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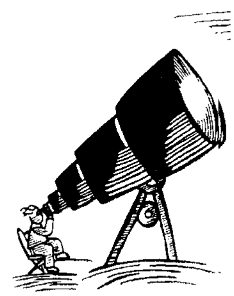

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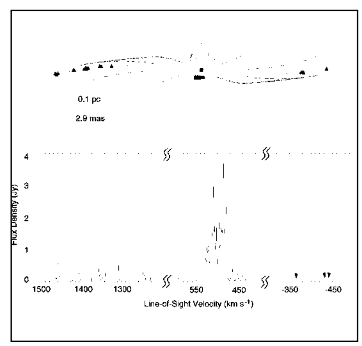

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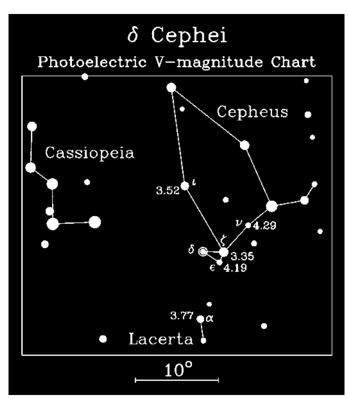

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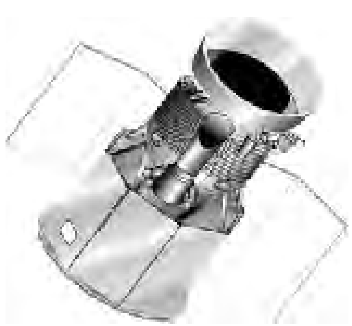

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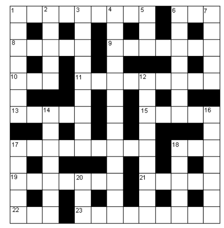

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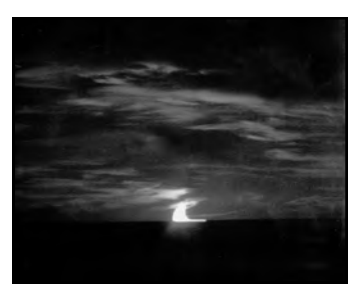

Cover:
A summer eclipse brings out the resourceful traits in our astronomers!
(Photo by Mary Lou Whitehorne)

From the Editor

by David Turner

There was a general sadness in the RASC earlier this year at the news of the passing of Father Lucian Kemble, who referred to himself as "Lamplighter" in his correspondence. Father Kemble took great delight in viewing all of the splendours that Nature has to offer, and not just those that are visible through the eyepiece of a good telescope (see JRASC, 92, 62, 1998; JRASC, 93, 151, 1999). It is perhaps a fitting tribute to the memory of Father Kemble that the *Journal* encourages the contribution of "Lamplighter Moments" from RASC members. "Lamplighter Moments" are articles describing the types of sights in which Luc took particular delight — in the words of his friends and colleagues, moments where, through careful observation of the mundane, one unexpectedly discovers something profound. We are delighted to publish the first such "moment" in this issue, a description by Bruce McCurdy of an out-of-the-ordinary sunset.

Also included in this issue is a summary by David Chapman of comet discoveries by Canadians. David was clearly inspired by an earlier summary published in the *Journal* in 1991 by former editor Jeremy Tatum — at that time describing the first 19 discoveries. Dave's column provides an interesting perspective of the last twenty-five years of comet hunting, and serendipitous comet discoveries, by Canadians. When will the next such discovery — number 31 — be made?

The inclusion of both of the above articles in the present issue somehow combined to bring back memories of my own first "comet" discovery, which occurred on October 10, 1972, when I was a graduate student at the University of Western Ontario. Comet Turner-Leparskas 1972 never attained "official" status, as should be evident, but it was nevertheless a remarkable sight in the early morning sky from Elginfield, Ontario, upon its discovery.

At the time I was using Western's 1.2-m telescope to obtain observations for my thesis research, on that night with undergraduate student Henry Leparskas as my observing assistant. We were just finishing a long clear night of spectroscopy at the Elginfield Observatory — at around 6:00 a.m. — when I decided to inspect the eastern sky from the Observatory's catwalk in order to check on the progress of morning twilight. To my surprise I noticed an unusual faint streak of light, about 10° in length, lying just above the horizon below Venus and Regulus, which dominated the morning sky at that time. I called Henry to the catwalk to confirm the sight. The streak had a definite comet-like appearance — a narrow "head" and a more diffuse "tail" — and was oriented exactly like a comet, with its head directed towards a point on the horizon where the Sun would soon be rising. Combined with its location near the zodiacal band and the fact that it exhibited no apparent motion relative to the stars, it seemed as if Henry and I had somehow been

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 one of the addresses given below.

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blessed with the remarkable appearance of a comet visible to the unaided eye. Yet no "naked-eye" comets were known to be visible at that time. Could this be our discovery? It had been an absolutely cloudless night up to that point, so we had ruled out the possibility that the "comet" was a cloud.

Henry and I observed the object anxiously over the next thirty minutes, noting in the process that the "comet" seemed to be rising with the stars. However, as the morning sky began to brighten with the coming dawn, the "comet" did an unusual thing — it also began to brighten! By sunrise, of course, Comet Turner-Leparskas 1972 was revealed to be nothing more than a remarkably stable jet's trail. It was high enough to catch the Sun's rays long before the sky brightened noticeably, and retained its shape and moved with the stars just long enough for us to consider it to lie outside the Earth's atmosphere. In fact, it was still visible in roughly its original appearance more than two hours after our discovery. That was also about an hour and a half *after* I had awakened my thesis supervisor from a sound sleep to "confirm our discovery"…

It was slightly more than two years later, after I had begun a postdoctoral interval at the University of Toronto's David Dunlap Observatory, that Sidney van den Bergh made the first official Canadian comet discovery. It is certainly true, however, that Comet van den Bergh 1974 XII = 1974g (C/1974 V1) never became as spectacular a sight as Comet Turner-Laparskas 1972, which is more properly described as an early "Lamplighter Moment."

President's Corner

by J. Randy Attwood (attwood@istar.ca)

I am saddened to inform members of the Society that we lost a distinguished member over the summer. Dr. J. Edward Kennedy, a founding member of the Saskatoon Centre, as well as a past National Secretary and past President of the Society (1968–1970) passed away July 28. Dr. Kennedy will be remembered as an expert on the history of astronomy in Canada and as a great friend to the RASC.

I know that most of our members have no idea how many hours our editors contribute to produce the Society's publications. In addition, it may surprise many to learn that the time spent is completely voluntary. Two of our editors have announced that they would like to step down from their positions. Dr. Roy Bishop has been editor of the *Observer's Handbook* for 18 years. The 2000 *Observer's Handbook* is the 19th edition Roy has produced. During his tenure, Roy has expanded the number of pages by over 50% and lowered the cost per issue so that the *Observer's Handbook* has become a major source of revenue for the Society. Dr. David Turner has been editor of six volumes of the *Journal* since 1994. He oversaw the revitalization process three years ago when the *Journal* and *Bulletin* were merged into what has become an excellent publication. The members of the Society owe a great deal to these two gentlemen who have given their expertise and hundreds of hours of their time to produce such fine publications. The Publications Committee (Dr. Robert Garrison, chairman) has the difficult task of finding successors for those two positions.

Many members of the Society traveled overseas to witness the August 11th solar eclipse. England, France, Germany, Romania, and Turkey all hosted RASC eclipse chasers. Not all were successful in finding clear skies, however. Observers in England and Germany were mostly clouded out, while those in Turkey observed in clear skies but suffered temperatures over 50° C. Fortunately, the visitors to Turkey escaped the effects of the devastating earthquake. I took my family to Paris for a holiday. We traveled north of the city to view the eclipse from the centre line. The weather looked pretty grim all morning with overcast skies. Before we reached the centre line, the traffic on the highway came to a halt. The Sun peeked in and out of the clouds as the partial phases started. With less than an hour until totality and the traffic inching along, we pulled off to the side of the highway and set up on a knoll. Luck was with us because, as totality approached, a large opening in the clouds settled directly overhead. We observed totality in clear skies. The number of prominences visible was stunning — a pink necklace around the entire black Moon. Less than an hour later, it was totally overcast again. If there is a finite amount of luck allotted to every eclipse chaser, I think we might have used ours up.

I hear many members were successful in observing the partial phases from the east coast and that some members traveled out into the Atlantic to greet totality at sunrise — on the water and in the air. I see many were able to report their observations on the nightly news. Congratulations!

Best wishes to everyone and clear skies in 2000!

Correspondence
Correspondance

IN DEFENCE OF ALBIREO

Dear Sir,

This letter is written in response to your request for a *slightly* longer and more scientific one than my original E-mail effort, which read simply, "Are you **sure** Albireo is optical? I would bet $100 that it is not!"

I have admired Albireo — surely one of the most beautiful double stars in the sky — ever since my early childhood, and with telescopes ranging from the smallest monocular to the Hale reflector, and I am quite affronted on Albireo's behalf to see it dismissed as optical (Middleton 1999).

It is wildly improbable, as is intuitively obvious and readily confirmed statistically, that two stars as bright as the components of Albireo should be so close together (35″) in the sky just by chance. *Hipparcos* (1997; vol. 1, Table 3.2.1) shows that the number of stars as bright as the $5^{m}.1$ of Albireo B is not much more than a thousand, so on average there is only about one per 40 square degrees of the sky. Each component of Albireo, being less than 0°.01 from the other, finds the other within an area of less than π/10,000 square degrees centred upon itself, or less than 1/100,000 of the mean area that would need to be searched on average to find one star of such a brightness. As a statistical assessment of probability, the figure of 1/100,000 is rather rough and ready, since it does not take into account the fact that Albireo is in the Milky Way, where the star density is higher than average; on the other hand it does not allow for the fact that the primary of Albireo is much brighter than fifth magnitude and such stars are correspondingly much rarer. But the broad conclusion that it would be an extraordinary coincidence to find two such bright stars so close together just by accident is unassailable.

Turning from statistical to astrophysical arguments, we could usefully consider the parallaxes, proper motions, and radial velocities of the two stars. *Hipparcos* (1997; vol. 9, p. 1928, see nos. 95947 and 95951) shows the parallaxes of Albireo A and B to be 8.46 ±0.58 and 8.67 ±0.65 milliseconds of arc respectively. The values differ by only a quarter of their combined standard deviation, and show that both stars are at the same distance of 117 parsecs within the error of measurement.

The proper motions are both very small and appear to differ by about 5 milliseconds per annum in each co-ordinate, the motion of the secondary relatively to the primary being to the east and north. The total proper motion corresponds at the distance of Albireo to a relative transverse velocity of about 4 km s^{-1}, which seems on the high side for the orbital motion of a pair of stars (even massive ones, such as the components of Albireo are likely to be) with a projected separation of about 4000 astronomical units. Also, the relative movement seen by *Hipparcos* seems not to tally with the filar-micrometer measurements tabulated by Aitken (1932) in his double-star catalogue, which appear to show that over an interval of nearly a century the separation of the pair had remained constant within a small fraction of a second while the secondary's position angle of about 55° had possibly decreased by about 1°, implying a motion of the same order as found by *Hipparcos* but directed north-*west*. The explanation of those difficulties lies, in all probability, with the duplicity of the primary star. Recognized as having a composite spectrum in the very first tabulation of such objects (Maury 1897), wherein it was announced as consisting of a late-type star plus an early-type one, it has comparatively recently been discovered to be also a visual binary with a separation of nearly 0″.4 and a Δm of about two magnitudes. Motion of the photocentre of the close double that constitutes the primary component of the familiar wide pair is almost certainly the main cause of the relative proper motion and of any change that it may have undergone since the interval covered by Aitken's table.

The radial velocity of the primary star was measured many times between 1898 and 1926 in the course of the very reliable Lick survey published by Campbell & Moore (1928) of the velocities of the bright stars. They show (Campbell 1919) convincingly a slow change of something like 3 km s^{-1} in the first 20 years. I myself have had the star under approximately annual radial-velocity surveillance for a comparable length of time; since the first observation with the Hale telescope in 1971 (Griffin & Gunn 1974), the velocity appears to have changed by about 2 km s^{-1}, in the opposite direction to the drift witnessed at Lick nearly a century ago. The velocity of the secondary in the wide visual system cannot be measured very accurately owing to the smearing of all the spectral lines by its rapid rotation, but the mean velocity found at Lick (*loc. cit.*) is the same as the velocity of the primary to well within its own uncertainty.

Aitken (1932) already offered the considered opinion that Albireo "is almost certainly a physical pair", and there is nothing that has been learnt about it since to shake that conviction, which surely is widely shared. I hope that this letter will reassure readers of this *Journal* that they are viewing a real physical multiple system whenever they indulge themselves once again in the pleasure of beholding the beautiful Albireo!

R. F. Griffin, rfg@ast.cam.ac.uk
Cambridge Observatories, England

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Campbell, W. W. & Moore, J. H. 1928, Publ. Lick Obs., 16, 286

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Maury, A. C. 1897, Harvard Annals, 28, part 1, p. 93 (Table X); see also Note 145 on p. 99

Middleton, D. 1999, JRASC, 93, 109 (see p. 111, foot of second column)

News Notes
En Manchettes

STELLAR SCIENCE FROM FAILED *WIRE* SATELLITE

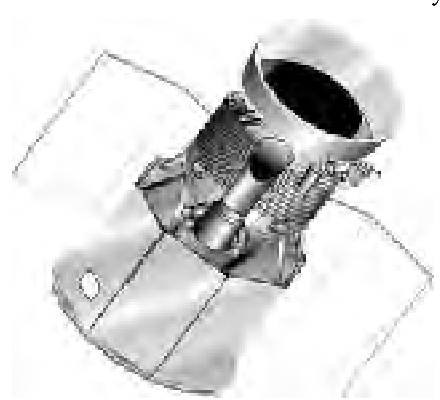
After the tragic failure of the *Wide-Field Infrared Explorer* satellite (WIRE), it appeared that all hope was lost for its use in scientific studies. A remarkable success story is associated with the mission, however, thanks to Derek Buzasi (University of California, Berkeley), who used the tiny guide scope of the satellite to do long-term photometry of the nearby star α Ursae Majoris (Dubhe). The data were used to calculate a new, more precise value for the mass of the star using a stellar model developed by Canadian and American astronomers.

Soon after the satellite's launch on March 4th of this year, the super-cold solid hydrogen onboard the spacecraft was lost when it was accidentally exposed to the Sun's light. The coolant was essential to the operation of the infrared telescope. The 5-cm CCD-equipped guide scope was unaffected, however. Although the main mission of the satellite had to be scrubbed, the tiny space-based guide telescope had the advantage of being available for long, uninterrupted observing with steady stellar images, both features that are difficult or impossible to achieve on the best ground-based instruments.

Buzasi used the little telescope to search for the signature of non-radial pulsations in Dubhe, which is the brighter K0 giant (K0 IIIa) component of a close binary system. The results of seismic events in a star are tiny changes in its brightness, with several different frequencies of vibration excited simultaneously. The changes can be so small that the noise of the instrument may be a thousand times brighter. To extract such a small signal, the astronomer needed a very long and continuous sampling period. To do that, the instrument recorded the brightness of the star every tenth of a second for a whole month, a feat that would be next to impossible to achieve on the surface of the Earth.

