. The commemorative medal for the golden jubilee of Her Majesty Queen Elizabeth II is awarded to those Canadians who have made a significant contribution to their fellow citizens, their community, or to Canada.

GUSTY WINDS IN MOLECULAR CLOUDS

Big whorls have little whorls,
That feed on their velocity;
And little whorls have lesser whorls,
And so on to viscosity.

The above verse by renowned English polymath Lewis Fry Richardson captures the essence of turbulence. In our everyday lives we experience the bumps and eddies of turbulent flows in such simple things as a gusty day or a babbling brook. But turbulent behavior also extends to the truly gargantuan scales of the interstellar medium. To better understand the phenomenon, Christopher Brunt of the Dominion Radio Astrophysical Observatory (DRAO) has measured the turbulent flow in some of the Milky Way's nearby molecular clouds and then compared his observations to computer simulations. The results of the study have recently been published in the January issue of the *Astrophysical Journal*.

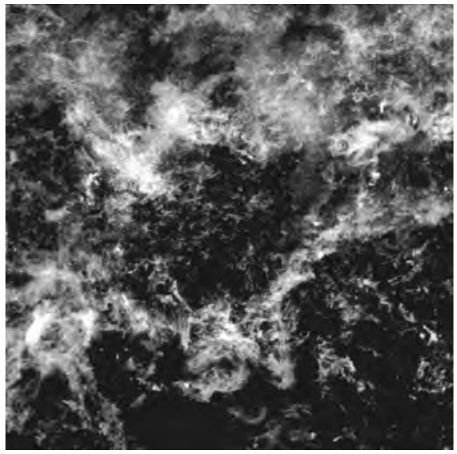


Figure 2 — Turbulent flow is visually apparent in this portion of the FCRAO Carbon Monoxide Survey of the Outer Galaxy. This image is a result of reprocessing done at the DRAO, which is operated by the National Research Council of Canada. (Courtesy of Christopher Brunt and Jerran Ontkean).

Understanding the large-scale motion of molecular clouds is necessary in the quest to unravel the mysteries of stellar birth. The motion of the gas and dust must allow for the cloud's own gravity to eventually collapse it into a spinning protostellar disk. A major question is whether the dominant form of turbulence originates from within the molecular cloud or from the outside. According to Brunt, "small-scale turbulence is more indicative of quasi-static clouds, supported for long times by turbulence generated by embedded sources, while large-scale turbulence is more indicative of transient clouds which come together, form stars quickly (but inefficiently) and disperse fairly promptly: [which indicates] a much more dynamic medium."

Using the Five College Radio Astronomy Observatory (FCRAO) in Massachusetts, Brunt performed a statistical analysis on the Doppler-shifted carbon monoxide emission lines found in 23 regions along the Milky Way. The amount by which the emission line is shifted to shorter or longer wavelengths reveals the velocity of the gas towards or away from the Earth. A map of the cloud's velocity field then illustrates its turbulent flow. Complementary observations from the DRAO of the 21-cm H I emission line uncovered the flow pattern of neutral hydrogen surrounding the molecular cloud. A comparison between the observed and "model" turbulence then enabled Brunt to see which parameters best matched the observations.

The collected observations reveal that the turbulent flow in the molecular clouds appears to be a relatively short-lived component of an even larger-scale flow from the surrounding atomic gas. Brunt therefore concluded that, "the H I data suggest that the surrounding atomic material is not just some relatively inert outer envelope of stodgy, quasi-static clouds, but rather is the more rarefied part of a larger-scale flow that is intimately connected to the highly dynamic star-forming part." This then begs the question; on an even grander scale would we find ever larger eddies and whorls extending to the ends of the observable universe?

Nineteenth-Century American Astronomy and the Sublime

by Brett Zimmerman (bazimme@attglobal.net)

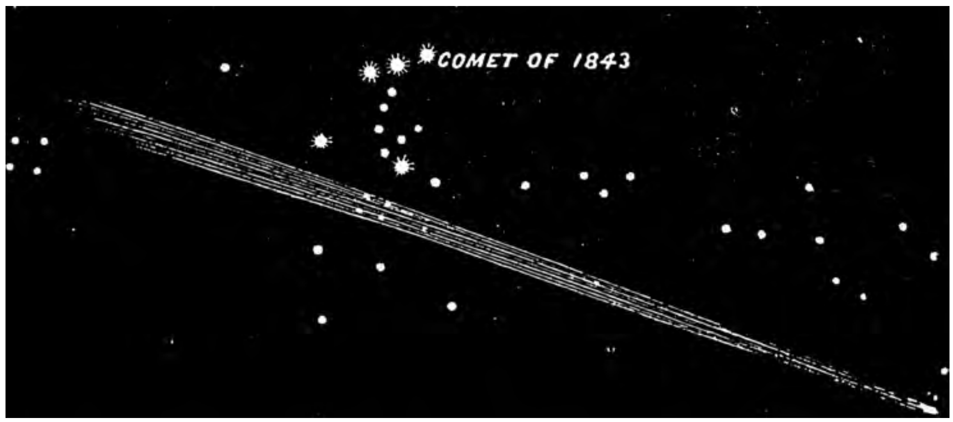


Figure 1 — From Hiram Mattison's *Atlas Designed to Illustrate Burritt's Geography of the Heavens* (New York, 1856).

In 1757 Edmund Burke published a famous treatise in which he argued that objects threatening us directly with pain or danger cause horror, with the most extreme degree of that emotion being *astonishment* — paralysis of thought and action; but if objects are *non*-threatening but still awesome, then they can cause in us a feeling of *delightful* terror, a kind of pleasure. Burke used the term *sublime* to describe both the objects capable of causing these feelings and the feelings themselves. Many spectacular astronomical events of the nineteenth century excited either feelings of astonishment or delightful terror, and when we indeed consider the truly memorable displays of comets, meteors, fireballs and their vapour trails witnessed by nineteenth-century Americans, it is hardly any wonder that in their time astronomy was nicknamed the "sublime science."

Edmund Burke, in his famous treatise *A Philosophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful*, provided a widely influential definition of the "sublime" — which, he insisted, is based on *terror*:

> "Whatever is fitted in any sort to excite the ideas of pain, and danger, that is to say, whatever is in any sort terrible, or is conversant about terrible objects, or operates in a manner analogous to terror, is a source of the sublime; that is, it is productive of the strongest emotion which the mind is capable of feeling."

Burke goes on to say that those objects that threaten us directly with pain or danger cause horror, with the most extreme degree of that emotion being astonishment — paralysis of thought and action; but if those sublime objects are non-threatening, then they can cause in us a feeling of *delightful* terror, a kind of pleasure.

In the nineteenth century, astronomy was widely known as the *sublime science*. And why not? Astronomy opens up to us cosmic vistas that fill us simultaneously with dread *and* wonder: the awesome spectacle of colliding galaxies; the startling burst of stars gone nova; the destructive potential of errant comets; the dazzling brilliance of meteoric showers — and the immeasurable depths of frigid space! Burke says, "Another source of the sublime, is *infinity* [which] has a tendency to fill the mind with that sort of delightful horror, which is the most genuine effect, and truest test of the sublime." He goes on to say that *magnificence*, by which he means a "great profusion of things," is "likewise a source of the sublime":

> "The starry heaven, though it occurs so very frequently to our view, never fails to excite an idea of grandeur. This cannot be owing to any thing in the stars themselves, separately considered. The number is certainly the cause. The apparent disorder augments the grandeur, for the appearance of care is highly contrary to our ideas of magnificence. Besides, the stars lye [*sic*] in such apparent confusion, as makes it impossible on ordinary occasions to reckon them. This gives them the advantage

of a sort of infinity."

For the informed amateur and professional astronomer, awesome celestial events more likely will fill the mind with fearful wonder; for the uninformed populace, astronomical phenomena can just as easily fill the mind with terror, especially when the threat is considered real rather than remote, apocalyptic rather than abstract. The professional and popular reaction to astronomical phenomena in nineteenth-century America, especially cometary and meteoric displays, illustrated extreme emotions on both ends of the sublime spectrum: *pleasurable terror* and *sheer horror*.

When I consider the relatively unexciting cometary displays witnessed in the twentieth century, the disappointing 1986 return of Halley's comet, particularly, I truly envy the men and women of the previous century, for many remarkable comets were seen during the 1800s. These "long-haired" wonders, some of which returned to Earth's vicinity several times, and some of which were seen only once in the nineteenth century, appeared 310 times between 1800 and 1899 (according to the catalogue in *Physical Characteristics of Comets*, by S.K. Vsekhsvyatskii). Several comets were absolutely stunning and fascinated both the astronomer and the nonscientific U.S. citizen.

A number of newsworthy comets appeared in the skies of the 1830s and '40s. The long-awaited return of Halley's Comet occurred in late 1835, its twenty-ninth recorded apparition. On that return, the appearance of the object did not cause alarm the way it must have in previous ages, but three years later the fourth observed return of Comet Biela occasioned a great deal of panic. Because of certain calculations published by the German amateur astronomer Heinrich Olbers in 1828, it was suggested that on October 29 the comet would intersect Earth's orbit not far from the point at which our planet would be at that time. Says Agnes Clerke, "It needed no more to set the popular imagination in a ferment" (Clerke 1885). American astronomer Ormsby Macknight Mitchel continues the account: "those unacquainted with the subject received the impression from this announcement, that the earth and comet would come into collision, producing the most terrific consequences" (Mitchel 1848). Apparently there was a great deal of consternation in France, especially Paris — so much so that the Academy of Sciences thought it highly expedient to study the matter in an attempt to calm public anxiety. Scottish astronomer Thomas Dick relates how a Parisian professor reminded the Academy about the consequences produced by a similar cometary scare in 1773: "Persons of weak mind died of fright, and women miscarried." Shrewd confidence-men exploited the alarm: *"places in paradise were sold at a very high rate"* (Dick 1858).

The problem was turned over to M. Arago, who in an elaborate treatise on comets demonstrated that Biela's would certainly sweep over Earth's orbit on the predicted day in late October but that our globe would in fact be more than 50 million miles behind and would not reach the point of orbital intersection until November 30. That knowledge served to calm public apprehension and the alarm subsided. If, on the other hand, the comet had somehow been delayed in its flight by a month, "it would have undoubtedly mingled its atmosphere with ours, and perhaps even have struck us!" (Dick quoting Arago; Dick 1858). (Harold Beaver is almost certainly correct when he suggests that Poe "may well have been thinking of Biela's comet" for his apocalyptic tale "The Conversation of Eiros and Charmion," first published in 1839; Beaver 1976.)

During the 1840s, comets continued to awe Earth-bound spectators. "The most brilliant comets of the century were suddenly rivalled if not surpassed by the extraordinary object which blazed out beside the Sun, February 28, 1843" (Clerke 1885). This "Great Comet of 1843" was observed by probably everyone in New England and Delaware, according to American astronomer Elias Loomis. It was so bright that it could be seen during the day: light from the comet's head was "equal to that of the moon at midnight in a clear sky" (Loomis 1851); its tail looked like an elongated white cloud brilliantly lit by the Sun. At its greatest length, in the third week of March, the tail was estimated at over 500 million miles (Clerke 1885). For almost all of March, in fact, the comet presented a marvelous spectacle every clear moonless evening, and it "was occasionally brilliant enough to throw a strong light upon the sea," Loomis maintains (Loomis 1851). As observers watched while weeks went by, the comet approached the Sun and almost grazed it; only the "prodigious" velocity of the comet prevented it from being pulled in. "Never before, within astronomical memory, had our system been traversed by a body pursuing such an adventurous career," says Clerke (1885).

This comet, like Biela's, was attended by a certain degree of alarm for those who believed the apocalyptic predictions of Father Miller, as the millennial movement culminated in America in the 1840s. As early as 1831, Miller prophesied that the end of the world would occur in 1843, and the appearance that year of the Great Comet "was regarded by many as an indication that the end of all things was at hand" (Burritt, 1873; see also Beaver 1976).

After the 1843 spectacle, comets would enter our region of the solar system twenty-nine times more before the end of the decade (Vsekhsvyatskii 1958). Some were invisible to sky-watchers without telescopes; others were visible and memorable, such as Comet Donati of 1858, however, on the night of November 12-13, 1833, an event occurred over the skies of eastern North America that was certainly more magnificent, more unforgettable, and perhaps even more terrifying to the superstitious and ignorant, than any comet witnessed during the century — "the most sublime phenomenon of shooting stars, of which the world has furnished any record" (Burritt 1873). The display began just before midnight, but the number of meteors in a shower always increases *after* midnight. The 1833 show was no exception, and the "falling stars" increased in frequency: "the first appearance was that of fireworks of the most imposing grandeur, covering the entire vault of heaven with myriads of fire-balls, resembling sky-rockets," Burritt maintains

(Burritt 1873). Thomas Dick quotes a writer for the *New York Commercial Advertiser* who insists that compared

> "with the splendor of this celestial exhibition, the most brilliant rockets and fireworks of art bore less relation than the twinkling of the most tiny star to the broad glare of the sun. The whole heavens seemed in motion, and never before has it fallen to our lot to observe a phenomenon so magnificent and sublime" (Dick 1858).

The number of meteors peaked between four and six o'clock in the morning. The same observer quoted above reckons that no fewer than twenty could be seen at any moment, while more than a thousand could have been counted each minute, and according to Clerke, one estimate of the total number of meteors visible over the shower's nine-hour duration is as high as 240,000 (Clerke 1885). No wonder many likened the exhibit to a December snowstorm!

More than just tiny meteors fell during the tempest, however: much brighter fireballs also plunged through the sky, some of which exploded in mid-air "with a sound like that of the rush of the distant sky-rocket" (Dick 1858). Several blazing objects appeared to be enormously large. One observed in North Carolina was bigger than the apparent size of a full moon and was so bright it lit up even small objects. The trains of light marking the paths of these fireballs were sometimes visible in the heavens up to half an hour after the fireballs themselves had fallen. Such trains were usually white but witnesses report that occasionally all the colours of the spectrum were displayed. Moreover, these luminous tails would now and then take on bizarre shapes in the sky. One fireball seen at New Haven exploded near the star Capella

> "leaving a trail of peculiar beauty. The line of direction was at first nearly straight, but it soon began to contract in length, to dilate in breadth, and to assume the figure of a serpent scrolling itself up until it appeared like a luminous cloud of vapor floating gracefully in the air, where it remained in full view for several minutes" (Dick 1858).

We can certainly imagine how the superstitious would have been terrified at such celestial apparitions.

As well as meteors and fireballs, a third variety of objects put on a show that November morning. Undefined glowing bodies of irregular form were seen neither falling nor exploding but hovering mysteriously in the heavens. At Niagara Falls one such object, shaped like a large square table, remained suspended near the zenith for a considerable time emitting streams of light. "The wild dash of the waters, as contrasted with the fiery uproar above them, formed a scene of unequaled sublimity," recalls a contributor to *Harper's New Monthly Magazine,* seventeen years later (Mitchel 1850). Thomas Dick relates that at Poland, Ohio, a luminous body was visible in the north-east for over an hour: "It was very brilliant, in the form of a *pruning hook*. . . It gradually settled toward the horizon until it disappeared" (Dick 1858). It is not unreasonable to speculate that Nathaniel Hawthorne may have been thinking back to this spectacular meteoric display, and especially to the outlandish, luminous forms that were seen in the sky, when he created the following passage in his 1850 novel *The Scarlet Letter:*

> "before Mr. Dimmesdale had done speaking, a light gleamed far and wide over all the muffled sky. It was doubtless caused by one of those meteors, which the night-watcher may so often observe burning out to waste, in the vacant regions of the atmosphere. So powerful was its radiance, that it thoroughly illuminated the dense medium of cloud betwixt the sky and earth. The great vault brightened, like the dome of an immense lamp. It showed the familiar scene of the street, with the distinctness of mid-day, but also with the awfulness that is always imparted to familiar objects by an unaccustomed light . . . the minister, looking upward to the zenith, beheld there the appearance of an immense letter, — the letter A, — marked out in lines of dull red light" (Hawthorne 1850).