Prior to the observations of α UMa, starquakes had only been observed on the Sun and on abnormal objects like neutron stars and white dwarfs. Dubhe is now the first "normal" star other than the Sun to exhibit them. Starquakes are much like seismic events here on the Earth, the difference being that it is the observed vibration modes of the starquakes that are used to probe the deep stellar interior. The data from Buzasi's experiment were compared with a variety of stellar evolutionary models calculated by Pierre Demarque (Yale University) and David Guenther (Saint Mary's University), and it was found that models with masses of 4.25 ±0.25 solar masses produced the best match to the observed vibration frequencies for α UMa. The value compares well with previous estimates of 4 to 5 solar masses determined from the orbit of Dubhe about its companion.

Two space-based telescopes dedicated to the search for stellar seismic activity are planned for launch in 2001 — the French *Convective and Rotation* satellite (COROT) and the Canadian *Microvariability and Oscillations of Stars* satellite (MOST). Both have been somewhat scooped by these surprising results.



The next star that will be observed by Buzasi and his team using the tiny guide telescope is one of our nearest stellar neighbors — α Centauri.

TWO MORE URANIAN MOONS?

Two years ago, Brett Gladman, of the Canadian Institute for Theoretical Astrophysics (CITA), and his international team discovered two new satellites orbiting the planet Uranus. They have since been named Sycorax and Caliban. In July a team of astronomers led by J J Kavelaars of McMaster University discovered what could be two additional small satellites orbiting Uranus (IAU Circular No. 7230). The planet Uranus now has an unofficial tally of twenty satellites, which surpasses Saturn's previous record of eighteen (not counting ring particles!).

There is a small possibility that the little worlds may actually be Centaurs — asteroids orbiting between Jupiter and Neptune — of which Chiron is a well-known example. Continued observations of the objects will be necessary to settle the issue. Kavelaars and Brett Gladman, now of the Observatoire de la Côte d'Azur (OCA), Matt Holman of the Harvard-Smithsonian Center for Astrophysics (CfA), Jean-Marc Petit (OCA), and Hans Scholl (OCA) found the tiny moons during three nights of observing on July 18, 19, and 21 with the Canada-France-Hawaii Telescope (CFHT) on Mauna Kea in Hawaii. The team used the new CFH12k, the world's largest CCD mosaic camera. The camera has 12 closely mounted 2048 × 4096

CCD chips that provide an angular coverage that is 1.5 times the area of the Full Moon, and generates 200 Megabytes of data with every image.

The two possible satellites for Uranus have been given temporary designations of S/1999U1 and S/1999U2, but once confirmed they will follow International Astronomical Union rules and be named after Shakespearean characters. The objects are probably less than about 20 kilometres in diameter, and are tentatively classified as irregular moons, having highly inclined and eccentric orbits. Their apparent distances from the centre of the planet are estimated to be 10 and 25 million kilometres, and their *R*-magnitudes (red) are a diminutive 23.3 and 24.3.

Asked if the group is planning any future searches, Kavelaars replied, "We've covered most of the region around Uranus, which can hold stable orbits. We are considering applying for more time to search the very outer edge of the field, but there is a group working in Chile that may cover that area soon (July), so we will have to wait and see."

A Lamplighter Moment[1]: Sunset

by Bruce McCurdy, Edmonton Centre (bmccurdy@freenet.edmonton.ab.ca)

It pays to be an optimist (time and a half on statutory holidays!), so on the evening of July 1st, I opened the Observatory in the face of gathering clouds in the southeast. After all, how could the Edmonton Space & Science Centre properly celebrate its 15th anniversary with its best exhibit closed? After I had enjoyed an early evening display of the current litter of sunspots, as well as a spectacular double rainbow set against the onrushing storm clouds, I closed the Observatory roof shortly after nine against the threat of the first (supposedly intermittent) evening shower. The odd flash of lightning and rumble of thunder suggested that I was in for Nature's own version of Canada Day fireworks. I popped in a tape by the under-appreciated Canadian guitarist Michael Brook, browsed the latest issue of *Sky & Telescope,* and hunkered down to wait it out.

The dull light, streaming in through the open door of the Observatory, suddenly intensified dramatically, and I stepped outside to see the Sun emerging from beneath the cloud deck, perhaps five degrees above the northwestern horizon. I grabbed the 7×50 binoculars, equipped with jury-rigged #14 welder's glass filters, for a quick look. Normally I use such equipment when the Sun is high in the sky, so I expected to see the standard image of the Sun surrounded by complete blackness. Instead, the sight that met my eyes bordered on the surreal.

While Brook strummed a song called "Red Shift" in the background, my world was effectively *green-shifted*. It was as if I had donned a pair of night vision goggles. The Sun appeared larger than life thanks to the notorious Full Moon effect, its circular symmetry broken only by the sunspot groups. The narrow gap between the heavy cloud decks was not completely clear as I had first thought, but filled with veils of haze. The Sun illuminated that haze to provide a pale green backlight, perhaps five degrees wide, against which my local surroundings were displayed in silhouette. The leaves of a black tree swayed in the breeze, black geese soared in the distance, and the ragged edge of the storm clouds looked even blacker than to the naked eye, all set against the distinctive yellow-green of the welder's glass. Figure and ground seemed to switch roles like a photographic negative.

The haze was stacked in layers of varying thickness, and the setting Sun burning through those layers appeared banded. Two bright bands temporarily appeared at remarkably similar latitudes much like Jupiter's equatorial belts, separated by a darker zone, while the north polar region appeared dimmer through a thicker haze. The overall effect was like one of those weird false colour infrared images of Jupiter.

Did you know you can observe lightning through welder's glass? I had not known that until that night. But suddenly there was an unmistakable fork of a more local light source, followed rather immediately by a clap of thunder. I quickly retreated back inside the Observatory as a heavy downpour ensued. The sunlight continued to stream inside the door. Still equipped with the binoculars, I observed our local star gradually disappear into the roiling storm clouds that were hugging the horizon. The rain on the aluminum roof provided a rather overpowering percussion accompaniment to the ambience of Brook's appropriately titled "After Image."

"The serendipitous nature of the observation made me think of the Lamplighter, and we shared a private smile"

That sunset was not a classic beauty, but happenstance provided a sight far more striking and unusual than I had any right to expect. The serendipitous nature of the observation made me think of the Lamplighter, and we shared a private smile.

Past President of the Edmonton Centre RASC, Bruce McCurdy is also the resident "semi-pro" astronomer at the Edmonton Space & Science Centre's Public Observatory, where he has provided volunteer service for thirteen years and has enjoyed paid employment for the past five summers. As an observer, Bruce classifies himself as a "Mira-type," i.e. long-period, semi-regular, but definitely variable. In his more lucid moments he occasionally experiences the type of non-linear observation described above.

[1] Dedicated to the memory of Father Lucian Kemble (1922–1999), *a.k.a.* "Lamplighter," who touched the lives of countless members of the RASC through his love for all aspects of observing. A "Lamplighter moment" is simply an occasion where, through careful observation of the mundane, one unexpectedly discovers something profound, something achieved by Lucian Kemble fairly regularly during his lifetime. This section is intended as a regular part of the *Journal* devoted to guest articles by authors describing their Lamplighter moments.

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

Canadian Comet Watchers

In any field of science, one feels a certain thrill in discovering a truly unexpected result while following some entirely unrelated course of investigation. Just ask Sidney van den Bergh, who 25 years ago discovered the first "Canadian" comet while studying bright variable stars in nearby galaxies. Comet van den Bergh 1974 XII = 1974g (now called C/1974 V1 according to the revised naming scheme) was the first of 30 comets discovered to date by seven Canadian amateur and professional astronomers. There are too many Canadian comet tales to give a complete account of each here, but I will try to capture the highlights. In 1991, Jeremy Tatum — then editor of the *Journal* — published a Canadian comet roundup in *News Notes* (JRASC, 85, 384–388, 1991) that described the first 19 Canadian comets and their discoverers. Since then, there have been 11 more!

Sidney van den Bergh

At the time he discovered his comet, Dr. Sidney van den Bergh was an astronomer at the David Dunlap Observatory, but had journeyed to Palomar Mountain for a five-day photographic observing run with the 48-inch Schmidt telescope. As he describes in his article "The Discovery of Comet 1974g" (JRASC, 69, 29–31, 1975), the magnitude 17 comet crept into his exposure of the Triangulum Nebula (Messier 33) on the night of November 11/12, 1974. Comet van den Bergh turned out to be unusual, as it had the largest perihelion distance (6.02 A.U.) of any comet known to that time. Today Dr. van den Bergh is a Senior Research Scientist at the Dominion Astrophysical Observatory and an Adjunct Professor of the Department of Physics and Astronomy at the University of Victoria.

Astute readers may have noticed that I used four different designations for the same comet: the proper name Comet van den Bergh, the provisional (order-of-discovery) name 1974g, the definitive (order-of-perihelion-passage) name 1974 XII, and the new IAU designation C/1974 V1. The various systems are described by David Levy in his article "Observing Comets" on pages 214–216 of the 1999 *Observer's Handbook*. For those who enjoy such things, the *International Comet Quarterly* Internet site `cfa-www.harvard.edu/iau/CometDes.html` has an interactive converter that accepts any designation and returns a full citation with the four equivalent names. It really works! (Caution: the input form is case sensitive.) Comets discovered since the beginning of 1995 carry only the proper name and the new IAU designation.

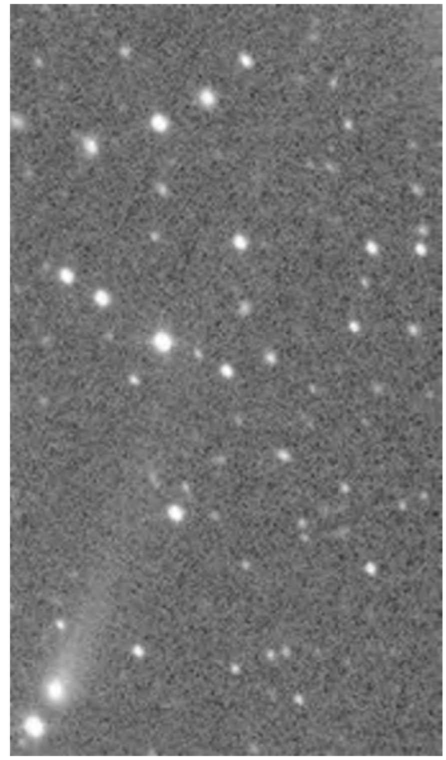
Rolf Meier

The next four Canadian comets were Comets Meier C/1978 H1, C/1979 S1, C/1980 V1, and C/1984 S1, discovered by amateur astronomer Rolf Meier of the Ottawa Centre. Rolf discovered his first comet on April 27, 1978, using the 40-cm reflecting telescope at the Ottawa Centre's Indian River Observatory. It was the first comet discovery from a Canadian observing site. In fact, Rolf used the same telescope for all four discoveries. Peter Broughton profiled Rolf Meier — the 1979 Chant Medal winner — on page 142 of *Looking Up: A History of the RASC.*

David Levy

So much has been written by and about David Levy and his comets that I am hard-pressed even to attempt a summary within the confines of this column. Observing visually from his backyard observatory near Tucson, Arizona, David discovered Comet Levy-Rudenko C/1984 V1 on 1984 November 14, ten years and three days after the discovery of Comet van den Bergh. It was the first of 21 comets bearing the Levy name (so far): eight were discovered visually, and 13 were discovered photographically in collaboration with the team of Carolyn and Eugene Shoemaker. The story of David's first comet discovery is told in the Preface to his book *The Quest for Comets* (Plenum Press, New York, 1994). JRASC readers might want to look up his 1993 Ruth J. Northcott lecture "The Art of Comet Hunting, Part II" (JRASC 88, 5–23, 1994).

David' s first "professional" comet was Comet Shoemaker-Levy 2, or



Comet Jedicke P1996 A1, on the night of its discovery: January 14, 1996.

137P/1990 UL3, the "P" standing for "periodic" and "137" indicating that it is the 137th comet with a well-defined periodic orbit. The most famous Levy comet is Comet Shoemaker-Levy 9, the "String of Pearls" comet, the approximately two dozen fragments of which smashed into Jupiter in July 1994 just 28 months after discovery. That remarkable event earned the comet the prosaic designation D/1993 F2, the "D" standing for "disappeared," although in its case I think "deceased" would be more appropriate! David Levy tells his comet tale in his book *Impact Jupiter* (Plenum Press, New York, 1995). Levy's banner year for comets was 1991, when he discovered or co-discovered eight comets. His latest comet discovery — for now — is Comet Takamizawa-Levy or C/1994 G1. To catch up on David Levy's latest exploits, surf to his fascinating home page at `www.lpl.arizona.edu/~dhlevy/index.html`. David continues to hunt for comets, both visually and photographically, although one wonders where he finds the time, between writing books and presenting illustrated lectures.

Christine Wilson

Now we turn the clock back to August 5, 1986, when graduate student Christine D. Wilson exposed a plate for the second Palomar Observatory Sky Survey. Like Sidney van den Bergh, she found the comet later while examining the developed plate. Unlike Comet van den Bergh, Comet Wilson— or C/1986 P1 — became bright, reaching naked-eye visibility. Currently, Dr. Wilson is an Associate Professor in the Department of Physics and Astronomy at McMaster University, where she studies the interstellar medium and star formation in nearby galaxies.

Doug George

Amateur astronomer Doug George of the Ottawa Centre became the fifth Canadian to discover a comet on December 18, 1989, using the same telescope that Rolf Meier used to find his four comets: the 40-cm reflector at the Indian River Observatory. Against all odds, Doug began scanning at the end of evening twilight on a night two days after the Full Moon, and found his comet just 90 minutes later. He had logged a total of 65 hours of comet hunting at the eyepiece before the discovery. Naturally, Doug became quite excited at his discovery, and drove home at 15 km/h below the speed limit to avoid driving off the road! He reported his discovery by telegram and followed up with a phone call the next morning, but recalls that his claim was received with some skepticism. His claim was confirmed, however, and he is credited as co-discoverer of Comet Skorichenko-George, or C/1989 Y1. Currently, Doug George is the Past President of the RASC, and is involved in several commercial projects that combine his love of astronomy with his software engineering skills.

Robert and Victoria Jedicke

The most recent Canadian comets are Comets Jedicke P/1995 A1 and P/1996 A1, the former discovered by Robert Jedicke and the latter by Robert and his wife, Victoria Jedicke. Dr. Robert Jedicke is a member of the Niagara Centre, and studied at the University of Western Ontario and the University of Toronto, although his doctoral degree is in high energy physics, not astronomy. While a postdoctoral fellow in Tucson at the Lunar & Planetary Laboratory, University of Arizona, he assisted with the search for Near Earth Asteroids (NEAs) using the Spacewatch telescope at Kitt Peak. (The program is described at the web site `pirlwww.lpl.arizona.edu/spacewatch/`.) The operation is very high-tech, and the system automatically detects most NEAs, but human observers are still required to monitor the activity, each observing for six nights in a row. It seems that diffuse comets frequently elude the grasp of the software. (Perhaps they should use fuzzy logic in their code.)