Hawthorne's seventeenth-century Puritans would certainly have seen some religious significance in this sublime exhibit.

Even in his own century, this magnificent November spectacle filled with frantic terror those whom it did not fill with pleasurable terror. Many thought that real stars were falling and considered them omens of dreadful events. In some districts the meteoric storm generated a belief that the Apocalypse was beginning. The edition of *Harper's* cited above provides a fascinating, though pathetic, account of the effect the fiery storm had on the slaves of a South Carolina planter:

> "I was suddenly awakened by the most distressing cries that ever fell on my ears [relates the planter]. Shrieks of horror and cries for mercy I could hear from most of the negroes of three plantations, amounting in all to about six or eight hundred. While earnestly listening for the cause, I heard a faint voice near the door calling my name. I arose, and taking my sword, stood at the door. At this moment, I heard the same voice still beseeching me to rise, and saying, "O my God, the world is on fire!" I then opened the door, and it is difficult to say which excited me most — the awfulness of the scene, or the distressed cries of the negroes. Upward of one hundred lay prostrate on the ground — some speechless, and some with the bitterest cries, but with their hands raised, imploring God to save the world and them. The scene was truly awful; for never did rain fall much thicker than the meteors fell toward the earth; east, west, north, and south, it was the same" (Mitchel 1850).

We have already seen in several reports how often nineteenth-century writers employed the word *sublime* to describe such celestial events, and Edmund Burke himself would have labeled the response of many of the South Carolina slaves thus:

> "The passion caused by the great and sublime in *nature,* when those causes operate most powerfully, is

> Astonishment; and astonishment is that state of the soul, in which all its motions are suspended, with some degree of horror. . . Astonishment, as I have said, is the effect of the sublime in its highest degree. . ." (Burke 1757).

Certainly other celestial events throughout time have had a similar effect on ignorant populations, especially full, annular, and even partial solar eclipses.

One of the positive effects of the meteoric display, however, was brought about by those more inclined to experience the sublime as *pleasurable* fright rather than paralyzing terror. Previous theories explained meteors as electrical sparks, or the ignition of hydrogen, in the upper atmosphere. Denison Olmsted of Yale, however, seized upon the observation that these meteors all radiated from the same part of the sky, in the constellation Leo, and that the radiant point traveled with the stars in their nightly progression from east to west. This meant, Olmsted correctly argued, that the "falling stars" of 1833 must be combustible particles of various sizes traveling in parallel paths and originating *outside* the Earth's atmosphere, in space. Furthermore, because the November display was known by 1833 to be an annual event — although never so memorable as it was in that year! — it was inferred that the meteors must be fellow members of the solar system orbiting the sun and crossing Earth's path every November 12 and 13. As a result of the display — hereafter referred to as the *Leonids* — the true nature of meteors became known, and "the study of luminous meteors became an integral part of astronomy," says Clerke (1885).

Thank goodness for the objective scientist who can overcome our human tendency to feel sheer terror, amounting even to "Astonishment," at the sublime displays of the nocturnal sky. For *heaven's* sake, let us never allow objectivity to curtail entirely that sense of *pleasurable terror,* that frightening wonder, which the celestial movie screen presents to us on a nightly basis. Once, when I was an undergraduate at the University of Toronto, our astronomy class climbed up to the observatory and broke out the telescopes. One of my female peers asked our instructor — a graduate student, I think — "Where's the Andromeda Galaxy?" *He didn't know.*

"Let me get out my *Observer's Handbook* and I'll give you the coordinates," he replied.

"It's *there!* It's *right up there!*" I pleaded, pointing to the exact spot. I could identify that wondrous spectacle by sight, but to our instructor, the Andromeda Galaxy was merely a faint smudge of light at RA 00^h 41.6^m, Dec 41° 10´. Let us never allow mere mathematics and numerical coordinates to erase our emotional, our psychological, our aesthetic appreciation — even amounting to a kind of pleasurable *fear* — of the objects of astronomical investigation. Let us allow astronomy to remain the *sublime science*.

References

Beaver, H. ed., 1976, The Science Fiction of Edgar Allan Poe (Penguin: New York)

Burke, E. 1757, A Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful, ed. Adam Phillips (Oxford UP: New York)

Burritt, E.H. 1873, The Geography of the Heavens, and Class-Book of Astronomy (Rev. ed.: New York)

Clerke, A.M. 1885, A Popular History of Astronomy During the Nineteenth Century (Edinburgh)

Dick, T. 1858, Complete Works, 2 vols. (Cincinnati)

Hawthorne, N. 1850, The Scarlet Letter (Houghton: Boston)

Loomis, E. 1851, The Recent Progress of Astronomy; Especially in the United States

Mitchel, O.M. 1848, The Planetary and Stellar Worlds: A Popular Exposition of the Great Discoveries and Theories of Modern Astronomy. In a Series of Ten Lectures (Arno: New York)

Mitchel, O.M. 1850, Harper's New Monthly Magazine, 1.4, 439

Vsekhsvyatskii, S.K. 1958, Physical Characteristics of Comets (Israel Program for Scientific Translations: Moscow)

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.*

Magnetically Powered Gamma-ray Bursts

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

Opinion is coalescing around the view that at least one class of gamma-ray bursts arises from something like a supernova explosion, in which a very massive star — more massive than the progenitor of an ordinary supernova — explodes. But many unknowns remain, so data that illuminate new aspects of the explosions are greeted with enthusiasm. Two recent papers by Derek Fox of Caltech (and his many collaborators around the world) and Steve Boggs and Wayne Coburn of Berkeley (respectively in the March 20, 2003 and May 22 2003 issues of *Nature*) reveal new clues about the bursts.

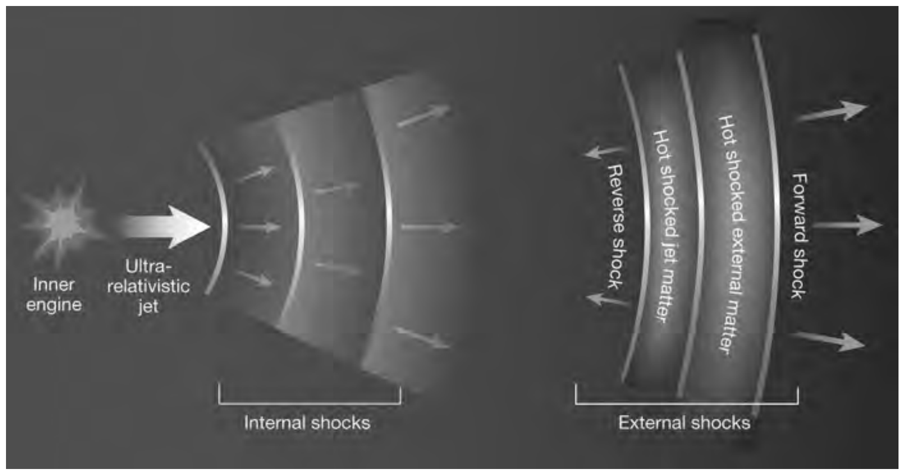


Figure 1 — Within the context of the internal-external shocks model of GRBs, the gamma-rays that we see are generated by internal shocks in a jet of ultra-relativistic electrons. As the jet hits the surrounding material, two external shocks are generated. The forward shock heats the existing gas around the progenitor (it could be a wind from the star, or a surrounding cloud), making it glow and producing the "afterglow" emission. The other — short-lived — external shock moves backwards through the jet material and produces a brief optical pulse. The forward and reverse shocks begin while the burst of gamma rays is still being generated. The figure is from Piran, T. *Nature* 422, 268 (2003).

From an observational perspective, gamma-ray bursts (GRBs) are simply a burst of gamma-rays (lasting from under a second up to about 1000 s) from a point source in the sky. Some of them have bright X-ray, optical, or radio afterglows, which are associated with the cooling and expanding ejecta from the explosion. The total energy involved in the burst generally is a few percent of the rest-mass energy (mc^2) of a solar-mass star. One of the problems of investigating the source of the explosion is that the vast amount of energy released tends to make the afterglows look similar. It's like the mushroom cloud from a nuclear explosion — the overall shape doesn't tell you much about the type of bomb (though the size of the cloud is related to the power of the burst), because all such bombs give the same kind of mushroom cloud. In order to investigate the source of the bursts, astronomers try to catch them as early as possible after the explosion or — ideally — while the burst is still going on.

Coburn and Boggs used a new satellite — the *Ramaty High Energy Solar Spectroscopic Imager* — to find that the gamma-rays emitted by the burst of December 6, 2002 (GRB021206, with the number determined by year, month, and day) were linearly polarized. In a high-energy environment, linearly polarized radiation generally arises from synchrotron emission, where relativistic electrons spiral around magnetic field lines. (The most common form of linearly polarized light on Earth is the glare from a road, but this is not the mechanism that produces the polarization in the GRB.) As the electrons follow their helical path they are continuously accelerated, because they are always changing direction, and therefore emit photons. The energy (or wavelength) of the emitted photons is related to the energy of the electrons and the strength of the magnetic field in which the electrons spiral. Coburn and Boggs measured a polarization of 80 ± 20 percent. They conclude from this, and what we already know about GRBs, that the magnetic energy must be comparable to the kinetic energy in the expanding fireball. They argue that the magnetic field was not simply dragged along with the ejecta in the explosion, but rather is an integral part of what produces the burst of gamma rays. They offer some possibilities for how this might occur: the extraction of the rotational energy of an accretion disk around a compact object (a neutron star or black hole); or by extracting the spin energy of a black hole or neutron star out of which magnetic field lines come.

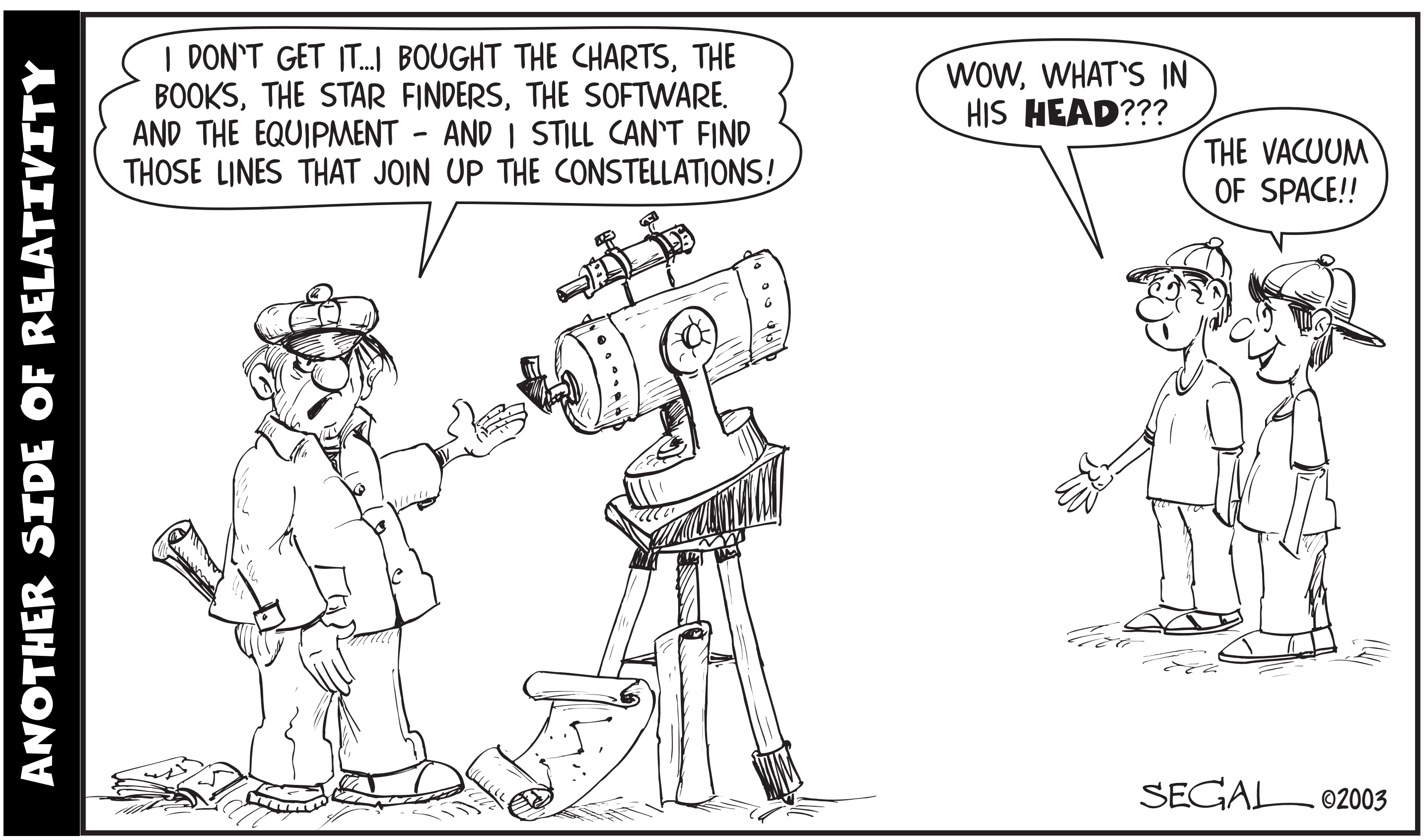
Physically, this is quite different from a supernova, in which most of the energy (~99 percent) is carried away by neutrinos. It's curious to think that the light we see in a supernova is just the leftovers, but it's true.

Fox and his colleagues found an optical counterpart to GRB021004 only about four minutes after the gamma-ray trigger went off on the *HETE-II* satellite. The first optical data came from an automated telescope in Japan, while Fox himself found the counterpart using the 48-inch Schmidt telescope at the Palomar Observatory about four minutes after that. Only one earlier optical counterpart has been seen (by Carl Akerlof, April 1, 1999 issue of N*ature*) — that was part of the "prompt" emission associated with the burst itself. Fox's data reveal the earliest behaviour of the "afterglow." Within the overall picture of the "expanding fireball" model, the prompt optical emission is thought to arise as a shock wave propagates backwards through the relativistic ejecta. The shock wave was reflected back from the boundary between the ejecta and the gas surrounding the progenitor. The optical afterglow comes from the shock associated with the expansion of the ejecta into the surrounding medium (for more details, see Figure 1).

The rather complete worldwide coverage of the fading of GRB021004 reveals some interesting differences from what was expected. Early on, the optical counterpart faded very slowly, perhaps reached a plateau, then was characterized by bumps and wiggles in the light curve. Tsvi Piran of the Hebrew University in Jerusalem speculates that the plateau might indicate the transition from the reverse shock to the forward shock dominating the light, with the wiggles revealing fluctuations in the density of the surrounding gas (see March 20, 2003 issue of *Nature*).

While this is all internally self-consistent, and provides a nice picture of a GRB, we're still a long way from understanding GRBs in detail. Most of them are so far away, and the prompt bursts are so fleeting, that tight constraints on the physical models are rather few. Even the telescopes dedicated to searching for optical counterparts have had limited success. And we still have no counterpart for the "short" bursts. Advanced amateur astronomers might be able to play a role in unraveling the story, if they can capture scientifically useful images. It is likely to be quite some time before we truly understand what is going on physically. In the meantime, fascinated as always with gamma-ray bursts, I'll be enjoying the expanding story of these explosions.

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.*



J.W. Christy and the Discovery of Charon, Pluto's Satellite

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

Pluto is a unique planet, and it became especially interesting 25 years ago on June 22, 1978, when James W. Christy of the United States Naval Observatory (USNO) discovered the satellite Charon. Owing to its distance, little was known about Pluto, especially its diameter and mass, but the discovery of a satellite made it possible to estimate these quantities, and also to determine the inclination of the axis of Pluto's rotation. Pluto is now known to be smaller than the Moon, with a diameter of 2300 km and a mass of 0.0025 Earths. Charon itself is a significant fraction of the size of its primary, with diameter 1190 km, and is bigger than the largest classic asteroid, Ceres, which has a diameter of 1003 km. Perhaps the Pluto/Charon system should be considered a double planet, as the centre of mass is actually between the two objects, the only known pairing in the Solar System with this property.

James Christy was born on September 15, 1938 in Milwaukee, Wisconsin, but his family moved to Tucson, Arizona in 1954 when he was 16 for health reasons. In the seventh grade he became interested in physics and later built a telescope with his dad. He was involved with amateur astronomy in high school, and frequented the 36-inch telescope at the Steward Observatory in Tucson. He began his astronomy degree at the University of Arizona, but in 1962 left university before graduation to work at the 61-inch telescope at the Naval Observatory Flagstaff Station. He completed his degree by correspondence over the next two years!

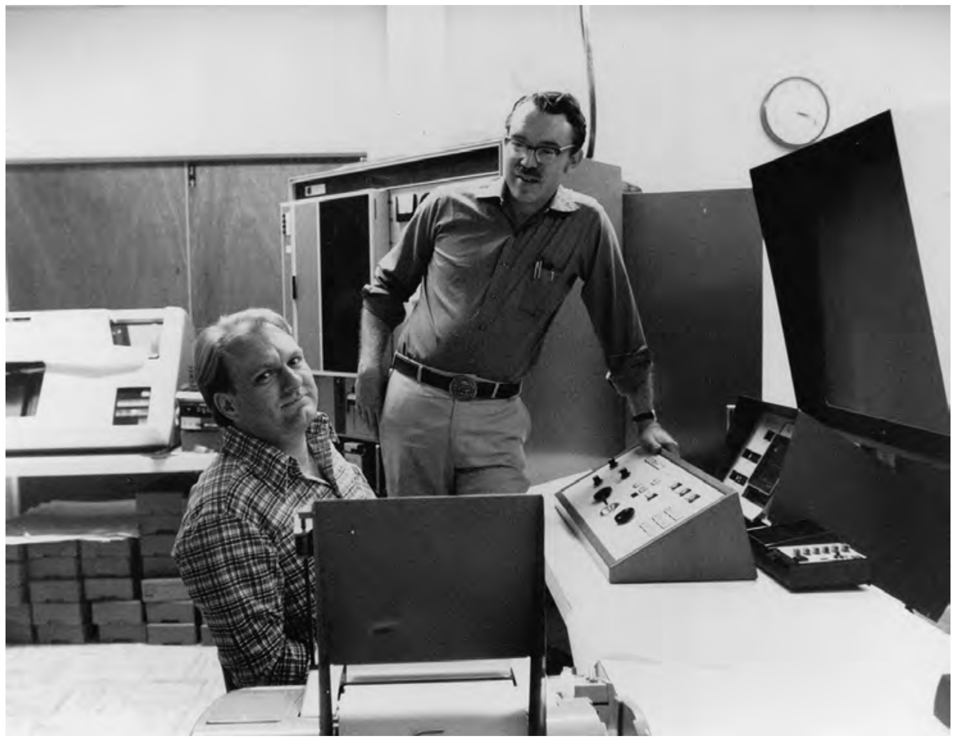


Figure 1 — Charon discoverer James Christy (seated), with the late Robert S. Harrington (courtesy of the United States Naval Observatory).

Christy pursued several research interests, including the radial velocities of stars near the galactic centre, spectroscopy, and parallax measurements. By the time of the Charon discovery, he was not working at Flagstaff, having been transferred (kicking and screaming) in 1971 to the USNO headquarters in Washington. He proposed that the observers at Flagstaff expose some Pluto plates along with exposures of Neptune and Uranus, in order to refine the planets' orbital elements. In 1965 Otto Franz had shown Christy some exposures of Pluto that showed an odd elongation of the planet's disk. Perhaps in the back of his mind Christy had a hunch that something was there. Six plates were exposed in April and May of 1978. The Flagstaff observers noticed the elongations, but did not investigate, thinking they were simply a consequence of orbital motion during the exposure time. Christy examined the plates later. It was nearly two years since he had requested the data, and he was getting ready to take a vacation to move from an apartment to a house. He had finished up some primary work, and was looking for something to fill the idle hours before his leave started. He attributes his discovery of Charon to his relaxed state of mind at this time. It did not take long for him to see the elongations and recognize what they were, and he even noticed a weekly periodicity to the anomaly. (The locked-in period of rotation of Pluto and Charon is 6.4 days.) The discovery was announced July 7, 1978.

Although Christy discovered Charon in 1978, the astronomical world is notoriously conservative, and the news was greeted with some skepticism. It turns out that the inclination of Pluto's axis is 123 degrees, nearly in the plane of the ecliptic. This means that Pluto and Charon rarely occult or transit; however, a series of these occurred in 1985–1990. This fortunate turn of events was predicted by fellow USNO astronomer and "Planet X" hunter Robert S. Harrington (now deceased). The existence of the satellite Charon was fully accepted only when the occultations and transits started on February 17, 1985, 40 minutes off schedule.

(James Christy left the USNO in 1982 for a non-government position. I have not been able to determine his current employment.)

Pluto, of course, is the ancient Greek god of the underworld; Charon is the aged boatman who ferries souls across the waters that divide the living world from the underworld. Being a Greek name, the "Ch" should be pronounced hard, like a "K," so the name of Pluto's satellite sounds like "Karen"; however, for those who prefer to pronounce the initial consonant soft, like "Sh," the name sounds more like "Sharon," which happens to be similar to the name of Christy's wife at the time, Charlene! By the way, anyone who expects a free ride across the river Styx has another thing coming: Charon is a choosy ferryman, only taking those who have been "duly buried," which involves cold, hard cash accompanying the stiff.

This is neither the time nor the place to tackle the "Is Pluto a planet?" debate. There was a pretty good article on this in the August 2002 *Sky & Telescope* magazine. Since that time, Mike Brown and Chad Trujillo of the California Institute of Technology discovered the object 2002 LM60, with proposed name Quaoar (kwa-whar), beyond Pluto in the Kuiper Belt. Quaoar has diameter 1260 km, larger than Charon. It is the largest object discovered in the Solar System since the discovery of Pluto itself in 1930. Perhaps Pluto is the "King of the Kuiper Belt Objects"; perhaps there is something even bigger out there; but for me Pluto will always be the ninth planet, for historical reasons.

Before signing off, I would like to express my sincere thanks to Steve Dick, the Historian of the USNO, for supplying me with a transcript of a taped oral interview with James Christy from 1989. Steve has just published a History of the USNO entitled *Sky and Ocean Joined, The U. S. Naval Observatory, 1830-2000* (Cambridge University Press, 2003). In that book, he recounts the story of the discovery of Charon, and he also has an entire chapter on Simon Newcomb, the Nova Scotian who became Superintendent of the Nautical Almanac Office at the USNO.

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.

FROM THE PAST — AU FIL DES ANS

NOTES FROM OBSERVATORIES
DAVID DUNLAP OBSERVATORY, RICHMOND HILL, ONTARIO

The major news from the David Dunlap Observatory is the commissioning of the new 24-inch telescope at the Las Campanas Observatory in Chile. Dr. René Racine and Gerald Longworth, the leader of our technical staff, spent six weeks in July and August erecting the telescope and aligning the optics. It is very fitting that the first photograph taken with this telescope was of the famous globular cluster 47 Tuc, because of the long-continued research on variable stars in such clusters carried out here by Prof. Helen Sawyer Hogg and her associates. We expect that this instrument will be devoted for a substantial fraction of its time to studies in this field. The optical performance of the telescope is very satisfactory and although our experience so far has covered only a short interval, we have found that the observing conditions on Las Campanas are living up to our expectations, with perfectly clear (photometric) nights occurring approximately 65% of the time, and partly clear nights 19% of the time.

by Donald A. MacRae,
from *Journal*, Vol. 66, p. 76, February, 1972.

A LEONID METEOR

By Roy Bishop
Halifax Centre, RASC
Electronic Mail: rg@ns.sympatico.ca

(Received January 29, 2003; revised February 9, 2003)

Abstract. A Leonid fireball was photographed in the dawn twilight of November 19, 2002 from two sites in Nova Scotia. Parallax data show that the meteor occurred approximately 250 km from the cameras beyond the southwestern end of Nova Scotia over the Gulf of Maine, and that the 43-km-long luminous track extended from 123 km (± 1 km) to 83 km (± 1 km) in altitude. The density of Earth's atmosphere increased by nearly three orders of magnitude along the meteor's visible track resulting in the characteristic burst near the end of the track.

Résumé. A l'aube naissante du 19 novembre 2002 un bolide léonide aît photographié de deux endroits en Nouvelle Écosse. Des données parallactiques indiquent que le météore est apparu près de 250 kms des caméras au delà du bout sudouest de la Nouvelle Écosse, au dessus du Golfe de Maine. La trajectoire lumineuse s'étendait de 123 kms (±1 km) 83 kms (± 1 km) en altitude. La densité de l'atmosphère terrestre s'accroissait de près de trois ordres de magnitude le long de la trajectoire visible du météore, ainsi créant un éclat typique vers la fin de son trajet.

1. Introduction

Oft shalt thou see, ere brooding storms arise,
Star after star glide headlong down the skies,
And, where they shot, long trails of lingering light
Sweep far behind, and gild the shades of night.

— Virgil (70 – 19 BC)

Meteors were poorly understood as recently as 200 years ago (Carey 1835). However, the mid-19th century brought many advances in this field of astronomy. After the exceptional Leonid meteor shower observed over North America on November 13, 1833, it was soon realized that meteors arise from Earth colliding with bodies orbiting the Sun, and that the luminous trails are apparently 50 km to 130 km high in the atmosphere (Olmsted 1840). Newcomb (1877) describes parallax measurements of Leonid meteors carried out by the U.S. Naval Observatory in 1867: meteors were first seen at an average height of 120 km and disappeared at a height of 88 km. More recently Abell (1982) cites 130 km and 80 km as the altitude limits of the luminous paths of most meteors.

Soon after the discovery of a comet in 1865 by Tempel in France and independently by Tuttle in the United States, it was realized that the Leonid meteor shower originates from debris scattered along the orbit of this comet. Comet 55P/Tempel-Tuttle orbits the Sun with a 33-year period, and especially strong Leonid showers occur for a few years following its perihelion passage (Newcomb 1877). This inconspicuous comet passed through the inner solar system again in early 1998, and Leonid meteors were abundant in the years 1998 through 2002. Unfortunately, because Jupiter will significantly perturb the path of the comet in 2029, a strong display of Leonid meteors will likely not occur again until 2098 (Rao 2002).

Figure 1 – The Leonid meteor as photographed from St. Croix Observatory by Barry Burgess.

The meteor described in this paper was photographed on the morning of November 19, 2002 from two sites in Nova Scotia. The photographers, both members of the Halifax Centre of the RASC, were Barry Burgess who was at the Halifax Centre's St. Croix Observatory

(SCO) and Michael Boschat who was on the roof of the Dunn science building at Dalhousie University in Halifax (DUNN). On that cold, windy, early morning Burgess and Boschat independently pointed their cameras to the same region of the sky and began time exposures within a minute of when this bright meteor appeared. Another remarkable coincidence is that one year earlier and from the same SCO site, Burgess took the spectacular photograph of a Leonid fireball that graces the cover of the 2003 *Observer's Handbook* (Gupta 2002).

Sherman Williams and I (also members of the Halifax Centre) were with Burgess at SCO and all three of us saw the meteor, the brightest one that we observed during the 2002 Leonid shower. We estimated its peak magnitude at −7, which classifies it as a "fireball." Burgess said at the time that he thought he had captured the meteor on film, and on December 13 I obtained two prints from him, one for myself and one for Williams (Figure 1).

Boschat's photograph was published on the cover of the December 2002 issue of *Nova Notes* (Boschat 2002), and in the Jan/Feb 2003 issue of *SkyNews* (Dickinson 2003). It was not until January 3 when I was browsing through the latter publication that I suddenly realized that Boschat and Burgess had photographed the same meteor! The brightness, the structure, and the angle of the tracks were similar; the tracks were in the same region of the sky; the photographs were taken at the same stage of dawn twilight; and the parallax evident in the photographs was consistent with the relative positions of the two cameras. I immediately contacted Boschat to ask when and where he took the photograph and if he would send me a copy (Figure 2).

Figure 2— The Leonid meteor as photographed from the Dunn building in Halifax by Michael Boschat.

It is apparent that the meteor was a Leonid and not a sporadic fireball because of three aspects: its track when extended backward points to the radiant of the Leonid shower; the meteor occurred 41 minutes prior to the second of the two peaks displayed by the 2002 Leonid shower (Seronik 2003); and the track shows the green-red-blue sequence of colours characteristic of bright meteors of this shower.

2. Required Information

Several things are required to determine the position of a meteor track in the atmosphere: two images of the meteor against background stars taken from two widely separated known sites, and the time at which the meteor occurred so that the positions of the reference stars relative to Earth are known.

The Sites

GPS measurements give the latitude and longitude of the SCO and DUNN sites as 44° 56′ 53″ N, 64° 02′ 27″ W and 44° 38′ 15″ N, 63° 35′ 36″ W respectively, and the separation of the sites as 49.45 km, with SCO bearing 315° from DUNN, and DUNN bearing 134° from SCO. The two bearings do not differ by 180° because the meridians at the two sites are at an angle of approximately 0.3° and apparently this small angle shifted the nominal 180° difference between the limited-precision GPS bearings by one degree. The two sites are at nearly the same altitude above sea level, about 65 m.

The Time

Williams had recorded the time of the meteor as 06:09 a.m. AST (10:09 UT). I would have used this without question except that the caption to Boschat's photograph in *Nova Notes* gives the time as "about 6:40 a.m." I suspected that 6:40 a.m. was incorrect for I had seen the meteor occur around 6 a.m. Furthermore, the similar stage of dawn twilight in the two photographs ruled out a half hour difference between them. Boschat later said that the time had been 6:20 a.m. but acknowledged that he had not written it down and was not certain of this time.

Fortunately Burgess' photograph includes many trees and I knew approximately where his camera had been located (to within ± 1 m). Also, in his photograph, the star Rigel is conveniently close to two distinct tree branches. (These branches, 130 m from the SCO site, show up better on the original print I received from Burgess than they do in Figure 1.) Although there had been a strong northwest wind that night, the SCO site is sheltered from winds in this direction and, as evidenced in the photograph, the tree branches had been nearly stationary.

I went back to SCO two months later on a still winter night with a full Moon (so I could see the trees). I used Burgess' photograph and parallax involving nearby and distant trees to reduce the uncertainty in the camera's position in a plane perpendicular to the direction of Rigel as recorded in the photograph. I thereby determined the camera's position to within ± 0.1 m, which, relative to the 130-metre-distant tree branches, corresponds to an uncertainty of ± 2.6′ in angle, or about ± 10 s in time. I then waited at this spot and, using 15 × 45 image-stabilized binoculars, watched the trees drift until they were in the same position relative to Rigel as they are in the photograph. The time was: January 19, 2003 02:09 a.m. AST. One minute later the two fiducial tree branches were obviously out of alignment with Rigel. A simple calculation involving the rotation period of Earth relative to the fixed stars confirmed that Williams' time was correct (to within ± 30 s).

The Images

A full Moon and dawn twilight produced the bright sky evident in Figures 1 and 2. The bright sky had two benefits: (1) It was easy to identify trees in the SCO photograph and thereby confirm the time as described above; (2) The exposure times of the stationary cameras had to be brief (about 30 s for the SCO photograph, 60 s for the DUNN photograph), which kept the star trails short thus minimizing the uncertainty of the position of the meteor against the stars. Fortunately

Boschat ended his exposure immediately after the fireball occurred, so the star trails in his photograph do not cause as much uncertainty in the meteor's position as would otherwise have been the case. The bright sky had one drawback: it hid the fainter stars and this made the determination of the meteor's position more difficult. The magnitude limit of the DUNN photograph is 6.5, about half a magnitude brighter than that of the SCO photograph since it was taken from light-polluted Halifax and, being further east, the dawn was brighter.