Robert's first comet was P/1995 A1, whose only distinction appears to be that it was the very first comet to be named using the new IAU designation. In any case, Robert does not have much to say about it, but I will let him tell the story of his second comet discovery in his own words. "For P/1996 A1 I was observing with my wife. She would typically spend one of the six nights with me. She would sit on my lap and we would watch the stars, galaxies, and asteroids go by. Often she would point to cosmic rays, unusually shaped galaxies, and 'spikes' caused by bright stars (or planets) just outside the field of view, and would ask if they were comets. Disappointed in being told all too often that what she saw was not a comet, she almost gave up. But then one night I got up to make us some tea. When I came back into the control room I was talking with her in front of the computer screen when we both pointed simultaneously at the image and she said 'What's that?'; and I replied 'That's a comet!' "

Rob is presently a software engineer with an optics company in Tucson, but spends about 25% of his time with the Spacewatch group.

* * *

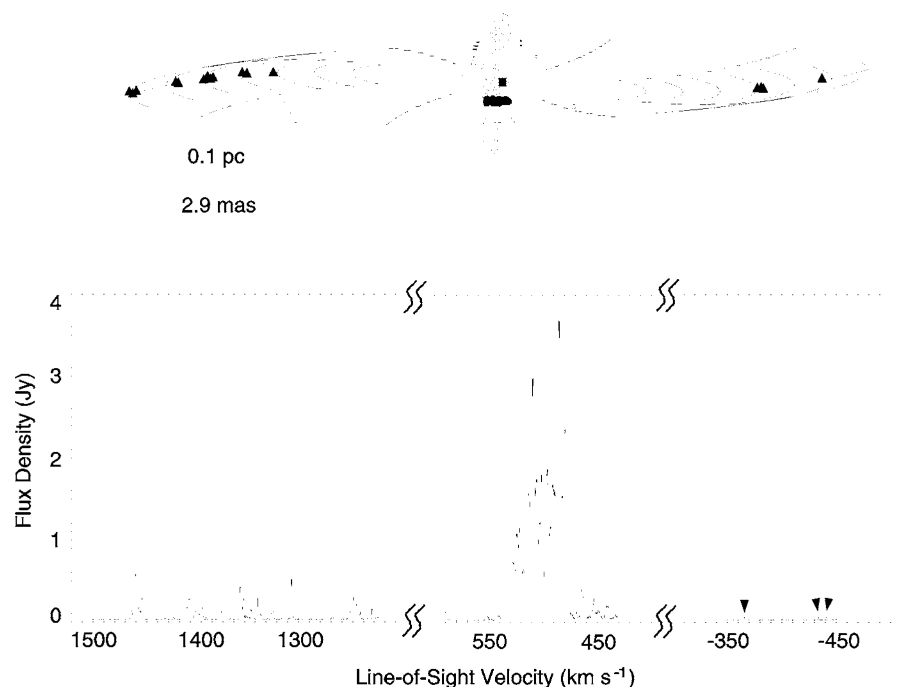
In a future issue of the *Journal*, perhaps we could publish a table giving the vital statistics of all Canadian comets to date. Who will find the 31st comet? At least two Canadian comet hunters are actively searching, but I wager that there are a few we have not heard from yet. Perhaps my column will be out of date by the time you read this!

David Chapman is a Life Member of the RASC and a past President of the Halifax Centre. He invites web surfers to visit Dave Chapman's Astronomy Page, *for which the URL is* `www3.ns.sympatico.ca/dave.chapman/astronomy_page.html`, *to view some of his other astronomical writings.*

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

Measuring Galactic Distances

Measuring the distances to objects outside the solar system has always been challenging, but the distances to other galaxies present even greater challenges, forcing astronomers to resort to indirect methods, often laden with risky assumptions. Now, using the technique of very-long-baseline radio interferometry, Jim Herrnstein of the National Radio Astronomy Observatory and his colleagues have measured the most accurate absolute distance ever for an object outside the Milky Way. They estimate the accuracy of their direct distance to the galaxy NGC 4258 to be ±4% (see 5 August issue of *Nature*). The technique involves measuring — astoundingly — the proper motion of clumps of gas orbiting very close to the centre of that galaxy.



The diagram shows the locations of maser spots in the model accretion disk, along with the spectral lines they generate. The spatial and spectral overlap of the masers along the line of sight to the centre of the galaxy is clearly demonstrated. The systemic velocity of the galaxy is 450 km s^{-1}.

Distances to galaxies are normally measured using a variety of techniques that make use of the "distance ladder," which is founded on the parallax of nearby stars. As the Earth orbits the Sun, the nearest stars appear to shift their positions slightly against the background of more distant stars. By measuring that shift through observations separated by six months, and knowing the distance of the Earth from the Sun, the distance to the star can be determined. You can demonstrate the basic idea to yourself by holding up a finger at arm's length, then watching it shift position relative to the background as you alternately open and close each eye. The total shift for even the closest star is less than two seconds of arc, which most small amateur telescopes are incapable of measuring.

Professional astronomers can measure enough distances to stars in such fashion to permit them to calibrate the distances to clusters of stars, some of which contain massive variable stars in a particular phase of their lives. Called Cepheid variables, they play a special role in astronomy, since there is, in principle, a tight relationship between their periods of pulsation and their luminosities. By measuring the period of pulsation we obtain the luminosity, and together with the apparent brightness, we derive a distance to the Cepheid. In practice, things are much more complicated, and in recent years the "zero point" of the Cepheid distance scale has been set using methods other than the distances to nearby clusters of stars. Cepheids have been used to determine distances to galaxies in the Local Group, and recently — using the *Hubble Space Telescope* — to even more distant galaxies, including some in the Virgo Cluster. Determining the distance to the Virgo Cluster was one of the main goals of the *Space Telescope* (see, for example, Wendy Freedman's article in the 27 October 1994 issue of *Nature*).

The relative distances between clusters of galaxies have been well established for some time, so all that was needed to establish the proper scale was one absolute distance. That is why so much attention has been focused on the Virgo Cluster. Once the absolute distance scale has been established, then the expansion rate of the universe (via the "Hubble constant") can be determined. The Hubble constant "Key Project" team announced, at the American Astronomical Society meeting in June, that the Hubble constant has a value of H_0 = 70 km s^{-1} Mpc^{-1}. The corresponding rate of expansion corresponds to an age of the universe that is just barely compatible with the ages of the oldest stars in our Galaxy.

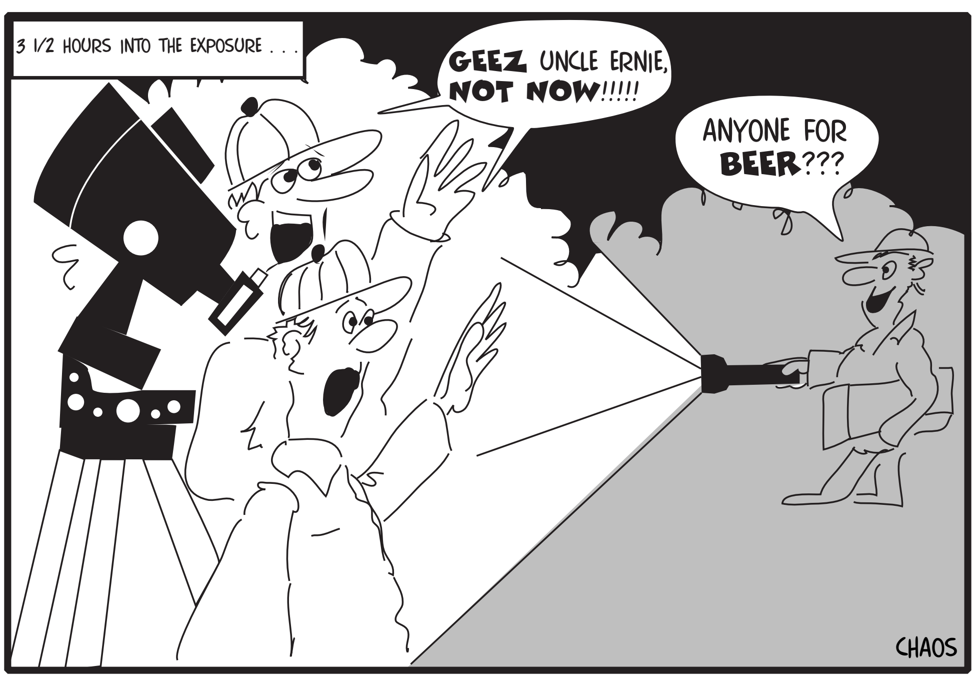
Some astronomers, however, have been uncomfortable with the chain of techniques used to measure distances, because there may be unknown "systematic" effects — that is, physical effects about which we know little or nothing — that lead to distortions in the extragalactic distance scale. Again, enter Herrnstein and colleagues. Four years ago (in the 12 January 1995 issue of *Nature*), they reported the discovery of water masers orbiting the massive black hole at the centre of NGC 4258. Masers are the radio-wavelength equivalent of lasers, and generally occur in dense clumps of gas. The masers found by Herrnstein and colleagues were orbiting, as best they could tell, in pure Keplerian orbits; in other words, they obeyed the same type of relationship between orbital speed and distance from the central mass as followed by the planets in the solar system. They got a very good measurement of the orbital speed, based on the red and blue shifts of the water maser spectral lines arising in spots where the orbits had them going either straight towards us or straight away from us. But there were also some maser spots that lay right between us and the centre of the galaxy, where the orbital motion is across the line of sight. Herrnstein tracked the motion of those spots over the three-year interval 1994–1997, and, provided that they are on circular orbits, their orbital velocity is known. It is then a simple exercise in trigonometry to calculate the distance to the spots from the observed motion and the known velocity. As the spots are less than a parsec from the centre of the galaxy, we now have a direct measurement of the distance to the galaxy itself.

The story is naturally a bit more complicated. Even with radio interferometry, Herrnstein cannot track the individual maser spots, simply because there is too much overlap of the clouds in real space as well as overlap of the spectral lines in "velocity space" (the lines of all the spots tend to merge together in the spectrum). They therefore have to resort to a pattern-matching technique to track the bulk motion of the cluster of maser spots. Provided that the technique of pattern matching is robust, they find that the distance to NGC 4258 is 7.2 ±0.3 Mpc. To complicate the matter even more, preliminary reports at the 194th meeting of the American Astronomical Society in June seemed to indicate that there might be a discrepancy between Herrnstein's distance and the one determined using Cepheid variables. The source of the discrepancy — if it exists — could indicate the presence of an unknown bias in the maser distance, perhaps related to the pattern matching, or of a systematic problem with the Cepheids. If it is the latter, then fixing the Cepheid distance scale to NGC 4258 would result in a necessary increase in the Hubble constant to about 80 km s^{-1} Mpc^{-1}. Such a large value for the Hubble constant would be very difficult to reconcile with the ages of the oldest stars, given what we currently know about cosmology. Look for an update on this fast-moving story in my next column.

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.*

Another Side of Relativity…

Well meaning, but ill timed, Uncle Ernie arrives with refreshments for the gang…



THE RELATIONSHIP BETWEEN A BRAHMANIC FIRE ALTAR AND A SOLAR FORMULA IN ANGKOR WAT

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Abstract. A fire altar described in the *Śatapatha Brāhmana* (circa 2000 bce) was built in five layers representing the universe. The top one, denoting the progress of the Sun along the ecliptic, was a circle of 29 bricks, the southeast quadrant containing eight bricks and the others seven. In the temple of Angkor Wat (12th century ce), which is recognized to have been laid out according to an astronomical plan, the dimensions of the rectangular central gallery are 176.37 hat one way and 189 hat the other. The disposition of bricks in the fire altar appears to be related to the dimensions of the gallery.

Résumé. Un autel du feu décrit dans le texte *Śatapatha Brāhmana* (datant de 2000 avant J.C.) a été construit en cinq niveau qui représentent l'univers. Le niveaux supérieur, qui représente la trajectoire du Soleil le long de l' écliptique, est un cercle de 29 briques dont le quadrant sud-est contient huit briques et les autres, sept briques chaque. Dans le temple d'Angkor Wat (12e siècle), que l'on reconnait avoir été conçu selon un plan astronomique, les dimensions de la galerie centrale rectangulaire sont de 176,37 hat dans une direction et de 189 hat dans l'autre. Il semblerait y avoir un rapport entre la disposition des briques de l'autel du feu et les dimensions de la galerie.
SEM

1. Introduction

In a pair of recent papers, Kak (1998a, 1998b) has discussed the astronomical implications of a fire altar described in Book 8 of the *Śatapatha Brāhmana*, a Vedic (ancient Sanskrit) text that may date from as early as 2000 bce. It is not certain that the altar, or others of the kind (Kak 1995), was ever constructed, but its design has interesting implications. The altar as planned consisted of five layers of bricks that denoted the layers of the universe spanning from the Earth to the Sun. The layout of the top layer for the altar is illustrated in figure 1, from which it is seen that the altar was rimmed by a circle of twenty-nine bricks. The bricks appear to denote the annual course of the Sun along the ecliptic. Three of the four quadrants contain seven bricks each, but the southeast (spring) quadrant contains eight, the two extra bricks representing two halves of a standard-sized brick, with one half-brick placed just after the spring equinox and the other just before the summer solstice. The altar appears to represent one of the earliest descriptions of the varying rate of motion of the Sun along the ecliptic.

Astronomy was prized as the greatest of sciences in ancient India. Our understanding of its cultural importance on the Indian subcontinent and of the relationship between Indian and Western astronomy is, at present, undergoing radical changes as a consequence of the study of pre-Babylonian Indian astronomy of the Brāhmanic era (circa 1000 bce). Indian astronomical ideas of that era were intertwined with ritual, and that made the astronomical traditions very conservative. We demonstrate here that the *Śatapatha Brāhmana* concept of the varying rate of motion of the Sun is also symbolized in the architecture of the famous abandoned temple complex of Angkor Wat in Cambodia. The latter was built during the reign of the Khmer Emperor Suryavarman II, who ruled from 1130 to 1150 ce, and its architecture and sculptural decoration clearly reflect a Hindu influence. Excellent popular books on Angkor Wat are available

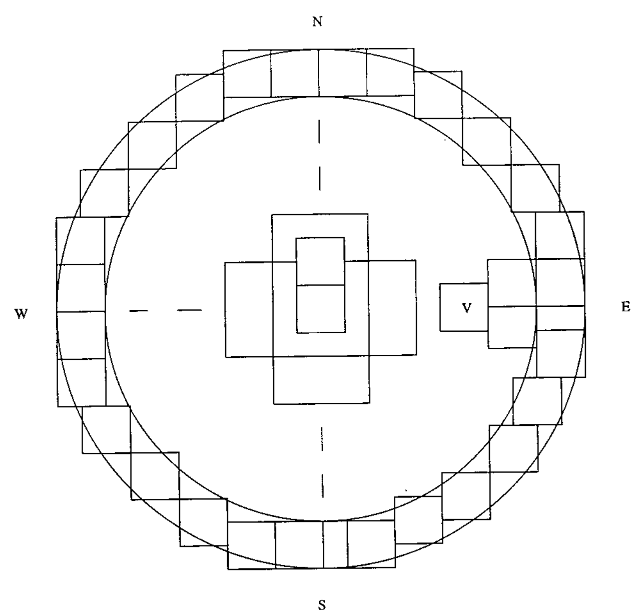

Fig. 1 — The topmost layer of the *Śatapatha* altar describing the circuit of the Sun (from Kak 1998b).

for interested readers. The work of Grolier & Artaud (1957) is recommended for its outstanding rotogravure illustrations. Coèdes (1963) has written a history of the builder and a description of the complex, and has shown that it was intended as a mausoleum.