To determine the azimuth and altitude of the lower end of the meteor track from each site, the photographs were compared with electronic skies for SCO and for DUNN generated by the planetarium program *Starry Night Pro*. Because of the darker sky at SCO, the end of the track recorded on the SCO photograph extends slightly further below the bright burst region; thus care was taken to use the lower end of the bright burst on both photographs as a common point to determine the parallax. The azimuth/altitude of this end of the track from SCO and from DUNN were: 228° 27′/18° 26′ and 240° 15′/17° 42′, respectively. Repeated independent measurements indicate that these angles are uncertain by about ± 3′.

3. Results

A triangle lying in the SCO horizon plane may be formed, its three apexes being located at SCO, at DUNN (which lies a negligible 0.2 km below the SCO plane), and at a point "P" directly below the lower end of the meteor track. Solving this triangle gives:

Distance to P from SCO	= 239 km
Distance to P from DUNN	= 247 km

These distances together with the altitude angles give:

Distance to lower end of track from SCO	= 252 km
Distance to lower end of track from DUNN	= 260 km
Altitude of lower end of track above P	= 80 km
Altitude of lower end of track above sea level	= 84 km

The four distances are uncertain by ± 2 km, the two altitudes by ± 1 km. The extreme lower end of the track visible on the SCO photograph is about 1 km lower, or 83 km above sea level. This is about 8 times higher than commercial jet planes fly, thus suggesting that Leonid meteors pose no hazard to aircraft. The endpoint of the meteor's track was directly overhead for a point on the Gulf of Maine 40 km south of Yarmouth, Nova Scotia (see Figure 3). With clear skies the meteor would have been visible from within a radius of nearly 1000 km, which includes all of the Maritime Provinces, Ottawa, Corner Brook, and Philadelphia.

It is not possible to use parallax to determine the beginning of the meteor track because that portion of the track is not well defined. Also, the brighter sky on the DUNN photograph shortened the recorded track (6.5°) compared to that on the SCO photograph (8.0°) by more than would be expected based on the relative distances of the two sites from the meteor.

Figure 3 displays a scale model that shows the position of the meteor track relative to the SCO and DUNN sites. According to *Starry Night Pro*, the azimuth and altitude of the Leonid radiant (Hawkes 2002) at SCO were 161° and 66°, respectively. The bends in the metal sheet shown in Figure 3 were based on these figures, assuming that the meteor was moving on a straight path directly from the radiant of the shower. This assumption is a good approximation because at the meteor's speed of 71 km s^{-1} (Hawkes 2002), Earth's gravity has but a very small effect upon its speed and direction. The model ignores the curvature of Earth; the map lies in the SCO horizon plane.

Figure 3 — A scale model that incorporates a map of mainland Nova Scotia as viewed from the west. The folded metal sheet standing upright on the map displays the geometry of the lines of sight from SCO to the meteor track. The pointed left end of the metal sheet is at the SCO site, and my finger points to the DUNN site. On the right side, the short joint in the metal sheet highlighted with a white line is the meteor track.

The model, with an additional 4.5 km correction for the curvature of Earth, gives an altitude of 123 km for the beginning of the 8°-long track (as recorded on the SCO photograph), and a track length of 43 km. At 71 km s^{-1} the meteor traversed its luminous track in 0.6 s. This duration is consistent with the visual impression the fireball made on the morning of November 19.

Another interesting aspect of the track is the range of atmospheric density traversed. At an altitude of 123 km the density is about 2.3×10^{-8} kg/m^3 but at 83 km the density is 1.4×10^{-5} kg/m^3 (Hodgman 1962), over 600 times higher! This ratio is comparable to that between the air we breathe and water. Just as a bird or an aircraft comes to an abrupt halt when it strikes water, so too does a fragile, comet-derived meteoroid slow down abruptly as it approaches altitudes near 80 km. Thus we can appreciate why the first half of the luminous track is narrow and dim whereas the lower portion ends in a bright burst.

With a peak brightness of magnitude −7, this meteor had a mass of the order of a few grams (Rao 2002). In familiar terms, the rubber washer in a garden hose connector has a mass of about one gram. How could such a small lump of dust and ice produce a fireball that was visible from a large portion of eastern North America? The answer lies in its kinetic energy. One gram of TNT releases about 4200 joules (Bishop 2002). One gram of dust and ice moving at 71 km s^{-1} has a kinetic energy of 2.5 million joules, 600 times greater than the energy of one gram of high explosive.

4. Concerning Possible Errors

The uncertainties on the distances and altitudes (± 2 km and ± 1 km, respectively) are due primarily to the difficulty of determining the position of the lower end of the meteor track relative to the background stars (± 3′). Although the time of the meteor is uncertain by about ± 30 s, which corresponds to ± 7.5′ in the diurnal motion of stars near the celestial equator, the resulting uncertainties on the azimuths of the meteor are correlated such that the calculated distances to the meteor are unaffected to a first approximation. The time uncertainty does contribute uncertainties to the calculated linear altitudes, but these are significantly smaller than ones arising from the random ± 3´ uncertainties on the azimuth and angular altitude measurements.

Acknowledgements

Special thanks are due to Barry Burgess and to Michael Boschat whose initiative, determination, skill, and good luck resulted in the two photographs. Boschat has given an account of his odyssey that night (Boschat 2002). Also, thanks to Sherman Williams for recording an accurate time for the meteor, and for providing a digital image of the model (Figure 3). Comments from an anonymous referee were helpful and have resulted in a slightly longer but better paper. The powerful software program *Starry Night Pro* was very useful in this investigation.

References

Abell, G.O. 1982, Exploration of the Universe (4th ed.; Saunders College Publishing: New York), 378

Bishop, R. 2002, in Observer's Handbook 2003, ed. R. Gupta (The University of Toronto Press: Toronto), 31

Boschat, M. 2002, Nova Notes, the Newsletter of the Halifax Centre of The Royal Astronomical Society of Canada, M. Gatto ed., 33, No.6, 1, 4

Carey, G.G. 1835, Astronomy as it is Known at the Present Day (Chidley: London), Supplement, p.11

Dickinson, T. 2003, ed., SkyNews, VIII, No.5, Jan/Feb 2003, 4

Gupta, R. 2002, ed., Observer's Handbook 2003 (The University of Toronto Press: Toronto)

Hawkes, R.L. 2002, in Observer's Handbook 2003, ed. R. Gupta (The University of Toronto Press: Toronto), 223

Hodgman, C.D. 1962, ed., Handbook of Chemistry and Physics (44th ed.; The Chemical Rubber Publishing Company: Cleveland), 3501

Newcomb, S. 1877, Popular Astronomy (2d ed.; Harper & Bros.: New York), 397

Olmsted, D. 1840, Letters on Astronomy (Marsh, Capen, Lyon and Webb: Boston), 346

Rao, J. 2002, Sky & Telescope, 104, No.5 (November), 95

Seronik, G. 2003, Sky & Telescope, 105, No.2 (February), 124

A native of Nova Scotia, Dr. Roy Bishop was a professor of physics at Acadia University from 1963 until 1994. He has served the RASC as Editor of the Observer's Handbook, *as President, and is currently Honorary President both of the National Society and of the Halifax Centre. He is a recipient of the Service Medal and the Chant Medal of the Society. He is a member of the Canadian Astronomical Society, the International Astronomical Union, the American Association of Physics Teachers, and a life member of the RASC. In 1997 the I.A.U. named asteroid 6901 Roybishop. He has three children, four telescopes, five sailboats, and six grandchildren.*

CANADIAN THESIS ABSTRACTS

Compiled by Melvin Blake (blake@ddo.astro.utoronto.ca)

The Formation and Survival of Disk Galaxies by James E. Taylor (taylor@uvic.ca), University of Victoria, Ph.D.

The dynamical evolution of substructure within dark matter halos is of central importance in determining many aspects of galaxy formation and galaxy evolution in cold dark matter cosmologies. The overall sequence in which the different stellar components of galaxies are assembled, the survival of galactic disks, the number of dwarf satellites orbiting giant galaxies, and the nature of stellar material in galactic halos all depend on the dynamics of halo substructure. In this thesis, I develop an analytic description of the evolution of substructure within a dark matter halo, and use it to construct a semi-analytic model of the formation and evolution of disk galaxies.

Substructure within an individual halo is modelled as a set of distinct subhalos, orbiting in a smooth background. These subhalos evolve through three main processes: dynamical friction, tidal mass loss, and tidal heating. By including analytic descriptions of these three processes explicitly in a simple orbital integration scheme, it is possible to reproduce the results of high-resolution numerical simulations at a fraction of the computational expense. The properties of a subhalo can be estimated with an accuracy of 20%, until it has lost most of its mass or been disrupted.

Using this description of satellite dynamics, I construct a semi-analytic model for the evolution of a galaxy or cluster halo. I show that this model reproduces the basic features of numerical simulations, and use it to investigate two major problems in current galaxy formation scenarios: the prediction of excessive substructure in galaxy halos, and the survival of galactic disks in halos filled with substructure.

I show that the small number of dwarf galaxies observed in the Local Group can be explained by considering the effects of reionisation on star formation in small halos. The stellar luminosities predicted in this case match the observed luminosities of local satellites. The predicted spatial distribution, sizes, and characteristic velocities of dwarf galaxies are also consistent with those observed locally.

Many of these satellite galaxies are disrupted by tidal stripping or encounters. I investigate the properties of their debris, and show that its total mass and spatial distribution are similar to those of the stellar halo of the Milky Way. Furthermore, the stars in this debris are mainly old, satisfying another observational constraint on models of galaxy formation. Some satellites have been disrupted fairly recently, however, suggesting that coherent tidal streams may still be visible at the present day.

Finally, I investigate the effects of encounters on the central disk within the main halo. I find that the rate of disruptive encounters drops off sharply after the galaxy is assembled, such that the typical disk has remained undisturbed for the past 8–10 billion years. Less disruptive encounters are more common, and disks are often heated as they re-form after their last disruption, producing components like the thick disk of the Milky Way. These results may resolve the long-standing uncertainty about disk ages in hierarchical, cold dark matter cosmologies. It is less clear whether the bulge-to-disk mass ratios predicted by the model, for the currently favoured LCDM cosmology, are consistent with observations. The relative mass of the bulge in typical disk galaxies may place an upper limit on the age of their stellar contents.

Searching for Missing Baryons by Pengjie Zhang (zhangpj@cita.utoronto.ca), University of Toronto, Ph.D.

More than 90% of baryons are likely in the form of intergalactic medium (IGM) and have been difficult to detect directly. To understand the IGM state, such as density, temperature, peculiar velocity, and metallicity, stands as a major challenge to both observation and theory, and is crucial to understanding the thermal history of the Universe and galaxy formation.

In this thesis, I investigate various observable IGM tracers such as the thermal and kinetic Sunyaev Zel'dovich effect and the soft X-ray background. I build analytical models to calculate their statistics and their dependence on cosmological parameters, the IGM state and the thermal history of the Universe. I then run and analyze hydro simulations to understand more-detailed physics, test the analytical models, and fix some free parameters in the analytical models. I then simulate upcoming observations using simulation data to suggest the optimal survey strategies and data analysis methods, and forecast the sensitivity and accuracy of these observations. Applying these understandings to observation data, the IGM state and the thermal history of the Universe is very likely to be extracted.

MARS IN MOTION: KEPLERIAN EARTH CENTRED ORBITS?

By David Orenstein
Toronto Centre, RASC
Electronic Mail: david.orenstein@utoronto.ca

I'm amazed by Johannes Kepler's successful struggle in the early 17th century with Tycho Brahe's planetary data, especially for Mars. He developed three laws of planetary motion:

1) Planets follow an elliptical path around the Sun at one of the two foci.

2) The radius vector from the Sun to the planet sweeps out equal areas in equal times.

3) The cube of the mean distance of the planet from the Sun is proportional to the square of the period of one orbit.

How well does the geocentric orbit of Mars we started to construct in April fit this pattern? First of all, we can't really investigate the third law using only one planet. We have nothing with which to compare the possible proportionality. In a future issue of the *JRASC* the satellites of one of the gas giants will verify (or not) the square-cube relation.

For the first law we can graph the orbit of Mars' path around the Earth to see if the shape is at least close to being an ellipse.

For the second law, let's use the triangles between successive position vectors to approximate the areas swept out in equal times.

In the previous installment of *Mars in Motion* (*JRASC*, 97, 82) position vectors were calculated with the conversion:

$$x = r\cos(\delta)\cos(\alpha)$$

$$y = r\cos(\delta)\sin(\alpha)$$

$$z = r\sin(\delta)$$

Table 1 shows these vectors for the seven months surrounding the June 19, 2001 opposition of Mars. As before this leaves the 2003 opposition as an exercise for your students.

Figure 1 shows the projection of this portion of the geocentric orbit onto the *XY* plane, omitting the *Z* coordinate. This is a projection onto the plane of the celestial equator. The loop just to the left of the negative *Y*-axis clearly indicates we don't have an ellipse, not even before projection.

To investigate the second law in the geocentric context, a new vector operation comes into play, the vector cross product ($\mathbf{u} \times \mathbf{v}$), which is explained in the call out. The area of the triangle between two vectors is half the magnitude of their cross product (see Figure 2). We'll use this to calculate the area between the Martian position vectors on the 1st and 11th of each month listed in Table 1.

If Kepler's second law matched the geocentric positions, then the radius vector from Earth to Mars would sweep out equal areas in equal times. We can use the triangular area between successive position vectors to approximate the area swept out.
Here's a sample calculation for the triangle between March 1 and 11:

$$\begin{aligned}
A\ (\text{March } 1 \rightarrow 11) &= (1/2)\cdot|r_{M1} \times r_{M11}| \\
&= (1/2)\cdot|(-0.46566, -1.02180, -0.42319)\ \text{AU} \times \\
&\qquad (-0.34164, -0.96476, -0.403150)\ \text{AU}| \\
&= (1/2)\cdot|(-1.02180)(-0.40315)-(-0.42319)(-0.96476), \\
&\qquad (-0.42319)(-0.34614)-(-0.46566)(-0.40315), \\
&\qquad (-0.46566)(-0.96476)-(-1.02180)(-0.34164)| \\
&= (1/2)\cdot|\ 0.003661, 0.043152, 0.100162|\ \text{AU}^2 \\
&= (1/2)\cdot[(0.003661)^2 + (0.043152)^2 + (0.100162)2]^{0.5} \\
&= (1/2)\cdot[0.011907931]^{0.5}\ \text{AU}^2 \\
&= (1/2)\cdot 0.109123\ \text{AU}^2 \\
&= 0.054561\ \text{AU}^2
\end{aligned}$$

This result is compiled with the remaining cross products and areas for the other months in Table 2. From that table it's clear that the second law also doesn't apply to the geocentric orbit. This is not surprising because near the stationary points the radius vector sweeps very slowly.

The actual cross product, and not just its magnitude, can be used as a measure of angular momentum. Just looking at the signs of the coordinates shows that its direction just keeps wobbling around:

(+ + +), (+ − +), (+ − +), (+ + −), (+ + −), (− − −), (− − +)

Thus both Kepler's first and second laws break down for the geocentric orbit of Mars. The next article in this series changes the geocentric into heliocentric positions and tries to apply Kepler's laws again.

David Orenstein
Mathematics Department
Danforth CTI
800 Greenwood Avenue
Toronto ON M4J 4B7

VECTOR CROSS PRODUCT

Unlike the dot product of two vectors, for the cross product the result is also a vector:

$$\mathbf{u} \times \mathbf{v} = \mathbf{w}$$

Geometrically, $\mathbf{u} \times \mathbf{v}$ has a direction perpendicular to the plane containing both u and v and a signed magnitude

$$|\mathbf{u} \times \mathbf{v}| = \sin(\theta) \cdot |\mathbf{u}| \cdot |\mathbf{v}|,$$

Or more succinctly,

$$w = \sin(\theta) \cdot u \cdot v.$$

Here, θ is the angle from **u** to **v**. As a result of this

$$\mathbf{u} \times \mathbf{v} = -(\mathbf{v} \times \mathbf{u}).$$

For coordinate vectors, the cross product of each coordinate comes from a cross multiplication of values of the other two coordinates.

$$\mathbf{u} \times \mathbf{v} = (u_1, u_2, u_3) \times (v_1, v_2, v_3)$$
$$= [(u_2)(v_3) - (u_3)(v_2), (u_3)(v_1) - (u_1)(v_3), (u_1)(v_2) - (u_2)(v_1)]$$

Note that the cyclic ordered pairs are added and the counter-cyclic ones are subtracted.

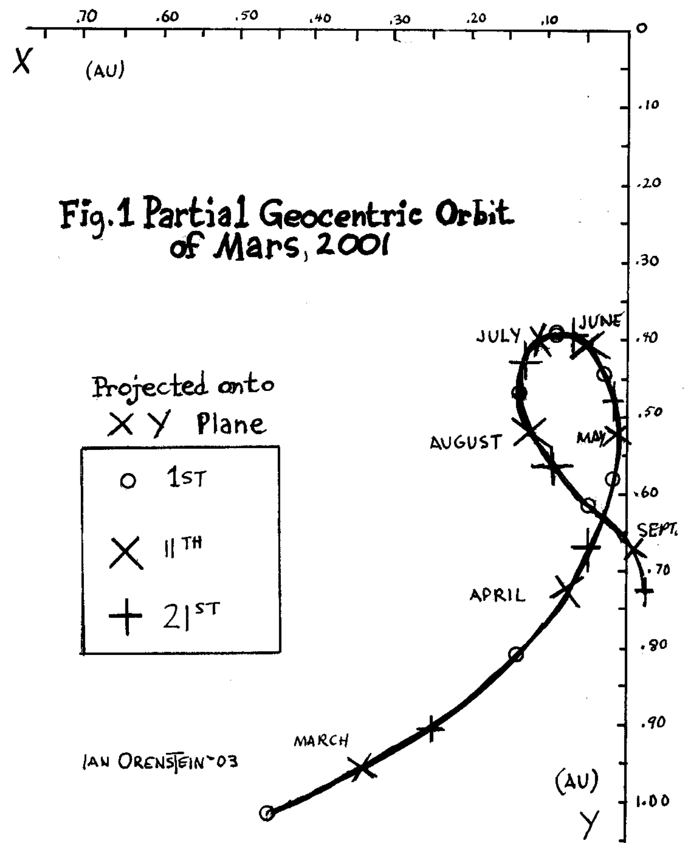


FIGURE 1

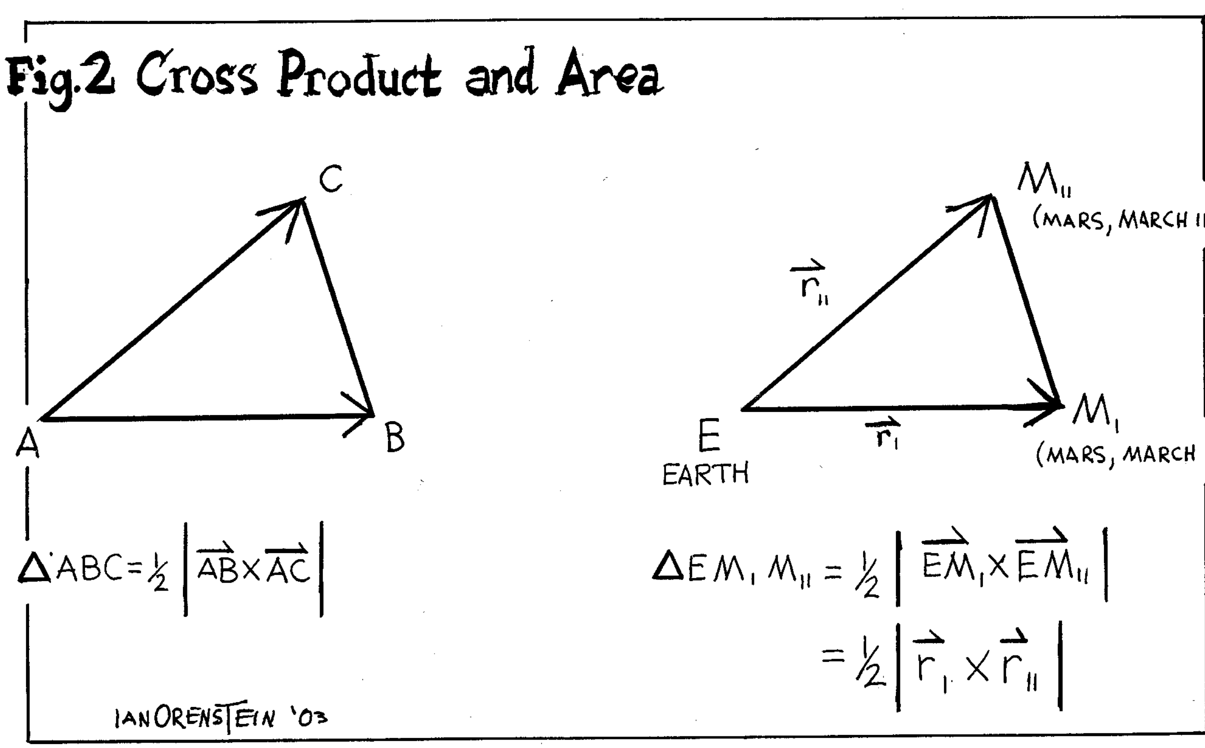


FIGURE 2

Table 1 — Geocentric Rectilinear Coordinates of Mars, 2001 (distances in AUs)

Date		x	y	z
Mar	1	−0.46566	−1.02180	−0.42319
	11	−0.34164	−0.96476	−0.40315
	21	−0.23811	−0.90442	−0.38135
Apr	1	−0.14764	−0.81643	−0.34876
	11	−0.08424	−0.73934	−0.31996
	21	−0.04372	−0.66700	−0.29342
May	1	−0.01811	−0.59283	−0.26593
	11	−0.00936	−0.53615	−0.24607
	21	−0.01464	−0.47920	−0.22594
Jun	1	−0.03075	−0.43977	−0.21930
	11	−0.05021	−0.40896	−0.20453
	21	−0.07497	−0.39490	−0.20231
Jul	1	−0.09927	−0.39822	−0.20776
	11	−0.11804	−0.41166	−0.21680
	21	−0.13115	−0.43578	−0.23021
Aug	1	−0.13112	−0.47279	−0.24855
	11	−0.12031	−0.52113	−0.27193
	21	−0.09557	−0.57113	−0.29526
Sep	1	−0.04622	−0.62199	−0.31779
	11	+0.01480	−0.67810	−0.34286
	21	+0.09587	−0.72820	−0.36460

Table 2 — 1st and 11th of Month Triangles Swept and Cross Products, 2001

Month	Area Swept Out (AU^2)	Cross Product (x, y, z)
March	0,054561	(0.00366, 0.04315, 0.10016)
April	0.055214	(0.03372, −0.01675, 0.04038)
May	0.003297	(0.00330, −0.00200, 0.00536)
June	0.036655	(0.00026, 0.07264, −0.00951)
July	0.003441	(0.00081, 0.00300, −0.00614)
August	0.006426	(−0.00101, −0.00575, −0.01145)
September	0.045514	(−0.00224, −0.02055, 0.04055)

David Orenstein teaches mathematics at Danforth CTI and observes from Trinity-Bellwoods Park, both in downtown Toronto. Cloudy evenings are spent enjoying the local cultural riches, weekends and holidays of other Canadian cities. He is a member of the RASC's National Education Committee and the Toronto Centre.

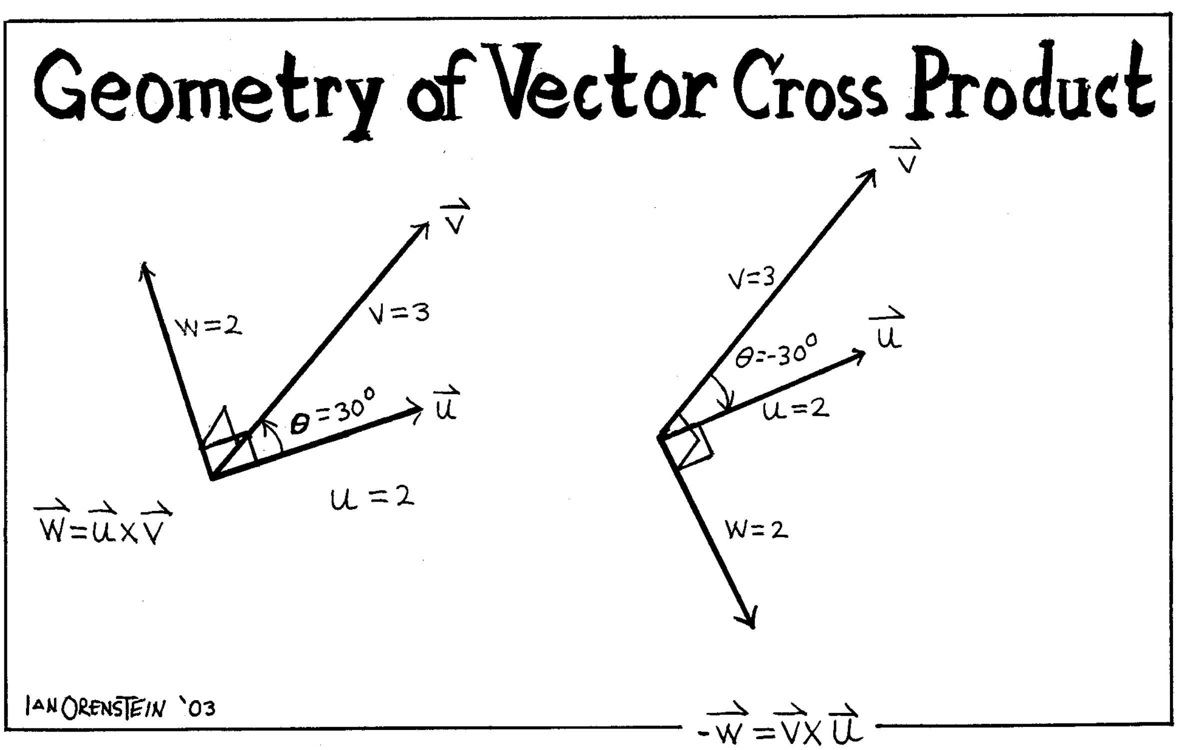


Figure 3

Society News/Nouvelles de la société

by Kim Hay, National Secretary (kimhay@kingston.net)

National Council Meetings

In the last issue, I reported that there was on February 22, 2003 a National Council meeting (NC031). Well, the weather did not cooperate and we had a major blizzard in Ontario, but despite this there were 32 people present, including 29 voting council members of which two were teleconference participants. The meeting went well being the first teleconference. At the meeting the following people were awarded their Messier Certificates: Geoff Meek (Ottawa), Martin Bonert (Toronto), Berni Plett (Winnipeg), Michael A. Earl (Ottawa), Riyad B. Abu-Laban (Vancouver), William R. Hydomako (Saskatoon), Jason Colley (Ottawa), Stephen B. Meister (Regina), Jenn Tigner (Ottawa). Congratulations to all, and good luck with your NGC observations, the next step.

Our Nominating Committee brought forth two names to fill the vacancies of the Honourary Members. The nominees are: Dr. Jean Meeus and Prof. Jay M. Pasachoff. Letters of invitation were sent off to both by the National Secretary, who is pleased to announce that both men have accepted our invitations, and they are now Honourary Members of the RASC.

Dr. Jean Meeus is known for his algorithm work. He was born in 1928, studied Mathematics in the Louvain University in Belgium, receiving his Master's degree in 1953. For more than 30 years he has published books and articles on Astronomy of Position. His other books include; *Elements of Solar Eclipses 1951-2200*, *Astronomical Formulae for Calculators*, *Astronomical Tables of the Sun, Moon and Planets*, *Transits*, and *Mathematical Astronomy Morsels*, all published by Willmann-Bell, Inc.

In 1981 the International Astronomical Union, for his numerous contributions to Astronomy, gave the name "Meeus" to asteroid 2213 in his honour.

Prof. Jay Pasachoff is the Director of Hopkins Observatory, Field Memorial Professor of Astronomy and has been at Williams College, Massachusetts since 1972. He graduated from Bronx High School of Science in 1959 and attended Harvard College with an A.B. in 1963, Harvard University with A.M. 1965, and his Ph.D. in 1969. For a much more detailed information on Prof. Pasachoff, visit `www.williams.edu/Astronomy/jpasachoff/`.

For more in-depth information on the February NC meeting, and in preparation for the upcoming National Council meetings in Vancouver, visit the RASC Web site at `www.rasc.ca/members` (members only section), under Minutes. If you have any questions, contact your local Centre National Council representative or myself at `kimhay@kingston.net`.

Upcoming Events

The 2003 General Assembly will be held in Vancouver, B.C. from June 26-29, 2003. If you have not already done so, please consider attending. It is a wonderful event and there will be great speakers featuring: Peter Broughton, David Dodge, Alan Dyer, Dr. David Levy, Dr. Jaymie Matthews (to be confirmed), Pál Virág, Dr. Gordon Walker, Peter Ceravolo, John Nemy, Carol Legate, and Jack Newton. In addition to the National Council and Annual Meetings, you will enjoy great friends and great times. In the meantime, visit the RASC Web site at `ap.stmarys.ca:8080/rasc/index.jsp` for updated information. I am sure that our next issue will feature several reports on the event.

Martian Motion II: *Zig Zag*

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

I can't seem to face up to the facts
I'm tense and nervous and I can't relax
I can't sleep 'cause my bed's on fire
Don't touch me I'm a real live wire
Psycho killer, qu'est-ce que c'est
Better run, run, run, run, run, run, run away
— Talking Heads, "*Psycho Killer*"

Serendipity would be a lovely name for a cat.

My own cat is named for Mars, the God(dess) of War, which not coincidentally is the object of my affection in the current three-part series about the closest outer planet. Other than being orange and bearing a vaguely warlike demeanour, I didn't really think the two had much in common. But late one evening when I was pondering subtitles to differentiate the three columns, my marmalade kitty serendipitously provided the answer with a typical bout of what some people call the "midnight crazies." Like an orange balloon that suddenly had its nozzle released, she zoomed into the living room, zigged across the mantelpiece, zagged behind the love seat, and zoomed back out again. Within seconds, the thundering hooves of an undersized Man O' War rumbled over our heads from upstairs as Venus (the dog) and I arched an eyebrow at each other in silent agreement. Psycho kitty, *qu'est-ce que c'est*? I retained a blurred image of folded ears and a live-wire brush of a tail bent at an aggressive angle and swollen to thrice its normal diameter.

By now you're objecting, Mars the planet doesn't have ears, or even canals.

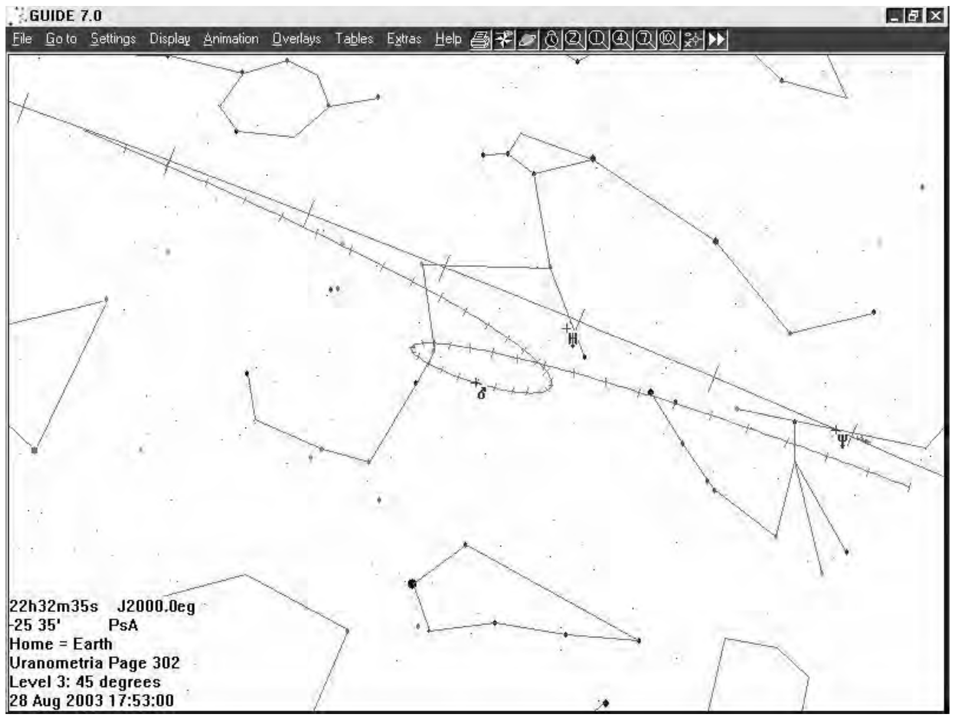


Figure 1 — The position of Mars against the background stars in 2003. Mars will be at the position of the first tick on the extreme right of the chart on April 30, at the centre of the retrograde loop precisely at opposition (shown), and at the left edge where the path meets with the ecliptic on December 26. As with the other charts, all of which are on the same scale, the entire path displayed covers a period of 240 days with ticks at 5-day intervals. The retrograde loop will occur roughly midway between the Water Jar of Aquarius, the Y-shaped asterism at top centre, and the bright star Fomalhaut (alpha Piscis Austrini) at bottom centre, which can be used as observational anchors. Note also the position of Uranus, whose path is not shown.