The temples built by the Khmer kings functioned as focal points for the local cultural devotion to the Devaraja, and were at the same time earthly and symbolic representations of the mythical Mount Meru, which represents the cosmological home of the Hindu gods and the axis of the world system. An innovation introduced by the Khmer Emperor Jayavarman, who preceded Suryavarman II, was the adoption of Vedic symbols and other traditions with Indian roots. Such modifications help to explain why the concepts imbedded in the *Brāhmana* may be found expressed in the architectural features of Angkor Wat. The word Angkor itself derives from the Sanskrit word, "*Nagara*", which stands for city — the centre of the religious and secular cosmos.

Stencel *et al.* (1973, hereinafter SGM) identified several recognizable astronomical alignments in Angkor Wat. By making use of a measured survey of the temple done by Nafilyan and published in 1969, and by converting the measurements into their equivalents in Cambodian cubits or hat (= 0.435 m), they demonstrated that certain dimensions of the temple causeway symbolized the yuga cycles of Hindu cosmology. The temple complex was apparently designed as an observatory, since SGM were able to identify twenty-two alignments in the temple survey that correspond to seasonally important observational sight lines for the rising of the Sun and the Moon. According to Chou Te-kuan, a Chinese merchant who visited Angkor in 1296, just as in China "... there are people who understand astronomy and can calculate the eclipses of the Sun and Moon." The temple was situated in the midst of an extensive irrigation system that stored water from the monsoon flood. It seems likely that one of the responsibilities of the "people" was calendar keeping, which was necessary for anticipating the annual flood and its recession.

In the central tower, the topmost elevation (SGM Table 2, item 6, and figure 7) had external dimensions of 189.00 hat in the east-west direction and 176.37 hat in the north-south direction, corresponding to a semi-perimeter of 365.37 hat. In the words of SGM, it was "perhaps the most outstanding number" in the complex, corresponding as it does to "almost the exact length of the solar year" in days. Presented here is a likely explanation for the numbers as inferred from considerations of the illustration for the fifth layer of the Brāhmanic fire altar.

2. Outline of the Analysis

As a reflection of the annual motion of the Earth in its orbit about the Sun, the Sun appears to move relative to the fixed stars upon a path called the ecliptic, which is a great circle on the celestial sphere. Its angular position along the ecliptic relative to the vernal equinox, which serves as a reference point for celestial co-ordinates, is referred to as ecliptic longitude (or celestial longitude), and is measured eastward from the vernal equinox. Since the orbit of the Earth about the Sun is elliptical rather than circular, the speed of the Earth in its orbit varies with its distance from the Sun. It moves fastest near perihelion at the beginning of January and slowest near aphelion at the beginning of July. At such times the apparent speed of the Sun along the ecliptic is correspondingly faster and slower relative to the average rate.

A clue to the formula that appears to have been used to calculate the ratio of the dimensions in the gallery of Angkor Wat, *i.e.* 189.00/176.37, is to be found in a paper by Åaboe (1974). Around 100 BCE, Babylonian astronomers calculated the ecliptic longitude of the Sun by a rule called Babylonian System A. They assumed that the Sun travelled along the ecliptic at constant, but unequal, speeds in two separate sectors. The duration of the two sectors, in days, corresponds very closely to the dimensions of the gallery at Angkor Wat. Since the Angkor numbers can also explain the features of the fire altar described in the *Śatapatha Brāhmana*, it can be speculated that perhaps the Babylonians borrowed from Hindu predecessors.

The ancient Hindus had derived a remarkably accurate value for the length of the mean lunar month. By implication they must have had available to them several centuries of day-counts between various lunar phases in order to obtain a reliable value for the synodic month — the cycle of the Moon's phases. It seems that in all likelihood they would have discovered that the mean duration of the lunar month is also variable in its day-count on a seasonal basis, from which it would have been inferred that the angular speed of the Sun along the ecliptic is itself a function of the season of the year. Calculations for the mean day-count for different seasons would have been found to converge to minimum and maximum values, which occurred (as noted above) at times near perihelion and aphelion respectively. From that they could have formulated an algorithm for describing the motion of the Sun along the ecliptic. If the respective speeds were adopted to be constant over half-year intervals (of 6 moons plus $5^1/_2$ days), the results would be a duration of 176.37 days for the seasonal sector that included winter solstice and a duration of 189 days for the seasonal sector that included summer solstice.

3. The Astronomical Roots of the Temple Dimensions

According to Kepler's Laws of planetary motion, planets move in elliptical orbits about the Sun with the Sun occupying one of the two foci of the ellipse, and the radius vector from the Sun to a planet sweeps out equal areas of orbit in equal time intervals. In Newtonian mechanics such properties are readily derived from the laws of gravitation applied to central force problems and are paraphrased to read that the orbit of one object about another is described by a conic section, and orbital angular momentum is conserved.

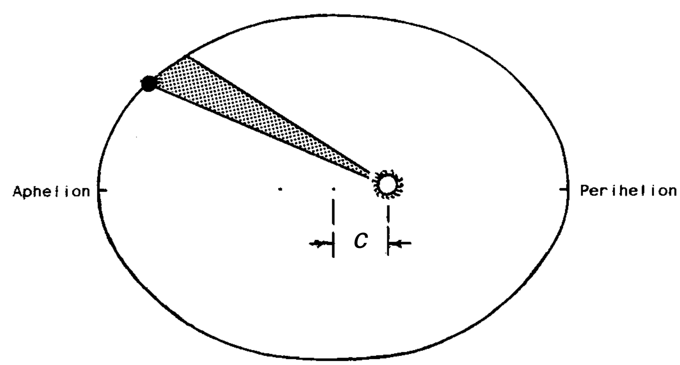

Fig. 2 — An illustration of Kepler's Second Law depicting the area swept out by the radius vector from the Sun. This distance *c* is the centre distance for the ellipse.

A typical elliptical orbit is illustrated in figure 2, which illustrates the terms inherent to Kepler's Second Law — the law of equal areas. Since the Second Law is simply an expression of the conservation of angular momentum in a closed system, it is equivalent to the expression

$$m\, v\, r = \text{constant} \;,$$

where m is the mass of the orbiting object, v is its orbital velocity, and r is its distance from the orbited object. For the orbit of the Earth about the Sun, it follows that the Earth's orbital velocity v is inversely proportional to its distance from the Sun. The properties of ellipses are also well known, and the distances from the focal point of an ellipse to the end points of the semi-major axis can be found geometrically. They are:

$$r_{\text{perihelion}} = a(1-e)$$

and

$$r_{\text{aphelion}} = a(1+e) \;,$$

where a is the length of the semi-major axis of the ellipse and e is the eccentricity of the ellipse = c/a, where c is the centre distance — the distance of the centre of the ellipse from either focus. It follows from the above relationships that the ratio of the velocity of the Earth at perihelion to its velocity at aphelion is expressed as

$$\frac{v_{\text{perihelion}}}{v_{\text{aphelion}}} = \frac{r_{\text{aphelion}}}{r_{\text{perihelion}}} = \frac{a(1+e)}{a(1-e)} = \frac{(1+e)}{(1-e)} \;.$$

The rate at which an elliptical orbit is swept out, however, is given by a separate expression given by

$$\frac{1}{2} r^2 \frac{\mathrm{d}\theta}{\mathrm{d}t} = \frac{1}{2} h \;,$$

where h is the areal constant and $\mathrm{d}\theta/\mathrm{d}t$ is the angular velocity of the planet in its orbit. Clearly, the rate of *angular velocity* for a planet is inversely proportional to the *square* of its distance from the Sun. Thus, for the Earth

$$\frac{\left(\frac{\mathrm{d}\theta}{\mathrm{d}t}\right)_{\text{perihelion}}}{\left(\frac{\mathrm{d}\theta}{\mathrm{d}t}\right)_{\text{aphelion}}} = \frac{r^2_{\text{aphelion}}}{r^2_{\text{perihelion}}} = \frac{a^2(1+e)^2}{a^2(1-e)^2} = \frac{(1+e)^2}{(1-e)^2} \;.$$

It is the angular velocity of the Earth that is tied to the duration of the seasons, since that value determines the rate at which the Sun appears to move along the ecliptic. The accepted value for the present eccentricity of the Earth's orbit is $e = 0.016722$ (Allen 1977). Thus, for the orbit of the Earth about the Sun,

$$\frac{\left(\frac{\mathrm{d}\theta}{\mathrm{d}t}\right)_{\text{perihelion}}}{\left(\frac{\mathrm{d}\theta}{\mathrm{d}t}\right)_{\text{aphelion}}} = \frac{(1+e)^2}{(1-e)^2} = \frac{(1+0.016722)^2}{(1-0.016722)^2} = 1.069182 \;.$$

The ratio of the dimensions of the central tower at Angkor Wat is remarkably close to the ratio of the angular velocities at perihelion and aphelion, and is given by

$$\frac{189.00}{176.37} = 1.071611 \approx 1.069182 \;!$$

The situation even improves if one considers the temporal dependence of the eccentricity of the Earth's orbit, which is decreasing over the long term. The value was 0.017065 at the time of Angkor Wat's construction, and was 0.017251 in the first century CE. The corresponding values for the ratio of angular velocities for the Earth at perihelion and aphelion are 1.070651 and 1.071474, respectively. The close similarity of the numbers to the ratio of dimensions for the central tower of Angkor Wat seems to be more than coincidental. The two ratios would in fact have been coincident at the beginning of the seventh century BCE.

In our time the seasons are not symmetric about the dates of perihelion and aphelion. For example, at 0^h UT on January 1, 2000, the longitude of the Sun is 280°.460, which follows the 1999 winter solstice (when the Sun's longitude is 270°) by 10°.460. Perihelion follows 0^h January 1 by (360° − 357°.528) = 2°.472. Hence, the date of perihelion at present follows the solstice by 12°.932.

As a result of precession of the equinoxes, however, the co-ordinate system that is used as a reference frame for determining the primary points in the Earth's orbit is actually shifting backwards very slowly relative to the orbit. As well, dynamical effects arising from the gravitational influence of the Sun and the other planets are gradually rotating the Earth's orbit in space relative to an inertial reference frame. The time frame over which the location of perihelion regresses along the ecliptic relative to the equinoxes can be determined as follows. The anomalistic year of 365.259635 days is the time it takes for the Earth to return to the same point in its orbit, whereas the tropical year of 365.242190 days is the time elapsed between consecutive passages of the Sun through the vernal equinox. The difference between the values amounts to 0.017445 day. When converted to a fraction of a tropical year, the value corresponds to a period of 20,937 years, over which the point of perihelion for the Earth's orbit gradually makes a complete regression relative to the equinoxes. The amount of regression amounts to 360°/209.37 centuries = 1°.71946 per century. A shift of 12°.932 (see above) therefore takes 12°.932/1°.71946 century^{-1} = 7.52 centuries, so that perihelion coincided with the winter solstice 7.52 centuries prior to the present era, *i.e.* circa 1250 CE — a century after the construction of Angkor Wat. When perihelion was a further 45° along the ecliptic, it was midway in the autumn sector, and aphelion was midway in the spring sector. That occurred 33.7 centuries before the present, *i.e.* circa 1370 BCE. The latter date coincides roughly with the epoch of the fire altar described in the *Śatapatha Brāhmana*, although the altar may have been planned some time before or afterwards.

With reference to Babylonian System A, we believe that, as an algorithm for the motion of the Sun along the ecliptic, the designers of the altar stipulated that in periods, each of exactly half a year in terms of the mean lunar month, the Sun travelled at two constant but unequal speeds along the ecliptic, consuming 176.37 days in the half year including the winter solstice, and 189 days in the half year including the summer solstice.

Thirty-four centuries ago the duration of the synodic month was 29.530595 days, and the duration of the tropical year was 365.242628 days (Allen 1977). Hence, in the course of a year there were 12 complete cycles of the Moon's phases plus 10.875 days. The ancients would have taken the last number to be 11 days, thereby making the length of the year (29.530595 × 12) + 11 days = 365.367 days long. The number is the same as that appearing in the sum of the dimensions of the tower at Angkor Wat, and appears as well as in the earlier *Śatapatha Brāhmana* (Kak 1998a, 1998b).

4. The Brāhmanic System of Observation

Although the ancients must have developed an arithmetic capable of forming means or averages, they had not yet formulated the concept of irrational numbers. Fractions were therefore expressed as ratios of integers. The arithmetic may have been clumsy, but they used it effectively.

Modern positional astronomy requires the use of exceedingly precise clocks. For the ancients, the only clocks available were day-counts taken from observations of the cycles of the Moon. Over the course of a year, because of the eccentricity of the Earth's orbit, a lunar month varies in length. However, day-counts for the lunar month are not affected by the tilt of the Earth's axis.

It is convenient to consider successive syzygies for the Moon rather than complete months of the Moon's phases. Syzygy refers to the times of either Full Moon or New Moon, *i.e.* to the alignment of the Earth and the Moon with the Sun. Between syzygies the nominal half-month averages 14.765 days, and there are 24.737 of them per annum. Because of the large eccentricity of the Moon's orbit, the half-cycle representing New Moon to Full Moon is in general not equal to the half-cycle representing Full Moon to New Moon. At first the ancients would have counted the days between syzygies without regard to type, and may have continued to do so out of conservatism.

As may be shown (although not simply), thirty-four centuries ago the spring quarter, equinox to solstice, contained 93.26 days, on average amounting to six half-months plus 4.67 days. The days elapsed from the date of the equinox to the first syzygy for the Moon would vary from year to year, and would be distributed randomly up to just under the maximum possible half-month of 14.765 days. The same was true for the days from the last syzygy of the quarter to the solstice. If we consider the situation to be symmetric about the midspring node, the initial and final waiting intervals must be identical, corresponding to a quarter month of about seven days. The two periods appear to be represented in the fire altar by the half bricks, one placed just after the equinox and the other just before the solstice. The remaining six full bricks correspond to the number of syzygies in the quarter.

Our conclusions are elucidated further by consideration of two possible situations. If the delay after the equinox were 0 to 4 days, six half-months would be completed in the quarter, and the residue to the solstice would be 4 to 0 days. If the initial delay were 5 to 14 days, however, only five half-months would be completed, and the residue to the solstice would be 14 to 5 days. In either case there was symmetry in the mean number of waiting days.