All figures courtesy of Alister Ling and the author, using Guide 7.0.

Furthermore, planets don't have tails, comets do. I'll admit that all analogies have their limits, but if you think I'm naming my cat Schwassmann-Wachmann 3, you're even crazier than I am.

My little Mars cat had inscribed, albeit in super speed, a very acceptable analogue to what her namesake will be doing in 2003. The Red Planet itself will itself be going through its paces at a clip much more urgent than normal.

As mentioned last time, Mars is currently zooming in for its closest approach to Earth in some 73,000 years. It occurred to me that its relative proximity would likely dramatically affect the planet's apparent motion in Earth's sky. Surely Mars will present a retrograde motion

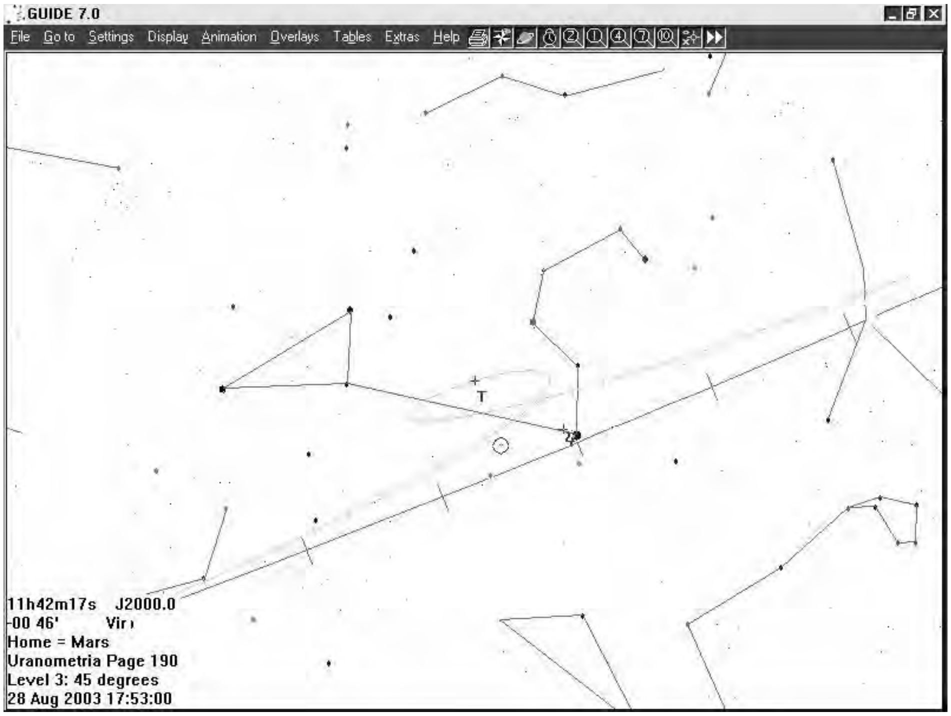


Figure 2. — The reciprocal path of Earth as seen from Mars presents a mirror image to Figure 1. Earth hits the top of the retrograde loop when it is at inferior conjunction, also on August 28. Of note here is the unusual position of the Sun (represented as a circle with a dot at its centre), *i.e.* **not** on the ecliptic. A Mars-centred coordinate system would define a different ecliptic, inclined 1.85° to the one familiar to us Earthlings. Also note the position of Jupiter (path not shown), next to Regulus and very near its own (superior) conjunction with the Sun. Jupiter's contribution to this summer's record close approach was discussed in the first column in this series (*JRASC*, April 2003).

that will be extreme in some form, either in duration or in the size of the loop.

I've always been fascinated by retrograde motion. As an outer planet passes through opposition, it appears to do a zig-zag against the background stars. Nearby Mars provides by far the greatest variety; Meeus (1997) identifies retrograde loops of 16 distinct shapes. Each is a sort of Texas two-step that is ominously reminiscent during these tense and nervous times, of the thrust-and-parry diplomacy of our modern-day gods of war.

Let's have a look at what to expect this summer. As Earth overtakes Mars in late July, the Red Planet will seemingly slow to a halt against the background stars of Aquarius, achieving its first stationary point on July 30. For the next two months or so as Earth zooms on by, Mars will appear to reverse its direction and drift westward some 10 degrees, achieving its maximum apparent reverse speed right around opposition before again slowing to a halt at its second stationary point on September 29.

This phenomenon is easily visible to the naked eye and makes a great project for observers of almost any level of experience. Unfortunately Aquarius doesn't provide many bright stars as reference points, although Mars can be pegged against the propeller-shaped asterism known as the Water Jar some 15° to its north. (See Figure 1) This summer the planet Uranus will also be in the vicinity, achieving opposition on August 24 about 7° to the northwest. The binocular observer can watch the bland gas giant do its own modest retrograde loop, covering about 4° of sky over the much longer period of five months (from June 7 to November 8).

In fact any planet as seen from any other displays a general eastward motion through the sky, which can be considered the spin of the solar system, but will reverse its field as the two near alignment. The inner planet will always be the faster, and for a portion of its orbit it will be traveling in sufficiently the same direction in space that even following a different curve, its own velocity more than negates that of the outer. Soon enough the inner planet "turns the corner" on its tighter orbit, and for an instant the velocities of the two, relative to the direction of the outer, will be equal (the stationary point). Then eastward motion resumes and starts to rapidly accelerate.

Did you know the inner planets also inscribe a retrograde loop around the time of their inferior conjunction? Venus and Mercury both do this as seen from Earth, although this is difficult to observe due to the presence of the Sun. As each dives toward the Sun at inferior conjunction, it moves briefly but decisively westward relative to the background stars. If you don't believe me, check out the table of right ascensions in the Sky Month-by-Month section of any *Observer's Handbook* around the time of opposition or inferior conjunction for any planet.

As seen, or at least imagined, from Mars this August the inferior Earth would appear to a do a reciprocal retrograde loop against the familiar backdrop of Leo. This loop would be a mirror image of what the terrestrial observer sees of Mars, the same relationship in opposite directions. Each would be of identical duration and angular size, both appearing east-to-west but reversed north-to-south. (See Figure 2) Against the celestial sphere simultaneous coordinates would be separated by exactly 12 hours of right ascension, with declination having the same value but with the sign reversed.

Of course, Mars itself can be seen against the stars of Leo when it is on the opposite side of its orbit, out near its aphelion. Such was the case in 1980, when Mars achieved both opposition and aphelion on the same day, February 25. At closest approach to Earth Mars was 0.67731 AU distant, some 82% further than the 2003 approach of 0.37272.

Some of our long-term members may recall that in 1980 the oppositions of Mars and Jupiter occurred within hours of each other, resulting in a rare triple conjunction of the two. Furthermore,

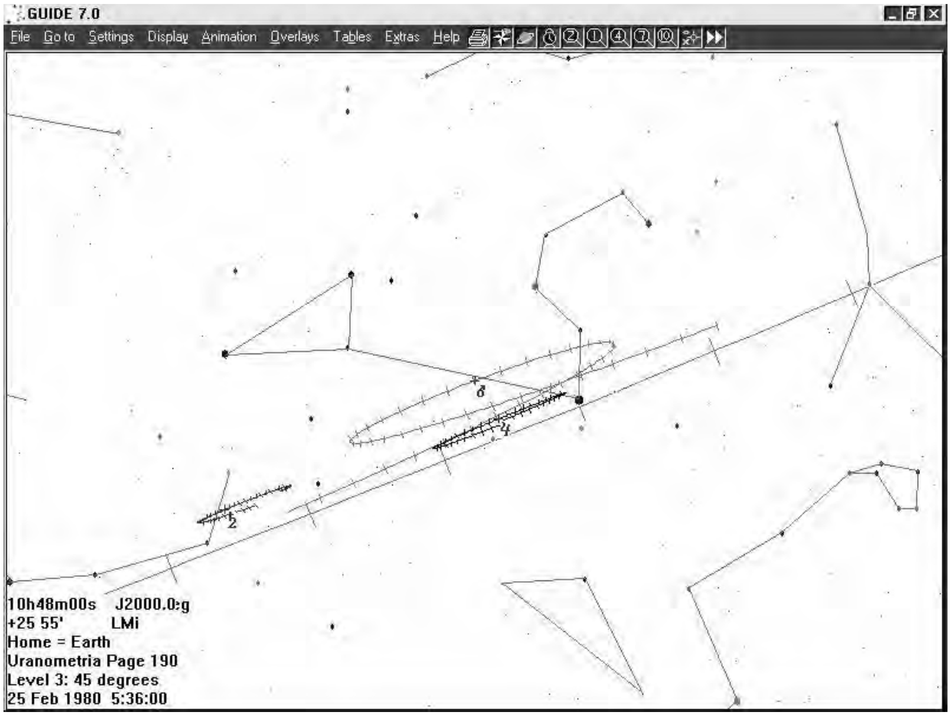


Figure 3 — The paths of the outer planets in 1980. Mars inscribes the broad, open loop, Jupiter the flatter tighter one just beneath it. Due to its later opposition, an asymmetric portion of Saturn's loop appears to the lower left (southeast), but the full extent of its retrograde motion is shown. Its loop is smaller still, as the parallax provided by Earth's orbit has a lesser effect at a greater distance. While in this instance the loop of Mars is significantly larger, for reasons described in the text this isn't necessarily the case. I leave it as an exercise for the interested reader equipped with a planetarium program to compare the sizes of the retrograde loops of Mars and Jupiter in 929 C.E.

Saturn was only some 20° away, reaching opposition on March 14. All three were therefore in retrograde motion simultaneously, allowing an excellent opportunity to compare the retrograde loops of the three bright outer planets. Through the magic of computers and particularly the software program *Guide 7.0,* such observations can be made at one's convenience; the events of 1980 are graphically captured in Figure 3.

Intuitively one might suspect that due to parallax, the closest of the three should inscribe the largest loop. Figure 3 supports that conclusion, as in 1980 Mars backed up some 20° of ecliptic longitude over a period of 80 days; Jupiter only 10° in 121 days, and Saturn 7° in 136 days.

So in 2003, with Mars substantially closer surely it should inscribe a still larger loop. Not so; the retrograde loop of this summer's perihelic opposition is much *smaller*, at 10° barely half as large as that inscribed at an aphelic opposition such as that of 1980.

To determine a pattern I visited my trusty shelf of *Observer's Handbooks* (Percy, Bishop, Gupta, 1980-2003) and obtained precise information of the past dozen Mars apparitions, as described in the table. I simulated each loop on *Guide 7.0,* and did a click-and-drag measurement to roughly measure the size of each loop in ecliptic longitude. A rhythm quickly emerges: the aphelic oppositions (1980, 1982, 1995, 1997) are all fairly similar at around 80 days retrograde motion and 20° loops. The closer apparitions exhibit shorter and sharper loops, and are much more sensitive to the conditions of the particular apparition; the oppositions of 1986 and 1988, which straddled the perihelion point, are significantly less extreme than this year's tight 60-day, 10° loop.

The extremes of this can be seen in Figure 4, which piggybacks aspects of Figures 2 and 3. It shows the retrograde loop of Earth as seen from Mars at perihelion in 2003, and the path of Mars at aphelion as seen from Earth in 1980. Against the timelessly infinite focus of the celestial sphere, Guide allows our minds to occupy two places and times simultaneously. From this tenuous vantage point we can see and compare both zig-zags, inscribed against the familiar feline form of Leo as mandated by serendipity.

So to answer my initial question, it turns out the 2003 apparition is indeed extreme in both duration and size of the loop, specifically that both are significantly shorter than usual. As with most good answers, it immediately generates another important question: What Gives?

The answer lies in the fact that Mars' eccentric orbit affects not only its distance from the Sun but also its orbital speed. You might think Mars is going to be a lot closer yet only moving a little bit faster, however since retrograde motion is caused by the relative motions of two moving planets, the key factor is the *difference* of the speeds of each. At its aphelion in February 1980, Mars was traveling at minimum velocity of 22.0 km s^{-1}, Earth at about 30.1 km s^{-1}, a difference of 8.1 km s^{-1}. This summer Mars will be at its maximum speed of 26.5 km s^{-1} while Earth, slightly nearer the aphelion of its own orbit, is going a little slower at 29.5 km s^{-1}, a difference of only 3.0 km s^{-1}. So while Mars will be 45% closer in 2003, the velocity difference will be reduced by some 63% to more than completely negate the foreshortening effect of parallax. (`nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html`)

Look again at Figure 4; in the 240-day period charted the light grey path of this summer's perihelic opposition moves some 60° eastward, from one edge of the chart to the other. The darker one of 1980 moves a much more leisurely 32° in the same period. It follows that, compared to the faster-moving Mars of 2003, the effect of Earth's passage will have a net subtractive effect (observed as retrograde motion) for both a fewer number of days and a smaller daily value. This is consistent with the observed facts of a retrograde loop of three-quarters the duration and half the displacement.

No less an authority than Meeus (1997) states, "More distant planets have shorter arcs of retrogradation." He is correct if he's talking about different planets. But in the case of the same planet at differing distances, the opposite seems to hold; the more distant the planet, the *longer* the arc. Indeed it is Mars' very eccentricity that causes this; it requires extra momentum at perihelion to fling itself out to a deeper aphelion. As confirmation I entered, at the suggestion of Alister Ling, orbital elements for a fake Mars in a circularized orbit at the perihelion distance, and another at the aphelion distance. The retrograde motions of both pseudo-planets moderated towards the middle ground between the observed extremes, with the closer one having a slightly larger arc as Meeus, and intuition, suggests.

With slight asymmetries due to the eccentricity of Earth's own orbit, one factor is almost entirely consistent: the closer the planet, the shorter the duration of its retrograde phase. This summer, in a shade under two months Mars will cut the quickest zig-zag we can hope to see for an outer planet. I'd be tempted to say quick as a cat, except I know better.

Year	First station	Opposition	Second station	Duration	~ Size of loop
1980	01-17, 03h	02-25, 06h	04-07, 09h	81d, 6h	20°
1982	02-21, 05h	03-31, 10h	05-13, 05h	81d, 0h	19°
1984	04-05, 02h	05-11, 09h	06-20, 10h	76d, 8h	17°
1986	06-10, 00h	07-10, 5h	08-12, 12h	63d, 12h	12°
1988	08-26, 23h	09-28, 4h	10-30, 14h	64d, 15h	12°
1990	10-20, 12h	11-27, 21h	91-01-01, 16h	73d, 4h	17°
1993	92-11-29, 16h	01-07, 23h	02-15, 11h	77d, 19h	19°
1997	01-04, 01h	02-12, 03h	03-25, 17h	80d, 16h	19°
1995	02-06, 18h	03-17, 08h	04-29, 06h	81d, 12h	19°
1999	03-18, 10h	04-24, 18h	06-05, 07h	78d, 21h	18°
2001	05-11, 15h	06-13, 18h	07-19, 23h	69d, 8h	14°
2003	07-30. 22h	08-28, 18h	09-29, 14h	60d, 16h	10°

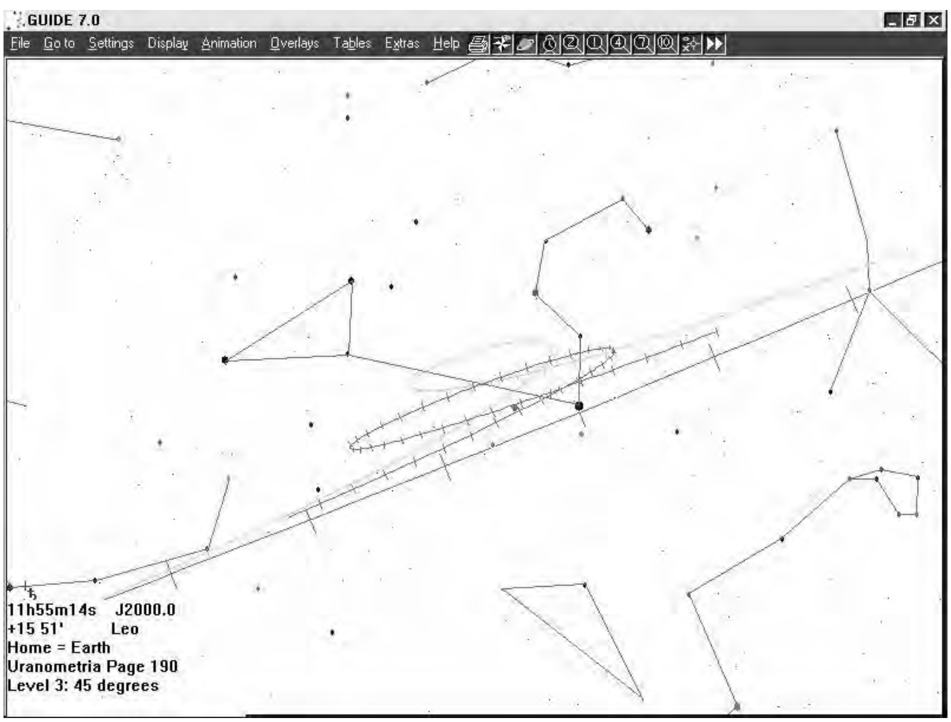


Figure 4 — A comparison between perihelic and aphelic retrograde loops involving Earth and Mars. One view from each planet at opposite sides of their orbits is shown to place both loops against the same background. That the planets are much closer together in 2003 can be seen by the height of the loop above the ecliptic, as foreshortening exaggerates the effect of inclination.

Acknowledgement

The assistance of Alister Ling is gratefully acknowledged.

References

Meeus J. 1997, Mathematical Astronomy Morsels (Willmann-Bell Inc.: Richmond), 233, 246

NASA Goddard Space Flight Center, Mars Fact Sheet, `nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html`

Percy J., Bishop R., Gupta R, Editors, 1979-2002, Observer's Handbook 1980-2003 (University of Toronto Press: Toronto)

Bruce McCurdy is the Education Development Coordinator of the Sky Scan Science Awareness Project, a not-for-profit initiative that offers Grade 9 students a science curriculum-related project observing meteors using FM radios. Active in astronomy and its public education outreach since the mid 1980s, Bruce is a past president of the RASC Edmonton Centre and currently serves the National Council as Astronomy Day Coordinator. Bruce may be the only person on the face of the Earth who can find inspiration for an astronomy article in a song entitled "Psycho Killer."

Cyg-*nice*!

by Mark Bratton (mbratton@generation.net)

On warm July and August evenings, as midnight approaches, the eye of the mid-northern observer is drawn again and again to the bright and distinctive constellation Cygnus and the billowing star clouds and dark rifts of the northern Milky Way. For Canadian observers, this region of the sky offers our home galaxy at its most brilliant. Although the galaxy is brighter still towards the south in Scutum and Sagittarius, atmospheric extinction tends to dull this region of the sky for observers in temperate climes. We are fortunate indeed that the Cygnus Milky Way is directly overhead during the most comfortable observing months of the year and can be explored at leisure in shirt-sleeved comfort.

Although it is one of the sky's larger constellations, covering 804 square degrees, Cygnus is home to only two Messier objects; the small, coarse star cluster M29 and the large, scattered cluster M39. Neither object is particularly interesting visually and if the observer limits his deep sky exploration to Messier objects, he or she stands to miss out on some of the most interesting and challenging objects of the summer sky. Dozens of star clusters and nebulae in Cygnus are worthy of telescopic scrutiny, but for the purposes of this article, we will concentrate on six of the best.

Many observers are familiar with the beautiful and distinctive NGC 7000, the aptly-named North America nebula.

Figure 1 — NGC 6888[1]. Courtesy of Digitized Sky Survey.

Photographs and tri-colour CCD images reveal a brilliant red and pink-hued nebula set against a spectacular star field. Unfortunately, visual observers must be content with a much more modestly glowing object. The surface brightness of NGC 7000 is about 22 magnitudes per square arcsecond, four magnitudes fainter than the Orion nebula, which can be counted on to show some colour in amateur-sized telescopes. The North American nebula, covering almost two square degrees of sky, is large enough to be considered a binocular object, though on the many occasions I have observed this region, I have never been able to entirely convince myself that I have seen the nebula itself. The star field it is set

[1] The Digitized Sky Surveys were produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present compressed digital form with the permission of these institutions.

Figure 2 — Barnard 145. Courtesy of Digitized Sky Survey.

against tends to overwhelm the glow of this emission nebula.

Much more success can be had with a moderate aperture telescope, a nebula filter of some kind, and dark, high-contrast skies. I experienced such conditions in September of 1993 when I had a spectacular view of NGC 7000 and the nearby Pelican nebula. At 48×, the nebula filled the field of view of my 15-inch Dobsonian reflector. "Mexico" and "Central America" were the brightest, most well-defined portions of the nebula with a prominent, bright chain of stars highlighting the nebula in the extreme southeast. The "Gulf of Mexico" was well defined as well, with the "Florida peninsula" highlighted by a seventh magnitude star where "Miami" should be. To the north, the nebula was bright too but it faded gradually into the brilliant star field and was poorly defined. West across a dark gulf from the "Atlantic seaboard" was the fainter, formless glow of the Pelican nebula, which just made it into the 85 arcminute field of the 40-mm eyepiece.

The Veil Nebula (NGC 6960 and NGC 6992-95) is, after the Crab Nebula, the brightest and most well known supernova remnant in the northern sky. Again, this is a subtle though rewarding visual target for the interested observer. Your best view of this extraordinary nebula will come with the use of at least a 12-inch telescope, an oxygen III filter, and the darkest skies possible. It is easy to locate, as the naked eye star 52 Cygni is set against the westernmost portion of the nebula, NGC 6960. In my 15-inch Dobsonian at 90×with an O III filter, NGC 6960 gently curves for about 30 arcminutes north from 52 Cygni. The nebula is moderately bright, but smooth textured and well defined, particularly along its western edge, which appears brighter and more opaque. The O III filter brings out a distinctly warm, yellow tint to the nebula. South of 52 Cygni, NGC 6960 is a little fainter but extends for about 40 arcminutes, curving gently towards the southeast. This portion of the nebula appears a little more detailed, with the nebula splitting into two main branches about 10 arcminutes south of 52 Cygni.

Moving eastward across a two-degree gulf, we come to NGC 6992-95, the brightest portion of the Veil nebula. A 40-mm eyepiece, unfiltered, on the 15-inch Dobsonian allows the entire curving arc of the nebula to be viewed at once. Even in a low power field, there are subtle hints of the rich detail that is visible with higher magnification and an O III filter. This portion of the Veil is broader than any part of NGC 6960. The northern half of the arc betrays many brighter, star-spangled concentrations and a stubby branch that breaks off in the northeast. The southern portion of the nebula is the payoff; a complex region of lace-like tendrils, much broader at its southern extremity and adorned with many foreground stars.

Between the Veil's two main components is an unnumbered portion of the nebula that extends for about 30 arcminutes visually in a north-south direction. The nebula tapers gently to the south and in the north splits into two stubby branches. Because of its complexity, the Veil nebula is a fascinating object to explore with various sized telescopes under varying conditions.

NGC 6888, the Crescent nebula, is a far more challenging and difficult object to observe. This is an extremely peculiar nebula, which surrounds a magnitude +7 Wolf-Rayet star, HD 192163. This very hot star is shedding mass at a prodigious rate and violent winds blow this matter into a shell surrounding the star. At least

Figure 3 — NGC 7008. Courtesy of Digitized Sky Survey.

part of the gas that makes up the Crescent nebula is made up of the mass shed by the Wolf-Rayet star. The rest may be gas and dust that already existed in the interstellar medium surrounding the star and is now being caused to shine by radiation from the Wolf-Rayet star.

The field is easy to locate as it is marked by a diamond-shaped asterism of four stars, elongated in an east-west direction. The southernmost star in the asterism is HD 192163. With an unfiltered 12-inch telescope under mediocre dark skies (limiting magnitude about +5.3), the brightest portion of the nebula can just be detected using averted vision. An O III-filtered 15-inch under the same conditions makes the brightest arc, about 5 arcminutes in extent, visible with direct vision. Under darker skies (limiting magnitude +6.0) the 15-inch equipped with the O III filter reveals the bright arc, now almost 10 arcminutes in length, to be neatly bisected by the northernmost star in the diamond-shaped asterism. The asterism's easternmost star lies near the tip of the nebula. To the west, a small detached portion of the nebula is visible and to the southwest, a faint, broad expanse of nebulosity is just visible with direct vision.

About 2 degrees south-southwest from NGC 6888 is Barnard 145, a large, dark nebula spanning almost 60 arcminutes in length. The nebula is visible because it is set against a rich Milky Way star field that defines its shape. Located just south of a magnitude +7 field star, the nebula is dark and sharply defined visually, quite broad at its western extremity and gradually tapering to a point in the east. The Palomar Sky Survey image reveals a more complex object; a dark nebula with some of its gas and dust faintly glowing, particularly to the east.

A much easier target, particularly for smaller telescopes, is located in the northern regions of Cygnus, immediately east of the double star 16 Cygni. NGC 6826 is a bright planetary nebula that is fun to observe. In a small telescope, particularly under mediocre skies, the nebulous shell surrounding the magnitude +10 central star may initially be difficult to observe. Using averted vision, however, causes the planetary nebula to come into view and overwhelm the central star. Moving the eye rapidly between direct and averted vision will cause the nebula to blink on and off, hence NGC 6826's nickname: the Blinking Planetary. This effect is lost when using larger telescopes under darker skies. Under these conditions, both the central star and outer shell of gas are readily visible.

Far less well known, but just as interesting, is the planetary nebula NGC 7008. Part of this beautiful planetary's anonymity is due to the fact that it lies in the middle of a relatively rich star field that is very difficult to star hop through. Observers with computer-guided scopes will have no difficulty finding it, however, and will come across a fascinating object. With my 15-inch reflector under dark, New Brunswick skies (limiting magnitude about +6.2), this planetary is a broken ring of gas surrounding a magnitude +14 central star. It is quite obviously crescent shaped and well defined along its rim. The shell is open to the east-southeast where a pair of stars, magnitudes +9 and +10, are visible. At least two other magnitude +14 stars are visible within the nebula itself and the shell is well defined towards the north, west, and south.

Many nights of challenging exploration await the dedicated observer in the region of Cygnus the Swan. These six unique objects are a good starting point into a constellation that is fascinating to explore.

RASC member Mark Bratton, who is also a member of the Webb Society, has never met a deep sky object he did not like. He is one of the authors of Night Sky: An Explore Your World Handbook.

The Visibility of Jupiter During the Day

by Russell D. Sampson (sampsonR@easternct.edu)

It is common knowledge that the Moon can often be seen with the unaided eye during the day. However, relatively few people, mostly astronomers, know that under the right conditions the planet Venus can also be seen in broad daylight with no optical aid. Fewer still realize that Jupiter, the next brightest of the planets, can also be visible in the day.

Since the mid 1980s I have been interested in the naked eye visibility of planets in the day. On September 12, 2001 the conditions for a daylight sighting of Jupiter were nearly ideal. As an informal experiment I used the students in my introductory astronomy class to test how many people could see such a challenging object.

I first noticed the Moon and Jupiter were very close to each other about 06:15 EDT. The skies were clear but there was some scattered fog.

At 07:21 EDT (11:21), while walking to work, I tried to see Jupiter next to the Moon. I first found it in my 7×20 binoculars. Afterwards I could easily see it with the unaided eye. The Sun was 9.6 degrees above the horizon. As Alister Ling has mentioned before, this is the best time of day and best elongation distance for Jupiter to be seen in the day. Jupiter is very close to the darkest part of the sky — the polarization band. It also really helps to have the Moon so close since it is difficult to focus on an empty sky.

On the way to my AST 225 class (Introduction to Stars, Galaxies, and the Universe) I looked for Jupiter again at 08:40 EDT. This time the Moon had moved a little further away but Jupiter was still visible.

At that point I decided to let my class try to see the planet. I usually arrive about 15 minutes before class and I briefly introduced the subject in the classroom. The early students were taken outside the planetarium into the shadow of the building. Within a few moments students were remarking with surprise that the planet was visible. At this point it was 08:50. We remained outside until 08:56. The Sun was 26 degrees above the horizon. Once back in the classroom I quizzed the students about who saw what. Out of the 14 early arrivals, 9 could see it, 2 could not, and 2 did not try. At the end of class two late-arriving students asked to see the planet. It was now 10:05 and both could see it — as could I. We remained outside until 10:30 at which time the planet was still visible. The Sun was now 42 degrees above the horizon. These two students also found Venus while I could not find it.

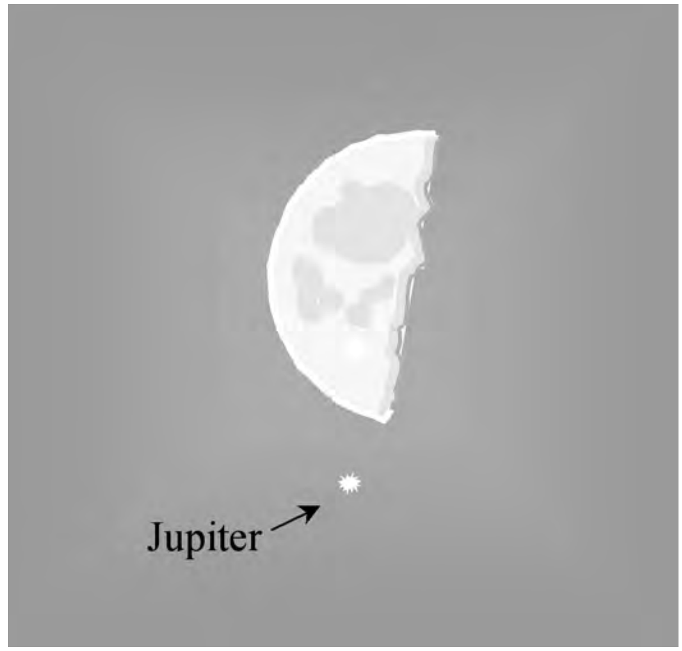


Figure 1 — A Sketch showing the approximate location of Jupiter during class sightings on September 12, 2001

The challenging nature of the observation presents its own limitations. It is certainly possible, especially for untrained observers such as these students, that many may have convinced themselves they could see the planet when in fact they observed only an artifact of their vision. Also, it was necessary to tell the students where to look and what to look for. This also could have biased their observations. On the other hand, if the students were simply asked to look around the Moon and describe what they saw, there would have been very few who might have thought to look for a planet. This seems apparent since those students who took part in the experiment appeared not to know that planets could be seen in the day.

Russell Sampson is an assistant professor at Eastern Connecticut State University where he teaches astronomy and meteorology. His research interests include atmospheric refraction, photogrammetry, astronomy education, and the history of astronomy. He has been an amateur astronomer since 1973 and a member of the RASC Edmonton Centre since 1984.