After a century or two, observers would have discovered that the averages, Full Moon to Full Moon, converged better than the averages of the half-month. We refer to observations of the Full Moon rather than of the New Moon, because the New Moon, occurring very close to the Sun in the sky, could be observed less easily. The Earth's orbital velocity reaches a stationary point as it passes through perihelion or aphelion. Thirty-four centuries ago the Sun passed through those points in midautumn and midspring. The velocity of the apparent Sun varied by only a small amount over the two or three weeks before or after reaching those points. Over a few centuries the regression along the ecliptic is only a few degrees, so the average day-count per month would change very little over that time. According to the evidence presented by the layout of the bricks in the altar, we argue that the ancient priests discovered the two stationary points. The average day-count of a month containing either point would converge to the true angular velocity of the Sun along the ecliptic, or rather its reciprocal. It is very reasonable to believe that the marvellous accuracy that the ancients achieved in the ratio 189/176.37 resulted from averaging over centuries of observation.

Although the ancient priests observed the inequality of the half-months, they had no way of observing the continuous change of the Moon's velocity, thinking of it as constant between syzygies. Perhaps they assumed that the Sun behaved likewise, moving at constant but unequal speeds over each half-year.

We can now speculate about the distribution of bricks in the circle of the altar, seven in each of three quadrants and eight in the spring quadrant. The total, 29, differs from the number of half-months per annum, which is properly almost 25. We suggest that the priests retained a tradition of observing by the half-month, reflected in the circle of bricks. The four extras, one per quadrant, must have been added to comply with their system of arithmetic, in which ratios could only be expressed as a ratio of integers. The ratio of the midautumn and midspring day-counts would have to be expressible as a ratio of whole numbers. With one brick added per quadrant, the desired ratio was expressed — the half-year containing spring had 15 bricks, and the other half-year 14. Each brick stood for 12.595 days in the anomalistic year of the epoch. Note that 15×12.595 days = 188.9 days, and 14×12.595 days = 176.3 days. Once again we obtain the significant numbers seen in the dimensions of the central tower at Angkor Wat. There appears to be a symbolism to the layout of the bricks in the fire altar of the *Śatapatha Brāhmana*.

5. Conclusions

As argued here, the ancient Hindus observed the number of days per month over centuries, noticing that the averages converged to different constants for the seasons bracketing midspring and midautumn. The constants are virtually identical to the angular velocities of the Sun along the ecliptic at aphelion and perihelion, respectively. We suggest that the savants constructed an algorithm describing the motion of the Sun along the ecliptic. It moved for half a year with one velocity and half a year with the other, yielding a count of 189 days for the half-year centred on midspring, and 176.37 days for the half-year centred on midautumn. In a fire altar described in the *Śatapatha Brāhmana*, the arrangement of bricks in the fifth and topmost layer, symbolizing the motion of the Sun, appears to depict the same algorithm. The same numbers are found in the dimensions of the central tower of Angkor Wat, and are mentioned in the *Śatapatha Brāhmana*. Apparently, the Indian astronomical concept of a varying rate of motion for the Sun was later adopted by the Babylonians and independently handed down to the astronomers of Angkor Wat.

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A NUMERICAL TECHNIQUE FOR PREDICTING THE LEVEL OF SOLAR ACTIVITY AT SUNSPOT MAXIMUM

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Abstract. Alignments with the Sun of the three planets Venus, Earth, and Jupiter, the main planets responsible for solar tides, appear to be tied to the 11-year cycle of sunspot activity. Computations presented here are used to demonstrate that, since 1837, there is a correlation between the observed temporal differences leading towards approximate alignments of planetary tides on the Sun and the levels of maximum solar activity. A possible mechanism that might explain such an effect is considered. Although such computations tend to be empirical by nature, they do make possible long-term predictions for future levels of sunspot activity at the time of solar maximum. The prediction from such calculations is that sunspot activity at the next solar maximum in the year 2000 should be relatively low, certainly relative to existing predictions, with an expected mean Wolf number of about 104 ±19.

Résumé. Les planètes Vénus, Terre, et Jupiter sont responsables de la majeure partie des marées solaires. L'alignement des trois planètes avec le soleil paraît lié au cycle de 11 ans des taches solaires. Les calculs présentés ici servent à démontrer que, depuis 1837, il y a une corrélation entre le temps variable mis pour réaliser cet alignement approximatif et les niveaux maximaux d'activité solaire. Un mécanisme possible, qui pourrait expliquer cet effet, est examiné ici. Bien que ces calculs aient tendance à être de nature empirique, ils peuvent néanmoins fournir des prévisions à long terme pour les niveaux de taches solaires lors des périodes d'activité solaire maximale. Les prévisions résultant de ces calculs indiquent que, pour l'an 2000, le niveau de taches solaires, durant la période d'activité solaire maximale, devrait s'établir a un nombre moyen de Wolf s'élevant à environ 104 ±19, grandeur relativement basse comparée aux prévisions assez récemment publiées. JB

1. Introduction

Tidal forces between objects vary according to the product of the masses of the objects involved and the inverse cube of their separation. The difference in magnitude of the tides in the Earth's oceans raised by the Moon and the Sun, for example, is a consequence of a factor of 2.18 difference between the tidal forces arising from each. In similar fashion, the major planets are capable of raising weak tides on the Sun, the expected magnitude of the tidal force arising from the four planets capable of producing the largest effect on the Sun being in the ratio 2.26:2.16:1.00:0.95 for the planets Jupiter, Venus, Earth, and Mercury, respectively. Jupiter, Venus, and Earth combined exert slightly more than 80% of the total planetary tidal forces to which the Sun is subjected.

Maximum tidal heights for the Earth's ocean waters are linked to alignments of the Sun and the Moon with the Earth. In similar fashion, the maximum effect of planetary tides on the Sun arising from Jupiter, Earth, and Venus occurs when the three planets are closely aligned with the Sun. Alignments of Jupiter and Earth with the Sun occur at half multiples of Jupiter's synodic period of 399 days, namely intervals of 0.6 year, 1.1 year, 1.6 years, 2.2 years, *etc.* Alignments of Venus and Earth with the Sun take place at half multiples of Venus's synodic period of 584 days, namely intervals of 0.8 year, 1.6 years, 2.4 years, 3.2 years, *etc.* All three planets are closely aligned with the Sun when the two cycles coincide, which occurs at intervals of 10.4 years and 12.0 years. As noted by Nemeth (1966), the average of those two periods — 11.2 years — corresponds rather closely to the mean duration of the solar sunspot cycle. Although planetary tides on the Sun are sufficiently weak that they may not produce any observable effects, it is worth considering whether or not the 11-year sunspot cycle, which is also the time scale for reversal of the Sun's magnetic polarity, is somehow linked to planetary tides.

On the basis of such considerations, various authors have suggested that solar activity may be modulated by planet-generated tides on the Sun, *e.g.* Link (1948, 1950, 1951, and 1952), Trellis (1966a, 1966b, 1966c), and Nemeth (1966). Since Jupiter, Venus, and Earth dominate such tides, it seems natural in any search for a link between the cycle of solar activity and planet-generated tides to give primary consideration to those three planets, as was done by Nemeth (1966). The same philosophy was followed in the present study, in which we have adapted the computational method of Nemeth to examine the characteristics of sunspot activity at solar maxima as recorded over the last one and a half centuries. The technique as presented also makes possible long-term predictions about expected sunspot numbers for forthcoming solar maxima.

Such an approach may have been overlooked previously because of a curious solar phenomenon that has only been brought to light in recent years. It is now known that another indicator of solar activity, faculae appearing near the poles of the Sun, anticipates sunspot activity by six to seven years (*cf.* Makarov *et al.* 1989; Makarov & Makarova 1996). Coincidentally, the planets Jupiter, Venus, and Earth pass through their closest alignments with respect to the Sun at roughly the same time, namely during the period centred about six to seven years prior to Wolf number minimum. It is during such periods of intense polar facular activity that the action of the planets noted by Nemeth is considered.

2. Nemeth's Technique

The present study, like that of Nemeth (1966), considers only effects generated by the planets Venus, Earth, and Jupiter, as established by their relative alignments with the Sun. Nemeth tabulated in some detail the dates for alignments of the three planets. Table I, which

Table I
Near Alignments of Venus, Jupiter, and Earth with the Sun, 1927–1962

Venus at Inferior Conjunction	Nearest Date for Jupiter at Conjunction/Opposition	Interval Between Dates (days)
Sept. 10, 1927	Sept. 22, 1927	12
Apr. 20, 1929	May 15, 1929	25
Nov. 22, 1930	Jan. 06, 1931	45
June 29, 1932	Aug. 26, 1932	58
Feb. 05, 1934	Apr. 08, 1934	62
Sept. 08, 1935	Nov. 27, 1935	80
Apr. 18, 1937	July 15, 1937	88
Nov. 20, 1938	Aug. 21, 1938	91
June 26, 1940	Apr. 11, 1940	76
Feb. 02, 1942	Dec. 08, 1941	56
Sept. 06, 1943	July 30, 1943	38
Apr. 15, 1945	Mar. 13, 1945	33
Nov. 17, 1946	Oct. 31, 1946	17
June 24, 1948	June 15, 1948	9
Jan. 31, 1950	Feb. 03, 1950	3
Sept. 03, 1951	Oct. 03, 1951	30
Apr. 13, 1953	May 25, 1953	42
Nov. 15, 1954	Jan. 15, 1955	61
June 22, 1956	Sept. 04, 1956	74
Jan. 28, 1958	Apr. 17, 1958	79
Sept. 01, 1959	Dec. 05, 1959	95
Apr. 10, 1961	Jan. 05, 1961	95
Nov. 12, 1962	Aug. 31, 1962	73
Venus at Superior Conjunction	**Nearest Date for Jupiter at Conjunction/Opposition**	**Interval Between Dates (days)**
July 01, 1928	Apr. 07, 1928	85
Feb. 06, 1930	Dec. 03, 1929	65
Sept. 07, 1931	July 25, 1931	44
Apr. 21, 1933	Mar. 09, 1933	43
Nov. 18, 1934	Oct. 27, 1934	22
June 29, 1936	June 10, 1936	19
Feb. 04, 1938	Jan. 29, 1938	6
Sept. 05, 1939	Sept. 27, 1939	22
Apr. 19, 1941	May 19, 1941	30
Nov. 16, 1942	Jan. 11, 1943	56
June 27, 1944	Aug. 31, 1944	65
Feb. 01, 1946	Apr. 13, 1946	71
Sept. 03, 1947	Dec. 01, 1947	89
Apr. 16, 1949	Jan. 01, 1949	105
Nov. 13, 1950	Aug. 26, 1950	79
June 24, 1952	Apr. 17, 1952	68
Jan. 30, 1954	Dec. 13, 1953	48
Sept. 01, 1955	Aug. 04, 1955	28
Apr. 14, 1957	Mar. 17, 1957	28
Nov. 11, 1958	Nov. 05, 1958	6
June 22, 1960	June 20, 1960	2
Jan. 27, 1962	Feb. 08, 1962	12
Aug. 30, 1963	Oct. 08, 1963	39

replicates the work of Nemeth, lists in the upper section in columns 1 and 2, the respective dates for inferior conjunctions of Venus and the temporally nearest oppositions or conjunctions of Jupiter, for the time interval 1927 to 1962. The time roughly midway between the dates in columns 1 and 2 represents the time of maximum alignment of Venus, Earth, and Jupiter with the Sun. Column 3 indicates the number of days between the two previously cited planetary alignments. The lower part of Table I lists similar data for superior conjunctions of Venus (column 1) and the temporally nearest oppositions or conjunctions of Jupiter (column 2). Once again, the time roughly midway between those dates represents the time of maximum alignment of Venus, Earth, and Jupiter with the Sun. Column 3 indicates the number of days between the planetary alignments indicated in columns 1 and 2. The time differences are central to the work of Nemeth.

Nemeth examined the decreasing temporal differences between alignments of Venus and Earth with the Sun and those of Jupiter and Earth with the Sun during those years corresponding to the declining portions of sunspot cycles. The trends are not identical from one solar cycle to another, but vary significantly owing to the eccentricities of the planetary orbits. That results in cyclically changing distances of the planets from the Sun, which affect the rates at which the planets traverse their orbits and hence the degree of closeness for alignments of Venus, Jupiter, and Earth with the Sun. The changing distances also produce differences in the strengths of the combined planetary tides, which in Nemeth's view are assumed to affect sunspot activity. Nemeth suggested that when the temporal differences between alignments decrease rapidly, sunspot activity is very high at the subsequent sunspot maximum; when the temporal differences between alignments decrease slowly, sunspot activity is low at the subsequent sunspot maximum.

The trend was illustrated graphically by Nemeth in a plot depicting the level of sunspot activity at solar maxima occurring between 1837 and 1957 relative to the rate at which temporal differences between planetary alignments decrease during the preceding periods of declining sunspot activity. A very tight correlation was found, the correlation co-efficient for the data being 0.95. Nemeth did not publish the details of the calculations he used to obtain the values appearing in his graph, however, which makes it difficult to assess the validity of his conclusions. The present author has attempted to reproduce the calculations by means of the techniques described by Nemeth, but without success. A similarly impressive correlation was found in the process, however, and the present paper outlines our variant of Nemeth's methodology.

3. New Methodology

The present technique retains a portion of Nemeth's original methodology, starting with the data of Table I. The data there were used to generate calculations of the type presented in Tables II and III, which illustrate the manner of calculating an "alignment index" for the period leading up to the sunspot maximum of cycle 18, which occurred in July 1947. The data of Table II replicate a portion of the data summarized in columns 1, 2, and 3 of Table I, namely the dates of inferior conjunctions for Venus, the corresponding dates for the temporally nearest conjunctions or oppositions of Jupiter, and the elapsed days between the two dates.

The Table I data were used as follows. In order to analyze the

Table II
Intervals Separating Earth-Venus and Earth-Jupiter Conjunctions for Sunspot Cycle 18, with Differences Between Successive Intervals

Venus at Inferior Conjunction	Nearest Date for Jupiter at Conjunction/Opposition	Interval Between Dates (days)	Difference (days)
Nov. 20, 1938	Aug. 21, 1938	91	..
June 26, 1940	Apr. 11, 1940	76	15
Feb. 02, 1942	Dec. 08, 1941	56	20
Sept. 06, 1943	July 30, 1943	38	18
Apr. 15, 1945	Mar. 13, 1945	33	5
Nov. 17, 1946	Oct. 31, 1946	17	16
June 24, 1948	June 15, 1948	9	8
Jan. 31, 1950	Feb. 03, 1950	3	6

tidal alignments of the planets leading up to the sunspot maximum of 1947, for example, we first retained only the series of successive conjunctions/oppositions exhibiting temporal *decreases* in the intervals between Earth-Venus and Earth-Jupiter alignments, *i.e.* strengthening planetary tides. In Table II the useful data are the time differences between inferior conjunctions of Venus and the temporally nearest oppositions or conjunctions of Jupiter, in other words the data of columns 1, 2, and 3 in the upper part of Table I covering the period between 1938 and 1950. In other cycles the relevant data may correspond to those in the lower section of Table I. As indicated in Tables I and II, during the period between 1938 and 1950 the time interval between Earth-Venus and Earth-Jupiter alignments decreased from 91 days to three days.

We next computed an "alignment index" from the data by summing the time differences between the dates of near alignments, determined as follows. An initial date was chosen that corresponded to the month in which declining sunspot activity for that cycle fell definitively below 15% of its value at sunspot maximum. A final date was chosen that corresponded to the month 7.4 years from the initial date. The times of greatest alignment for Venus, Earth, and Jupiter with the Sun during the periods in question were established in relatively simple fashion by simply averaging the dates for the corresponding Venus-Earth and Jupiter-Earth alignments. The "alignment index" for the period between the initial and final dates was then established as indicated by the sample calculations in Table III.

Table III
Example of Method Used to Calculate the "Alignment Index" for Sunspot Cycle 18

Date of Closest Alignment of Venus, Earth, and Jupiter	Difference (days) Between Successive Earth-Venus and Earth-Jupiter Alignments
Oct. 06, 1938 = 1938.8	15
May 19, 1940 = 1940.4	20
Jan. 05, 1942 = 1942.0	18
Aug. 18, 1943 = 1943.6	5
Mar. 30, 1945 = 1945.2	16
Nov. 09, 1946 = 1946.9	8
June 20, 1948 = 1948.5	8
Feb. 02, 1950 = 1950.1	6
Initial Date = 1939.6	—
1939.6 to 1940.4	$\frac{0.8\text{yr}}{1.6\text{yr}} \times 15\text{ days} = 7.5\text{ days}$
1940.4 to 1946.9	20 days + 18 days + 5 Days + 16 days = 59.0 days
1946.9 to 1947.0	$\frac{0.1\text{yr}}{1.6\text{yr}} \times 8\text{days} = 0.5\text{ days}$
Final Date = 1947.0	—
Alignment Index	7.5 days + 59.0 days + 0.5 day = 67.0 days

For the example depicted in Tables II and III, the initial date for the calculations was established to be 1939.6. In other words, sunspot activity for cycle 17 fell definitively below 15% of the value at sunspot maximum in July 1939. Sunspot maximum for cycle 17 occurred, by the way, in July 1937. The final date for our set of calculations for the cycle is 1947.0, 7.4 years from 1939.6. The summary in Table III lists the dates of closest alignment for Venus, Earth, and Jupiter with the Sun, as well as the time interval between corresponding alignments of Venus-Earth and Jupiter-Earth with the Sun. The "alignment index" is identified here as the sum of the time intervals between corresponding alignments for the period 1939.6–1947.0. The initial and final dates clearly do not correspond exactly to dates of greatest alignment. The summation therefore included interpolations for those two particular dates. In other words, we compute "pseudo time differences" that correspond to the interval between the initial date and the date of the next greatest alignment, and to the interval between the date of the last greatest alignment in that interval and the final date. The bottom section of Table III illustrates the method applied to the cycle 17 data, which produces an "alignment index" of 67.0.

4. Results

The values for the "alignment index" calculated for all sunspot cycles falling in the period 1837 to 1991 are tabulated in Table IV along with a measure of sunspot activity at the subsequent sunspot maximum. To track sunspot activity for establishing the Wolf number at sunspot maximum and for determining the initial dates for our calculations, we used a sliding average of the monthly Wolf numbers covering an interval of six months about the month in question. Such a "smoothing" of the data is less extreme than what one usually considers, and the numbers averaged in such a fashion — which are generally 10% greater than the usual values — appear to be better than the monthly numbers or two-year averages for determining the date at which sunspot activity begins to decline sharply and definitively. The example in Table III illustrates how the computations for the "alignment index" were made for the data appearing in Table IV.

The sunspot indices computed here for sunspot maxima occurring in the interval 1937–1991 are plotted in figure 1 as a function of the "alignment index" calculated by the method illustrated. As in the similar plot given by Nemeth, there is a reasonably tight correlation in the data, the correlation co-efficient for the data being 0.90. The functional dependence of the plotted relation is given by

$$\textbf{Sunspot Number at Maximum} = [(5.15 \pm 0.68) \times \textbf{Alignment Index}] - 180.63 \pm 41.64 \;,$$

with a scatter of ±19 in the Wolf number. The data for alignments of

Table IV
Derived Numerical Data for Solar Maxima, 1837–Present

Cycle	Date of Sunspot Maximum	Mean Wolf Number at Sunspot Maximum	"Alignment Index"	Initial Date for Calculations
8	January 1837	162	63.5	1831.1
9	October 1847	148	61.7	1837.5
10	July 1860	103	59.3	1849.2
11	March 1870	153	65.5	1861.2
12	December 1883	85	47.8	1870.9
13	June 1893	93	62.1	1884.3
14	September 1905	71	48.1	1894.3
15	June 1917	118	56.4	1908.6
16	June 1928	87	54.7	1917.9
17	July 1937	126	60.4	1928.8
18	July 1947	174	67.0	1939.6
19	November 1957	218	77.0	1948.7
20	February 1969	116	60.4	1958.9
21	November 1979	175	66.4	1970.8
22	October 1989	170	64.1	1981.9
23	..	..	55.3	1991.8

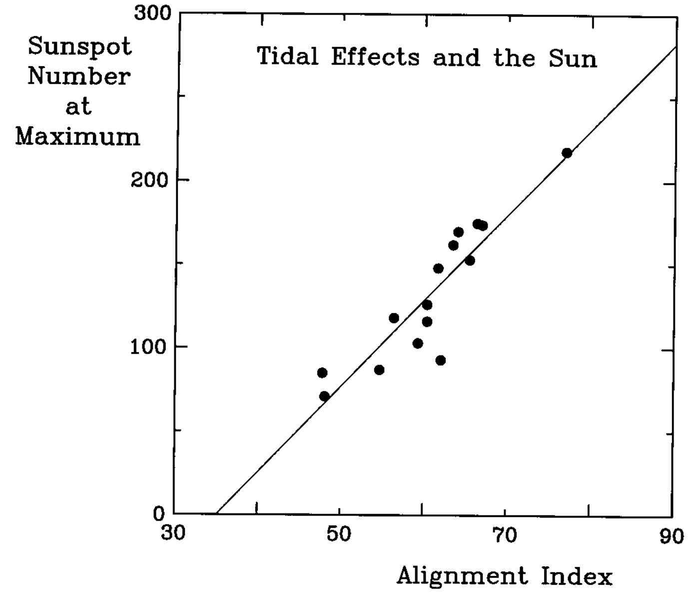

Fig. 1 — Mean Wolf numbers at sunspot maximum are plotted as a function of the "alignment index" calculated in this paper. The trend line is a least squares fit to the data.

Venus, Earth, and Jupiter for coming years are readily available, and it is possible to use the relation to establish the corresponding mean Wolf number that should apply to the next solar maximum. That value is 104 ±19, indicative of a relatively low level of sunspot activity at the next maximum. By way of comparison, the Sunspot Index Data Center has recently (March 1999) published possible predictions for a Wolf number ranging between 130 and 190 at the next solar maximum expected in the year 2000. The two predictions are quite different, reflecting the different methods by which they were obtained. The present value was also obtained several years previous.

Several predictions have been published for the level of activity at the next sunspot maximum, but, despite the different methods chosen, all tend to be rather similar. Two methods are currently preferred. One makes use of an observed correlation between measures for the level of particles ejected by the Sun and the strength of the subsequent solar maximum, while the other uses sunspot curves from the past as a basis for prediction. Lantos & Richard (1998) have summarized the predictions obtained by the former technique, while Leftus (1994) has summarized predictions obtained by the latter. Glanz (1997) retained only the most recent predictions in his survey. Using parameters describing the Sun's polar field, Schatten has proposed a Wolf number of about 130 for the next sunspot maximum. By comparison, an analysis of the intensity of the particle emissions by the Sun led Thompson to a predicted Wolf number of 164. Finally, the analysis of past sunspot activity curves yields predicted values for the Wolf number as high as 190 (see above). Clearly all such values are significantly larger than the present value of 104 ±19.

5. A Physical Basis for Predictions of Solar Activity

The previous sections have been devoted to the main features of Nemeth's technique, for which no details were provided by that author concerning the computations he made to obtain the amplitudes related to various sunspot maxima. Nor did he examine the important problem of how planetary tides affect solar activity, given that the tides generated by the planets on the Sun's surface are of extremely low amplitude. What are the amplifying mechanisms at work that permit us to relate such tides to various aspects of solar activity?

In order to provide a possible answer for the question just posed, it is necessary to consider the dynamo theory used to explain solar and sunspot magnetic fields. The mechanism as outlined by Babcock (1961) provides a good qualitative explanation for the Sun's periodic activity. As described by Babcock, the initial situation to consider is one in which the Sun has a general poloidal magnetic field. Such a simple magnetic field becomes more complicated over the next five or six years as a result of the Sun's differential rotation, and gives rise to a subsurface toroidal field that is believed to be responsible for the magnetic signatures of sunspot groups. As the toroidal field dissipates in subsequent years, the situation returns to the original situation of a generally poloidal magnetic field, but reversed in polarity.

The particular features of the poloidal field determine the nature of the subsequent toroidal field, and thereby affect future sunspot activity. If one applies empirical adjustments to the data to account

Table V
Comparison of Dates for "Alignment Index" Calculations with Dates for Polar Facular Activity

Initial Date for Index Calculations	Start of Polar Facular Activity	Final Date for Index Calculations	End of Polar Facular Activity
1939.6	1940.0	1947.0	1947.0
1948.7	1949.0	1956.1	1958.0
1958.9	1960.5	1966.3	1968.5
1973.8	1971.0	1978.2	1979.0
1981.9	1982.0	1989.3	1989.0

for past periods of greater or lesser duration, it is possible to use either the various physical parameters of the poloidal field or the amount of matter ejected by the Sun to predict future solar activity. As indicated by Schatten *et al*. (1978), for example, there is a good correlation between the number of polar faculae that occur during the sunspot cycle minimum and the number of sunspots during the following maximum. The monthly numbers of polar faculae correlate well with the monthly sunspot numbers, with an offset of six years between the trend lines (Makarov & Makarova 1996).

Let us consider what plausible role the planets might play in modulating solar activity. Various possibilities have been offered concerning the physical mechanisms at work, and they can be integrated into the dynamo theory for solar activity. The ejection of some prominences from the Sun, for example, indicates that matter in the surface layers can readily escape the gravitational attraction of the Sun under certain conditions, and that certain outer layers of the Sun are therefore in a delicately balanced equilibrium between radiation pressure and gravitational attraction. A third force may affect such a balance, namely that induced by the planets. It is not the vertical component of planetary attraction that should be considered, but its horizontal component, which is exerted cumulatively on layers as much as several thousand kilometres in length. Such volumes experience their own periods of oscillation. Of all of the modulation frequencies generated by conjunctions of the planets, only a portion would allow the appearance of resonance phenomena in such layers. Certain planetary alignments, selected always in the same fashion, appear to be preferred. Similarly, certain series of inferior and superior conjunctions of Venus should be retained according to specific rules.

The planetary tidal forces do not directly provide the energy dissipated in various forms at the Sun's surface, but may rather trigger a breakdown in equilibrium that generates the phenomenon. Presumably the first manifestations of such breakdowns appear in the form of polar faculae. The resonance action of the planets may have an effect only when certain physical conditions coincide in the Sun's poloidal field. The effect of the planets on the Sun can be compared to the triggering of an avalanche by a skier passing by every eleven years.

Periodically the 11-year sunspot cycle seems to vanish almost completely. The most famous example is the Maunder minimum that occurred between 1660 and 1719. Sokoloff & Nesme-Ribes (1994) have suggested an explanation for such great minima in the framework of the dynamo theory of solar activity. They feel that the usually overall dipolar magnetic field of the Sun may also be quadrupolar. The presence of a quadrupolar field could change the physical conditions at the poles of the Sun to the point where the action of planetary tides could be rendered ineffective. We may then generate sunspot minima that last for periods of as much as sixty to a hundred years, similar to what was observed for the Maunder minimum.

6. Discussion

The correlation we have obtained hints that sunspot activity during the ascending phase is initiated by effects occurring during the previous descending phase. When Nemeth (1966) initially published his hypothesis, the time shift of about six years between the starting date for his calculations and the beginning of the subsequent solar cycle was rather surprising. It is now recognized, however, that there is a similar shift between the beginning of polar facular activity on

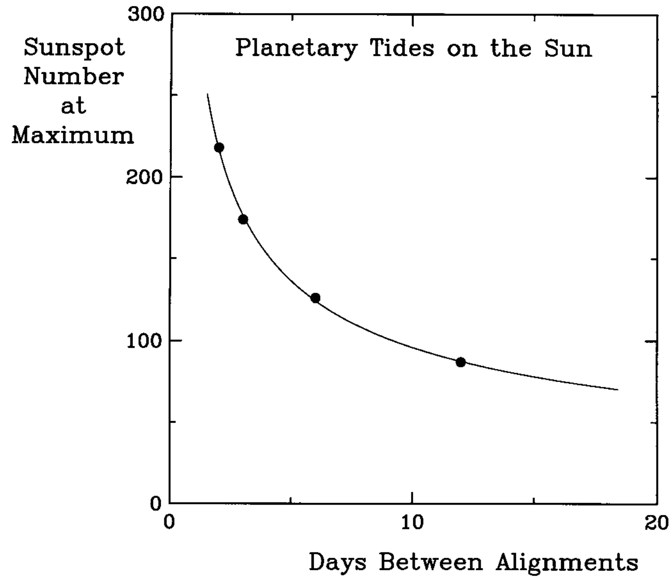

Fig. 2 — Mean Wolf numbers at sunspot maximum are plotted as a function of the time interval (in days) by which the closest of the temporally-adjacent separate alignments of Venus-Earth and Jupiter-Earth with the Sun deviated from perfect alignment during the adjacent interval of time.

the Sun and the start of a sunspot cycle. The initial dates used here, *i.e.* those at which the planetary tides begin to be counted, correspond rather well to the dates for the beginnings of polar facular activity published by Makarov *et al.* (1989) and Makarov & Makarova (1996). The final dates used here, *i.e.* 7.4 years later, correspond closely to the dates for the end of polar facular activity. The comparison presented in Table V indicates just how similar the two sets of dates actually are.

The link between polar facular activity and sunspots can be explained in the framework of the Babcock solar dynamo model, as noted by Schatten *et al.* (1978). Planetary tides, facular activity, and sunspot activity seem to be related to each other temporally, in that order. It would be interesting to compare our "alignment indices" for planetary tides with facular activity. Unfortunately, the time coverage, continuity, and homogeneity of the available facular activity and sunspot data tracked so far do not permit a detailed comparison.

The manner in which planetary tides affect the number of sunspots during a solar cycle is not entirely obvious from our analysis, which is primarily empirical in nature. For example, the nature of the correlation between the "alignment index" defined here and the Wolf number at sunspot maximum suggests that minimum deviations from greatest planetary alignments preceding a solar cycle — defined by a smaller value for the "alignment index" — correlate with a low degree of sunspot activity at the subsequent solar maximum. In other words, where planetary tides are consistently of similar strength there is little influence on sunspot activity, and where planetary tides are consistently gaining strength there is a positive effect on sunspot activity.