Web Site Reviews

by William Dodd, Toronto Centre (wwdodd@sympatico.ca)

Name	**Web Address**
International Astronomical Union	`www.iau.org`
Category	**Rating**
Professional Astronomers, Serious Amateurs, Astronomy Students, Education	☆☆☆☆

Overview

The International Astronomical Union (IAU) was founded in 1919 to promote all aspects of astronomy through international cooperation. Members of the IAU include 8300 professional astronomers from 66 countries around the world. The IAU is the international authority for naming celestial bodies and any features on them. The IAU functions through 11 scientific divisions that include over 40 Commissions and 70 Working and Programme Groups. Educational activities are one of its major interests, and the IAU works cooperatively with organizations of amateur astronomers.

Content

The main menu is simple: *News, FAQ, Organization, Activities,* and *Contact*. The *News, Organization,* and *Activities* items, in particular, lead to many astronomical items.

Under *News,* for example, you can currently find links to "A Summary of the International Conference on Light Pollution" and "Announcements for young astronomers."

Links to all the divisions, commissions, and working groups are located under *Organization*. As an example, Division IV Stars, includes Commission 26: Double and Multiple Stars, which is linked to the Double Star Library. This library includes IAU Circulars on double stars, announcements of conferences on double stars, bibliographies of recent papers on binary stars, links to binary and multiple star catalogues, and links to related databases, newsletters, and research. The IAU Double Star Library is a valuable catalogue of links to all the latest astronomical work, from around the world, related to multiple and binary star systems.

Selecting *Activities* leads to links such as Publications, Educational Activities, and Environmental Challenges to Astronomy. Educational Activities, in turn, leads to the detailed workings of IAU Commission 46: Astronomy Education and Development.

Aesthetics

The IAU Web site is text based, with a few graphics. Most of the top-level pages contain only brief notes and lists of links to items at the next level. One consults this site for its organized astronomical content, not its beauty.

Organization

The IAU Web site has been designed for fast and easy navigation. The main menu is always displayed across the top of the page. Sub-menus and links to other material are displayed down the page. Beyond the first few levels, menu selections may take you to a different Web site. Then the only way to return to the main menu is through repeated use of the BACK button, or to re-enter at the top of the IAU Web site.

Links

The IAU Web site contains a masterfully organized set of links that can be followed to conferences, research papers, databases, catalogues, astronomers, universities, and observatories around the world.

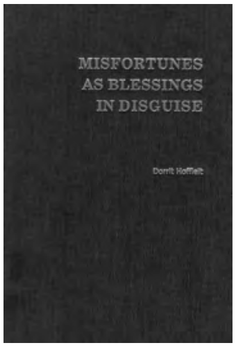
Final Comments / Recommendations

The IAU Web site is highly recommended for serious amateurs, and astronomy students. It connects you with the activities of the premier world governing body in astronomy, and provides links that lead to just about everything else in astronomy.

The IAU Web site is designed to start at the most general level for all areas in astronomy. If you are looking for introductory material on a very specific topic, you may find it more efficient to conduct a Web-search directly on your topic rather than working through the various IAU levels to find the same information.

William Dodd is the Education Notes contributing editor for the Journal *and a member of the RASC Toronto Centre. A retired math teacher, he is now a keen student of history as well as astronomy.*

Reviews of Publications
Critiques d'ouvrages



Misfortunes as Blessings in Disguise: The Story of My Life, by Dorrit Hoffleit, pages 176 + xviii, 17.5 cm × 25 cm, The American Association of Variable Star Observers, 25 Birch Street, Cambridge MA 02138-1205, USA, 2002. Price $21.00 US plus $2.95 US shipping and handling, hardcover (ISBN 1-878174-48-7).

This delightful book, with its warm and thoughtful *Foreword* by AAVSO Director Janet Mattei, is a collection of short pieces spanning the life of Dorrit Hoffleit, who is perhaps one of the most well-recognized astronomers of the past century. The collection of stories is less an autobiography than a delightful and heart-rending glimpse at the career aspirations and struggles of a highly productive woman astronomer, and is a "must read" for all aspiring scientists, particularly women. But be forewarned, once you start reading you will have trouble putting the book down until you have finished, as I learned, almost to my regret, when I delved into it at Logan Airport in Boston and almost missed my flight home because I was so engrossed.

Misfortunes as Blessings in Disguise grew from a random collection of stories about her life that Dorrit Hoffleit related to Janet Mattei during various visits to Janet's home over the years. After a number of earnest requests by Janet to put the stories in the form of an autobiography, Hoffleit has finally found time to assemble them into a very enjoyable personal history, thanks to the editorial assistance of AAVSOer Michael Saladyga. Unlike other autobiographies, however, the chapters do not comprise a complete life story from beginning to end, but rather a series of vignettes arranged roughly in chronological order. On a few occasions the narrative hops around a bit temporally, but not enough to affect one's enjoyment of the contents. The text is also remarkably free of typographical errors. Only two struck me during my first reading, and neither was particularly serious. Curiously enough, the first occurs in the very first paragraph of the book, where, in a description of Hoffleit's father, Fred Hoffleit, mention is made of the East Prussian town of Friedland as the "site of an important battle in the war of 1870-1871." More correctly, Friedland was the site of an important battle in 1807 between the French and Russians during the Napoleonic wars.

Misfortunes as Blessings in Disguise has many similarities to an autobiography. It begins with the meeting and marriage of her parents, Fred Hoffleit and Kate Sanio, who were both raised in German East Prussia, now Poland, and continues through the early struggles of her father in America in the early years of the 20th century as he struggled to support the family, which includes Hoffleit's older brother, Herbert. As the junior female sibling, Hoffleit's first struggle seems to have been to gain recognition of her worth from parents who were mainly devoted to Herbert. What follows is a brief description of her years at Radcliffe specializing in mathematics, before beginning work on variable stars at the Harvard College Observatory on graduation. Hoffleit's first supervisor was Henrietta Swope, and the Observatory director of that era was, of course, Harlow Shapley. There are captivating snippets of her work to be read, as well as correspondences and interactions with some of the famous astronomers of the era: Ejnar Hertzsprung, Rudolph Minkowski, Bart Bok (who, with Shapley, encouraged her to pursue a Ph.D.), Ernst Öpik, Antonia Maury, Paris Pişmiş, etc. There were also health problems to overcome. Short "chapters," most no more than a page long and in large type, make the book easy and interesting to follow.

Hoffleit worked in a number of different fields in her career, typically mastering each in its turn: variable stars, meteors, stellar parallax, binary stars, projectile motion, rocketry, photometry, what have I missed? During World War II she worked briefly for the Navy computing firing tables for cannons, then for the Army at the Ballistic Research Laboratory, where she faced further prejudices because of being a woman. She returned to Harvard after the war to spend several more productive and happy years under Shapley. Many of the stories are about Shapley as well as Hoffleit, and they provide captivating insights into the astronomy of that era.

The directorship at Harvard following Shapley's retirement fell to Donald Menzel with his new ways and new ideas, most of which appear to have conflicted with Hoffleit's research goals. Here the prejudice faced by Hoffleit was the indifference of one scientist for the field of study of another. But there were other avenues open. Hoffleit recounts her work with the American Association of Variable Star Observers, and her successful move to become director of the Maria Mitchell Observatory on Nantucket. Even that proved to be a struggle, as she found herself in the uncomfortable position of replacing the previous director, Margaret Harwood, who felt no need to be supplanted at the MMO. Yet Hoffleit's struggles eventually won out, and she forged her own distinct imprint on the Observatory with her summer program for women with its focused studies of variable stars. It is an imprint that is still maintained by the current director, but with a slight redirection using current technology. During the winter months Hoffleit maintained a separate position at Yale University in New Haven.

Reading through Hoffleit's autobiography, one gets the distinct impression that every happy bubble in her career was eventually burst by a replacement of the director for whom she worked, for example, the replacement of her civilian director at the Aberdeen Proving Ground by a colleague with similar credentials to hers, and Shapley replaced by Menzel at Harvard. At Yale it was apparently the opposite, since Brouwer's replacement by Pierre Demarque brought some good changes to Hoffleit's career. But I digress. *Misfortunes as Blessings in Disguise* also contains snippets of Hoffleit's family life, her relations with her brother and his wife, as well as her mother, her various pets, and life with her honourary grandchildren. Despite her early struggles, Hoffleit's career is very much a success story, a successful struggle against unexpected adversities, and a model for every aspiring young scientist, of whatever gender. She has been blessed by a variety of honours and awards over her lifetime, has outlived her various detractors, and has a list of several hundred publications to her credit, including book reviews, short magazine pieces, catalogues, and peer-reviewed journal papers. It is an inspiring record of a truly successful woman astronomer. And who among observational astronomers has not had occasion to use the *Yale Bright Star Catalogue*, which is the most obvious example of one of Hoffleit's contributions? My own copy sits beside me on my desk as I write this.

I love this book. There are a variety of images spanning Hoffleit's career that are contained in the middle section of the book, some of which contain little nuggets waiting to be discovered. In the images, for example, I discovered my colleague Nancy Evans in a group photo of former MMO students. The 70th birthday celebrations at Yale reveal a youthful David Guenther, who is currently a Department colleague of mine but who was then beginning his graduate career at Yale. *Misfortunes as Blessings in Disguise* is well worth the retail price established by the AAVSO. I was fortunate to obtain mine at the October 2002 meeting of the AAVSO in Somerville, and had my copy autographed by Hoffleit during the meeting. And, no, I did not miss my plane.

David Turner

David Turner is the Review Editor for the Journal, *an occasional contributor, and former Editor of* JRASC. *He is also an active variable star enthusiast, well, for Cepheids primarily, but for other intriguing types of variables, too.*

Star Testing Astronomical Telescopes: A Manual for Optical Evaluation and Adjustment, by Harold Richard Suiter, pages 364 + xvi; 15.5 cm × 23.5 cm, Willmann-Bell Inc, 1994. Price $30.00 US hardcover (ISBN 943396-44-1).

The main idea of this book is that one does not need expensive equipment and a doctoral degree to test telescope optics. All one needs to do is aim the telescope at a star and adjust the eyepiece to move the image in and out of focus: defects in the optics will betray themselves in the resulting defocused images. What Suiter has done is model the effects of various aberrations on the defocused images and presents the resulting model images in a useful manner. The result is a book that demystifies the telescope and enables one to evaluate image quality systematically and easily.

Who should buy the book? It is an easy one to recommend since it makes very good reading, and at $30 US is a bargain. If you have a degree in engineering or physics and enjoy astronomy, then you should have a copy of the book. If you make your own instruments, you should probably have a copy for reference. Amateur astronomers who wish to understand their telescopes should also consider purchasing it.

It is a book that I truly enjoyed reading. It is technical, but most of the dreary mathematics have been placed in appendices or (wisely) left out. Most importantly, Suiter has mixed a good amount of practical advice to aid interpretation of the figures. There are a number of anecdotal sections that make the book easier to read and that highlight potential difficulties in testing optics.

The book is organized into fifteen chapters, nine of which deal in-depth with specific optical problems such as spherical aberration. Each chapter includes a number of images of defocused stars, showing the effects of increasing the severity of a defect. Most of the images are modeled by computer algorithms, which allow each defect to be studied independently. Importantly, every case is duplicated: once for unobstructed optics (refractor) and once for obstructed optics (reflector). Suiter has also cleverly made chapter two a shortened version of a star-test manual. That allows the reader to understand very quickly what the tests illustrate.

One of the most useful features of *Star Testing Astronomical Telescopes* is its use of modulation transfer plots to show the relative effects of optical defects on image quality. For example, although a star test can tell you how much spherical aberration your telescope has, it is the plot of modulation transfer that tells you how it will affect the image.

I must admit there are a few sections of the text that I found difficult to follow. In spite of this, I had no problems with subsequent sections, perhaps because of the practical approach that Suiter uses when discussing the star tests.

There are a few things I learned from *Star Testing Astronomical Telescopes* that were important for adjusting my own telescope. For example, I found that the amount of alignment (collimation) recommended in my telescope manual was inadequate. Chapter six of Suiter's book demonstrates that telescope misalignment resulting in a very slightly out-of-round star test pattern is devastating to image quality. I realigned my telescope and still found the image quality very poor. A quick check in *Star Testing*

Astronomical Telescopes indicated that my telescope suffered from a massive amount of spherical aberration. Happily, leaving the telescope to cool in the garage overnight solved the problem.

A downside to *Star Testing Astronomical Telescopes* is something addressed by Suiter in the text. After reading the book, you may never be able to look through another telescope without seeing its flaws.

Daniel Rickey

Daniel Rickey is an imaging physicist at CancerCare Manitoba *and specializes in diagnostic ultrasound. He is, however, interested in all aspects of imaging.*

Astrocryptic

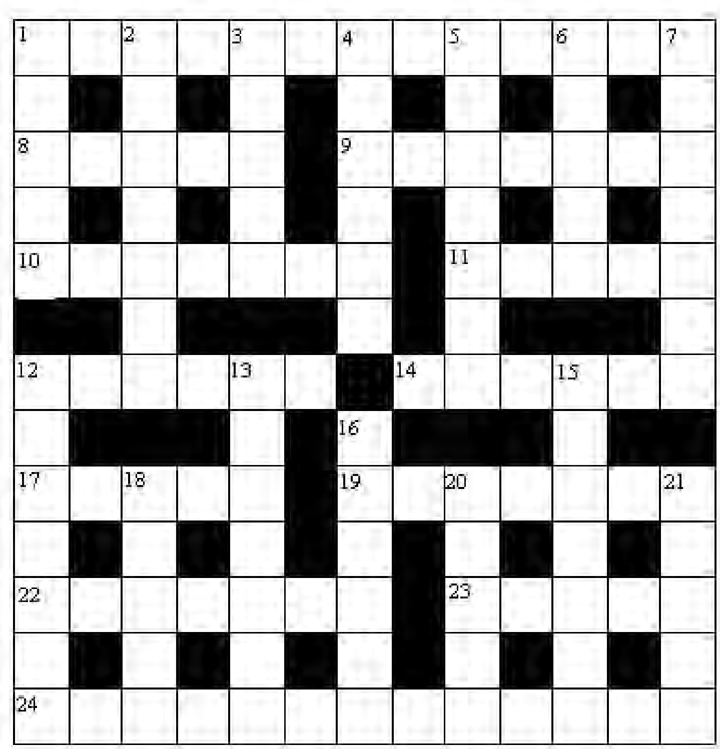
by Curt Nason, Moncton Centre

ACROSS

1. Long-armed Karl's radius reaches the event horizon (13)
8. Lightweight bouncer loses extremities (5)
9. Filter density selection for resolving lunar Te (7)
10. Lip curled in waste allowance makes fine objective (7)
11. Dance initially toward west in summer teapot (5)
12. Diving bird finds silver in nebulous waters … (6)
14. … and I drift around northward for a flower (6)
17. H. Arp went wildly around London calling Alpher by name (5)
19. Bayer's fifth rank defaces nose and lip (7)
22. DSOs seen at an unusual bun sale (7)
23. Energy envelops Nickelback at Saturn's outer loop (1-4)
24. Dusty glow returns Oz before a dial glitch scatters it (8,5)

DOWN

1. Barlow or refractor tube size (5)
2. Activity for Canes Venatici and an odd thin gun (7)
3. Astronomer rings in near recollection (5)
4. Buddhism leads it to heaven's beginning above (6)
5. Comet head's sheen among the group of stars (7)
6. Abbreviated galaxy type with railroad between tracks before one (3, 2)
7. Removed fifty extraterrestrials indeed (7)
12. Look to ruptured space at the zenith for relativistic transformation (7)
13. Hope is shaken before sick feeling rises around Uranus (7)
15. Meteoritic star (7)
16. Space station follows me to a spot atop Orion (6)
18. Somehow Doble technology describes planetary nebulae (7)
20. She will contract a star with emission lines (5)
21. Weird thing seen after sunset (5)



THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

NATIONAL OFFICERS AND COUNCIL FOR 2002-2003/CONSEIL ET ADMINISTRATEURS NATIONAUX

Honourary 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, M.Sc., Toronto
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
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**

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, 1974 Baseline Road, Ottawa ON K2C 0E0

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