If one simply examines the "tightness" of the possible alignments of Venus, Jupiter, and Earth with the Sun at times reasonably close to sunspot maximum, as measured by the time interval separating conjunctions/oppositions of Venus and Jupiter, one reaches similar conclusions. In Table I the times of maximum planetary tides on the

Sun occurred in 1927.7, 1938.1, 1950.1, and 1960.5, during which periods the conjunctions/oppositions of Venus and Jupiter occurred within time intervals of 12, 6, 3, and 2 days, respectively — clearly a strengthening tendency for any effects arising from planetary tides. The nearest associated sunspot maxima occurred in 1928.5, 1937.6, 1947.6, and 1957.8, when the Wolf numbers at maximum were 87, 126, 174, and 218, respectively — also a strengthening trend. The degree of such a correlation is illustrated by the power law fit in figure 2. Although the numerical data for the whole period between 1830 and 1999 are much less striking, it may be that correlations that are just as precise recur during 30-year or 40-year intervals with a constant frequency over the centuries. One could at least argue from the data of figure 2 that the strongest planetary tides appear to enhance the activity of the Sun at immediately adjacent maxima, a result that provides some support to what was concluded above. However, the exact manner in which planetary tides modulate the Sun's magnetic field and affect sunspot activity must await the results of simulations by a detailed physical model.

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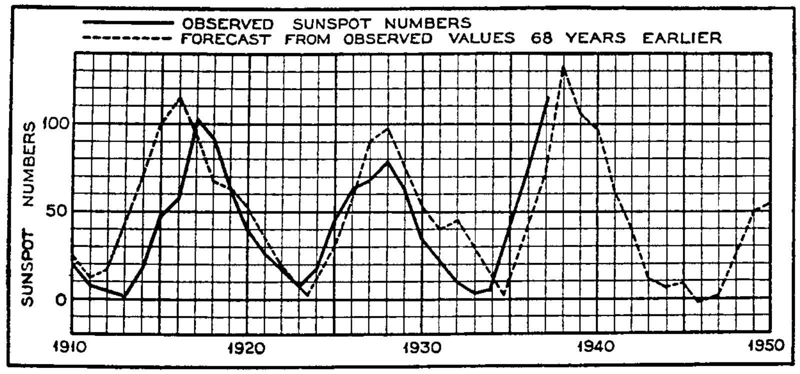
THE NEXT SUNSPOT MAXIMUM1



If weather depends on sunspots, then the desirability of predicting coming maxima and minima of solar activity becomes of the greatest public interest. The question of the moment is, when is the next sunspot maximum due?

If the answer to this question were as simple as adding the 11 years — the average length of the solar cycle — to the date of the last maximum, the answer would be as easy as two and two. The next sunspot maximum would then be due in 1939.

There are good reasons, however, for believing that this is not the best prediction. I have just been examining the records of the last 180 years of sunspots. In this interval there have been 16 completed cycles since the well-determined minimum of 1755. The average length of time from one sunspot maximum to the next over this interval is 11.13 years. It is a surprise, and a bit disconcerting, to find only four maxima of the last 16 have fallen within 11 years of each other. Three have been spaced 13 years apart, three 10 years apart, and two at 12-year intervals. Two others were separated by eight years, and there was one instance of 16 years elapsing between two adjacent sunspot maxima.

On these grounds alone there would be a chance that the next sunspot maximum might follow anywhere from eight to 16 years after the last maximum, which occurred in July 1928. There is only one chance in four that the 11-year interval will work for predicting the present coming maximum.

Years have been spent by numerous investigators in analyzing sunspot curves to discover the various periodicities that may enter into the question. When we examine the sunspot numbers month by month rather than year by year, it is important to note that there are secondary fluctuations that occur at more or less irregular intervals. These secondary or minor fluctuations have an important bearing on the prediction of the maxima. Some of these intervals of variation are much longer than the 11-year cycle, others are shorter.

The most recent and fruitful results which I have yet seen in an attempt to analyze the sunspot cycle into workable periods which may be used for prediction are those recently shown me by Mr. Clayton. By a rather novel trick he has treated the long record of sunspot numbers from 1750, and has determined significant periods of 8 ½ years, 10 years, 11 ⅓ years, 14 years, 17 years, 23 years, 34 years, and 68 years. He finds that, from 1750 to 1910, an interval of 68 years gives a close approximation to sunspot changes. Utilizing the dates of all the well-determined sunspot maxima and minima published by Wolf and his successor at Zurich, he finds that the mean value using nine intervals based on minima is 68 years, and that the mean value using eight available intervals based on maxima is 67.6 years. Utilizing these intervals of about 68 years, and utilizing only data up until 1910, he has made a forecast of sunspot numbers from 1910 to 1954. This curve agrees so remarkably with the observed values from 1910 to date that it merits more confidence than any prediction which I have yet seen. [From the curve the maximum should be expected in 1938.]

by Harlan T. Stetson,
from *Journal*, Vol. 32, pp. 67–68, February, 1938.

[1] Part of an article on "Weather and Sun-Spots" in the *Scientific American* for November 1937. This article is a chapter in a book entitled "Sun-spots and their Effects," recently published by the McGraw-Hill Book Co., N.Y.

OBSERVING DELTA CEPHEI AS AN OBSERVING PROJECT FOR THE UNAIDED EYE

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Abstract. The possibility of using the Cepheid variable Delta Cephei as a target for a student observation project is discussed in some detail. The star was observed by the author during the 1998-99 observing season with reference to a newly-constructed finding chart that is tied to published photoelectric *V* magnitudes and that also includes more reference stars than is the case for older AAVSO charts. The variable proves to be relatively easy to observe, as has been pointed out previously, and one can compute a very reliable light curve for it using only observations with the unaided eye. The practical use of such observations for students of astronomy is discussed.

Résumé. L'usage potentiel de l'étoile variable Delta Céphéi comme sujet d'observations par des étudiants est discuté en détail. Cette étoile a été observée par l'auteur durant la saison d'observations 1998/1999, où il s'est référé à une nouvelle carte d'acquisition qui est liée aux magnitudes photoélectriques *V* publiées et qui comprend plus d'étoiles de référence que celles publiée dans les anciennes cartes d'acquisition de l'AAVSO. La variable est relativement facile à observer, ainsi que l'on a indiqué par le passé. Il est aussi facile de calculer une courbe fiable de la variabilité de cette étoile en se servant de l'oeil nu seul. L'usage pratique de telles observations par les étudiants est discuté.
SEM

1. Introduction

"The variable star Delta Cephei is well suited to give elementary astronomy students the satisfying experience of observing a celestial object whose brightness varies from night to night. The star is easy to find, and is sufficiently bright even at minimum; it has a moderate range in brightness and an interesting, asymmetrical light curve. A few weeks of observations usually suffice to suggest to the observer that the star goes through a regular cycle of light variation. A few months permit a determination of the period of variation and give further insight into the light curve."
van de Kamp (1953)

So begins an article by Peter van de Kamp entitled "Student Observations of Delta Cephei," which was published as an education note in *Sky & Telescope* in 1953. From time to time, the author has resurrected that article for use by young people who are interested in astronomical observing that serves to challenge their intellectual abilities. It is always a pleasant surprise to discover how well novice observers do with such a project.

Delta Cephei (δ Cep) has also figured prominently in a variety of other sources highlighting observations of variable stars that can be made without the aid of a telescope or a pair of binoculars. The star appears near the beginning of David Levy's book on *Observing Variable Stars* (Levy 1998), for example, was highlighted along with Zeta Geminorum (ζ Gem) by Percy (1993), and also appeared as the "Variable Star of the Year" in the 1994 edition of the *Observer's Handbook* (Percy & Mattei 1994). The star is also featured in the activity sheets for *Hands-On Astrophysics* (Percy & Mattei 1998).

Although the star's name is used in abbreviated form — Cepheid — to denote the entire class of pulsating yellow supergiants that are so fundamental to the calibration of the extragalactic distance scale, δ Cep was not the first Cepheid to be discovered. That honour belongs to Eta Aquilae (η Aql), which was discovered to be variable in September 1784 by Edward Piggot in England. The variability of δ Cep was discovered about a month later — towards the end of October 1784 — by 19-year-old John Goodricke, who shared with his friend Piggot a fondness for observing stars that vary in light. An interesting account of the friendship between Goodricke and Piggot and of their discovery of Cepheid variability was published by Fernie (1984) on the occasion of a conference hosted by the University of Toronto celebrating the two-hundredth anniversary of the discovery of Cepheid-type variability. Because of the tight relationship that exists between the periods of pulsation for such stars and their luminosities — the period-luminosity relation — Cepheids have had a lengthy history acting as standard candles for the determination of distances to other galaxies (see, for example, Turner 1996*b*).

In introductory courses in astronomy, it is sometimes desirable to assign a variety of simple observing projects as a means of familiarizing students with astronomical objects that they can locate in the night sky. Students expect to gain some knowledge of the constellations, stars, and planets from their first astronomy course. At Saint Mary's University, "homework" projects of this type have entailed sketching the Moon, sketching or photographing constellations, tracking planetary motions, and making observations of sunsets or sunrises (see Turner 1996*a*) — all from the student's personal observing site — as well as the usual on-campus observations made with the university's telescope. As noted by the American Association of Variable Star Observers (AAVSO) in their *Hands-On Astrophysics* project (Percy & Mattei 1998), the study of one or more variable stars can be an interesting educational exercise as well. For Canadian universities, perhaps the most easily observed variable star for beginners is δ Cep, the name object for classical Cepheid variables.

2. The Advantages of Delta Cephei

As a potential object for an observing exercise in an introductory course in astronomy, δ Cep has several advantages. For one thing, the star is circumpolar from all Canadian sites, and is well placed for observation near the zenith during the critical period running from October to March, the "core" interval for the Canadian university year. It is bright enough that it can be observed in skies suffering from modest light pollution, and does not require the eyes to be fully dark-adapted for one to make magnitude estimates, even near light minimum (see, for example, Schaefer 1989-93). It is also faint enough that its brightness is frequently estimated visually with reference to stars that are within a few magnitudes of the limit of vision for unaided observations, which is exactly the regime where eye estimates of brightness are most reliable (Mayall 1970). It is therefore not unusual for such observations to be made with uncertainties of no more than $\pm 0^m.1$, the practical limit for most eye estimates of magnitude (*cf.* Percy 1993). The pulsational period of about 5.37 days for δ Cep is also short enough that its light variations are evident from one night to another, a feature that helps to sustain interest among novice observers. Changes can even be detected hourly near light maximum (see Table I), as the author discovered for himself through observations on the night of January 2, 1999, when the variable was expected — and observed — to pass through light maximum.

There is one minor problem encountered by novice observers, however. Most existing charts for δ Cep circulated by the AAVSO contain just three reference stars near the variable — Zeta Cephei

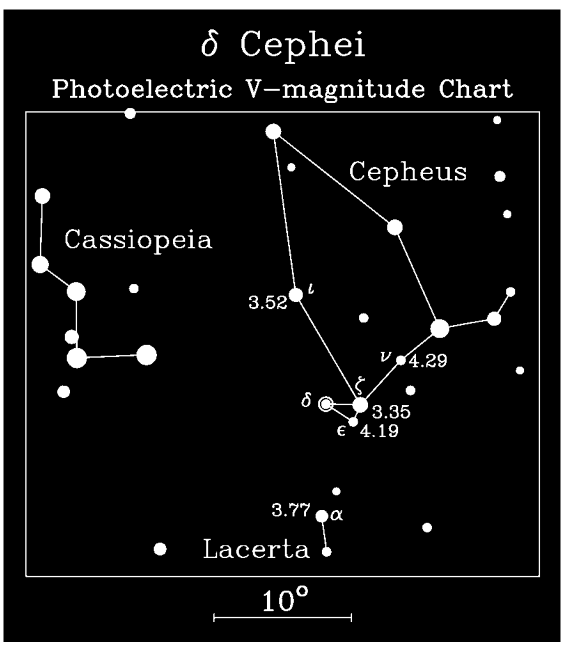

Fig. 1 — A new finding chart for δ Cep that includes photoelectric V magnitudes for five reference stars in the field that are ideally situated in both position and brightness relative to the variable for use in estimating the brightness of the star with the unaided eye.

(ζ Cep), visual magnitude 3.6 (m_v) but actually V = 3.35, Epsilon Cephei (ϵ Cep), visual magnitude 4.2 (m_v) but actually V = 4.19, and Nu Cephei (ν Cep), visual magnitude 4.6 but actually V = 4.29. [The brightness of ν Cep corresponds to m_v = 4.35 according to the standard relationship used to link visual magnitudes to photoelectric V magnitudes (Stanton 1981; Zissell 1998), so the listed value of 4.6 for the star appears to be incorrect in any event.] An example of the AAVSO chart is given in recent editions of the *Observer's Handbook* of the Royal Astronomical Society of Canada. On some charts (van de Kamp 1953; Levy 1998) only ζ Cep and ϵ Cep are used as reference stars. Yet there are two other reference stars [Iota Cephei (ι Cep), V = 3.52, and Alpha Lacertae (α Lac), V = 3.77], well placed in both magnitude and distance from the star, which can be used to establish a more extensive chart more suited to student observers. All stars lie within 8° of δ Cep, so they are close enough to be compared directly with the variable during

Table I
Visual Observations of Delta Cephei, Winter of 1998/99

Date	Julian Date	Cycle	Phase	V
Dec. 5, 1998	2451153.454	1564.767	0.767	4.20
Dec. 11, 1998	2451159.490	1565.892	0.892	3.70
Dec. 13, 1998	2451161.458	1566.259	0.259	3.80
Dec. 14, 1998	2451162.420	1566.438	0.438	4.00
Dec. 15, 1998	2451163.472	1566.634	0.634	4.20
Dec. 20, 1998	2451168.443	1567.561	0.561	4.20
Dec. 23, 1998	2451171.461	1568.123	0.123	3.60
Dec. 24, 1998	2451172.464	1568.310	0.310	3.80
Dec. 25, 1998	2451173.454	1568.494	0.494	4.00
Dec. 27, 1998	2451175.418	1568.860	0.860	3.90
Dec. 27, 1998	2451175.564	1568.888	0.888	3.80
Dec. 31, 1998	2451179.604	1569.640	0.640	4.20
Jan. 2, 1999	2451181.411	1569.977	0.977	3.40
Jan. 2, 1999	2451181.516	1569.997	0.997	3.35
Jan. 2, 1999	2451181.637	1570.019	0.019	3.40
Jan. 4, 1999	2451183.435	1570.354	0.354	3.90
Jan. 5, 1999	2451184.558	1570.564	0.564	4.20
Jan. 6, 1999	2451185.455	1570.731	0.731	4.25
Jan. 6, 1999	2451185.544	1570.747	0.747	4.25
Jan. 7, 1999	2451186.432	1570.913	0.913	3.70
Jan. 8, 1999	2451187.421	1571.097	0.097	3.50
Jan. 14, 1999	2451193.441	1572.219	0.219	3.70
Jan. 16, 1999	2451195.523	1572.607	0.607	4.20
Jan. 17, 1999	2451196.432	1572.776	0.776	4.20
Jan. 19, 1999	2451198.423	1573.147	0.147	3.60
Jan. 20, 1999	2451199.442	1573.337	0.337	3.80
Jan. 21, 1999	2451200.429	1573.521	0.521	4.10
Jan. 22, 1999	2451201.426	1573.707	0.707	4.20
Jan. 22, 1999	2451201.494	1573.720	0.720	4.25
Jan. 27, 1999	2451206.468	1574.646	0.646	4.20
Jan. 29, 1999	2451208.449	1575.016	0.016	3.35
Jan. 31, 1999	2451210.434	1575.386	0.386	3.90
Feb. 1, 1999	2451211.470	1575.579	0.579	4.20
Feb. 7, 1999	2451217.472	1576.697	0.697	4.25
Feb. 8, 1999	2451218.463	1576.882	0.882	3.80
Feb. 15, 1999	2451225.460	1578.186	0.186	3.65
Feb. 16, 1999	2451226.445	1578.369	0.369	3.90
Feb. 23, 1999	2451233.456	1579.676	0.676	4.25
Feb. 24, 1999	2451234.465	1579.864	0.864	3.90

observation. Both stars fall on the fovea during moderately averted viewing, which permits a direct comparison of their brightness using the most sensitive part of the eye's retina (Hallett 1998). That is an important criterion for making reliable visual magnitude estimates.

The new finder chart, which is based upon photoelectric V magnitudes rather than visual magnitudes, is given in figure 1. Percy (1993) published a similar reference chart for δ Cep, but it lists visual magnitudes (to one decimal) for all of the bright stars in Cepheus. Since many of the bright stars in Cepheus lie more than 8° from δ Cep, they can act as reference standards only by the method of successive comparison (see Hallett 1998), which can be a less reliable means of making eye estimates. Use of moderately averted viewing, in which the variable and reference star fall symmetrically on the fovea on either side of the less sensitive central region during observation, is preferred for eye estimates in most cases.

3. Practical Observations

There are some advantages to updating the finder chart for the variable in order to make use of two-decimal photoelectric magnitudes for the comparison stars rather than the one-decimal visual magnitudes commonly used by the AAVSO. One point to consider is that variations in the sensitivity of the human eye to starlight as a function of light level, the age of the observer, and the presence of corrective lenses, may affect the relationship between apparent visual magnitude and photoelectric V magnitude for individual observers. The stars α Lac, ι Cep, and ζ Cep, for example, are very similar in apparent visual magnitude according to the standard transformation relation (Stanton 1981; Zissell 1998), but differ in brightness to the author. Another advantage to the use of two-decimal magnitudes for the reference stars is that it permits finer estimates to be made from visual observations. For example, ϵ Cep ($V = 4.19$) and ν Cep ($V = 4.29$) differ in brightness to the human eye, despite a difference in magnitude of only $0^m.1$, and on many nights δ Cep appeared to the author to be intermediate in brightness between the two. That implies a V magnitude for the star of roughly 4.25 at such times. Rounding the value to 4.2 or 4.3 makes no sense in that situation. Likewise, on two nights the variable was judged to be of identical brightness to ζ Cep ($V = 3.35$), despite claims by van de Kamp (1953) that it is always fainter than that reference star. It seemed inappropriate to round such estimates to 3.4 (or 3.6!), since there were other times when the fainter value seemed more suitable.

A summary of observations of δ Cep made by the author with the unaided eye during the winter of 1998/99 is given in Table I. The data were taken from a simple *Excel* file into which each night's observations were entered. From the initial dates of observation and calculated Julian dates (see the *Observer's Handbook* for guidance), *Excel* calculates the corresponding cycle numbers and phases for the star from an existing ephemeris. It is a simple matter to code such calculations into the file. The magnitude estimates, once entered, show up immediately in an embedded light curve graphic constructed for such a purpose, and provide instantaneous feedback about how the project is proceeding. For novice observers, such a feature is marvelous for maintaining one's interest in the project.

The 39 observations made by the author do not represent a large amount of consumed observing time — little more than a few hours in total. At the beginning of the project a single observation often took more than ten minutes to acquire. That was because of the need to allow the eyes to accommodate to the lower light levels outdoors, the need to identify the field and the reference stars correctly, and the care needed to match the brightness of the variable to one or more of the five reference stars. As the project proceeded, however, single observations consumed less and less time, as the field of the variable and the five reference stars became familiar to the observer. On occasion, near light maximum for example, it was often possible to acquire an observation in less than a minute! Observations could also be collected on most winter nights — even from a site on the Atlantic seaboard — by taking advantage of available short clear periods. The small amount of time required to gather observations did not intrude on other activities, particularly once the observer became familiar with the reference field. In short, observing δ Cep as a target star can be done by just about anyone with a few minutes to spare a few nights a week, and it does not take long to complete an entire light curve for the star.

The smooth light curve resulting from the author's observations is shown in the lower part of figure 2, where the data are compared with photoelectric observations published by Szabados (1980) in the upper part of the figure. Some comments are necessary. At the beginning of the project, the eye estimates actually exhibited greater scatter, much like that evident in the light curves of Percy (1993) and Percy & Mattei (1994). As time proceeded, however, the author became more adept at making comparisons with the reference stars, and it was found that earlier observations made relative to the same reference stars needed minor corrections to match them to the estimates made later in the project. Such adjustments tended to remove all of the obvious outliers in the earlier visual observations. In the latter stages of the project, a few outliers were found to result from overly crude estimates of magnitude relative to the reference stars. Such problems,

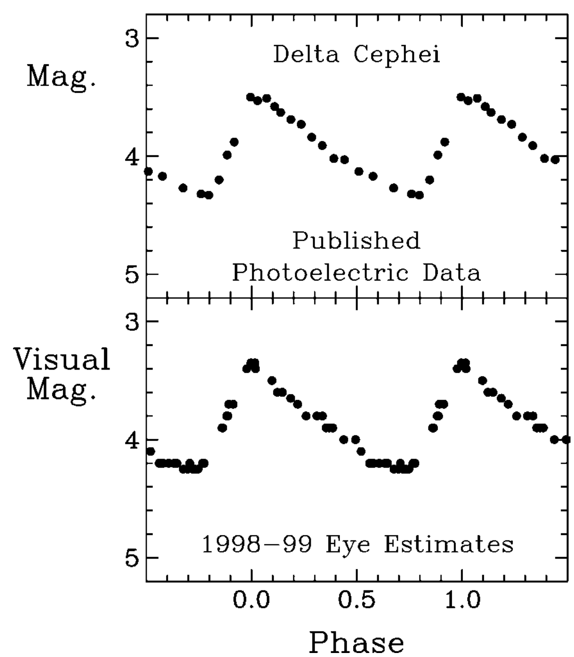

Fig. 2 – The visual observations of the author (at bottom) obtained during the 1998-99 observing season for δ Cep are plotted along with photoelectric V magnitudes (at top) published by Szabados (1980). The phases were calculated using the linear ephemeris given by Szabados.

while rare, were resolved as they occurred, either by making a more careful comparison with the reference stars or by redoing the calculations. For scientific research in general it is always a good idea to check one's work. The project therefore has practical aspects for potential "scientists-in-training."

Note that the use of binoculars is actually a hindrance for such a project, since the variable and reference stars appear so much brighter that they are much more difficult to match in apparent brightness. Also, the reduced field of view makes it impossible to match the variable directly to all of the available reference stars. Both features were evident to the author early in the project, when binocular observations were sometimes attempted. In every case the observations made in such fashion were found to be useless, and all subsequent observations were made without the aid of binoculars. The project is definitely one where the *unaided* eye is superior.

There is one feature of the visual estimates that proved to be consistent from the beginning to the end of the project, but which is a bit more difficult to explain. That is the existence of a small offset in the brightness of δ Cep, of perhaps ~$0^m.1$, relative to the photoelectric observations of Szabados (1980), in the sense that the eye estimates are slightly brighter. The feature was noted early in the study, and resulted in a special effort to confirm all later measurements. No inconsistencies were found, however. It is conceivable that the eye estimates provide more complete phase coverage than the photoelectric measures, in which case the "offset" might result from the larger light amplitude evident in the eye estimates, which appear to sample true light maximum for δ Cep better than the photoelectric measures. Another possibility is that it arises from the colour term in the relationship linking photoelectric V magnitudes and visual magnitudes m_v. The mean difference in $m_v - V$ for the five reference stars is $+0^m.09$, for example, in the sense that the visual magnitudes calculated for the reference stars are fainter by that amount relative to the V magnitudes. On the other hand, the mean visual magnitude of δ Cep itself should be $0^m.08$ fainter on average, so the net effect would seem to be negligible.

Not all of the observational aspects for δ Cep are positive. It was found, for example, that eye estimates of magnitude for the variable became more difficult to obtain and more time consuming the further the star was from the zenith. For zenith distances approaching 45°, the increased extinction and sky glow seemed to make it more difficult to match the variable with nearby comparison stars. It is not clear to the author why that should be, given that the extra amount of extinction is typically no more than a few tenths of a magnitude and the added amount of sky glow is also correspondingly small. The increased sky glow, for example, should be no more of a problem than that occurring during the bright phases of the Moon, which was generally not found to be a hindrance to observation. There may be hidden psychological influences arising from the presence of horizon objects entering into the field of view at larger zenith distances, but otherwise the source of the problem is difficult to explain. The effect on the present project was to produce an early end date for the observations even though the star was still visible at later dates.

4. The Value of Cepheid Observations

According to Percy (private communication), school teachers are especially excited by the possibility of making group observations for Cepheids, since it allows individual members of a group to compare their measurements with those of others. Such efforts can also provide practical demonstrations of how the accumulation of many individual observations of brightness reduces the measuring uncertainties associated with the data used to produce a Cepheid's light curve. Of course, observations by a single, experienced observer may result in more valuable applications than observations by many less-experienced observers with different eye sensitivities, but group observing is still a valuable learning exercise. Inevitably, however, practitioners also wish to know whether or not their observations have any scientific value.

As an indication of the scientific use of such observations, one can note that the times when δ Cep reached maximum brightness are readily extracted from Table I. The times of observation for the nights of January 2 and January 29 correspond to UT dates of January 3.02 and January 29.95, respectively. The former is a full four hours earlier than the time predicted in the 1999 *Observer's Handbook*. Calculations indicate that the time of peak brightness for the variable — true light maximum — occurred about four and a half hours earlier than the predicted time in the *Observer's Handbook*, which illustrates one type of "discovery" that can be made from such efforts.

The difference, incidentally, is a result of the steadily decreasing period of the Cepheid (see also Percy 1993), which is not taken into account in the linear ephemeris used for the times listed in the *Observer's Handbook*. Delta Cephei has a very lengthy observational record, which includes observations of light maximum in 1785 made by Goodricke and Piggot (Szabados 1980), and one can readily trace the gradual reduction in its pulsational period since that time — see figure 3. A newly computed time of light maximum for δ Cep can be calculated from the present data set by graphically estimating from figure 2 when the point of inflection (light maximum) was reached. Such an analysis yields an observed maximum for δ Cep on JD2451192.234

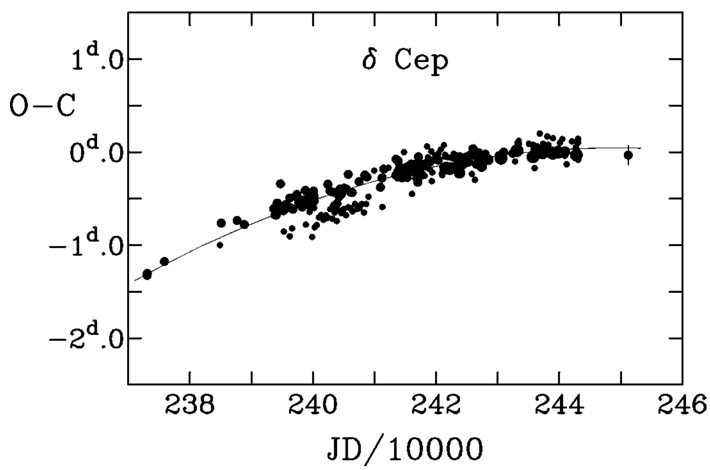

Fig. 3 — A comparison of observed (O) and computed (C) times of light maximum for δ Cep relative to the linear ephemeris given in the paper. The offset of light maximum from zero phase in figure 2 for the present data set corresponds to the last data point on the right hand side of the diagram. The uncertainty in the estimate is indicated. The curve is the best-fitting parabolic fit to all of the data, suitably weighted according to the weights assigned by Szabados (1980) — where the different weights correspond directly to the different sizes for the plotted points. A downward curving parabola of the type plotted here is predicted for a variable star that has a steadily decreasing period.

±0.107 — where the date was chosen to lie near the middle of the observing season — that differs by $-0^d.032 \pm 0^d.107$ (*i.e.* earlier by 0.77 hour) relative to the time predicted from a linear ephemeris published by Szabados (1980). That ephemeris (*not* the ephemeris given in the *Observer's Handbook*) is described by

$$JD_{max} = 2442756.490 + 5^d.366270\,E,$$

where E is the number of elapsed cycles, and was the relation used for computing the phases for the current observations.

The offset in the computed phase for light maximum was the parameter used to establish the time for light maximum given here. Note that even observations made with the unaided eye are useful for such purposes (see figure 3), since they help to confirm the well-established trend of decreasing period for δ Cep that is evident from an *O–C* diagram — which compares the difference between the observed times of light maximum (*O*) with those calculated (*C*) from a linear ephemeris. The observed rate of period decrease for δ Cep is, in fact, consistent with theoretical predictions for the evolution of the star through the Cepheid instability strip during a fourth crossing (Turner 1998).

5. Conclusions

As described here, the variable star δ Cep is an ideal target object for student observations in an introductory course in astronomy. The apparent brightness, short period of variability, and the placement of the star relative to the zenith for observers in Canada, as well as the close proximity of the variable to nearby reference stars of known brightness, are ideal for simple observations with the unaided eye during the Canadian university calendar year. The star has numerous advantages for novice observers who are interested in learning about stellar variability or about the practical aspects of scientific data gathering. As illustrated by the set of observations gathered by the author, the light variations of δ Cep are easy to track and simple to follow, and the accumulation of a full data set does not intrude upon other activities of the observer.

During the latter part of the season used for observing δ Cep, the author also made similar observations with the unaided eye for the Cepheid variable Zeta Geminorum (ζ Gem), which has a similar range of brightness to δ Cep but a period almost twice as long ($10^d.15$). ζ Gem proves to be much more difficult to observe than δ Cep, however, and is *not* recommended for novice observers. For one thing, the star is not well placed relative to potential reference stars, and those that are available tend to be clumped at specific values of apparent brightness rather than evenly distributed like those near δ Cep. Large gaps of sky lie between ζ Gem and its potential reference stars, which means for a typical observer that the variable and reference stars cannot be glimpsed simultaneously on the fovea (Hallett 1998). As a consequence, rapid offsets in sight line are necessary in order to make proper brightness comparisons. Such problems are well illustrated in the binocular study of ζ Gem published by Percy & Rincón (1996), which made use of a reference chart of one-decimal magnitudes for stars in Gemini published by Percy (1993). The extremely scattered nature of the light curve presented in the former paper provides a graphic demonstration of the more difficult nature of the star for such projects.

ζ Gem is also located in the zodiacal band, which means that the field of the variable is lost from view for several nights in a row when the Moon passes through that region of the sky. During such periods, sky glow alone is often a serious problem for observations of ζ Gem with the unaided eye. Finally, the pulsational period of the variable is long enough that changes in brightness are difficult to detect from one night to another. A lengthy series of observations is therefore necessary to produce a proper light curve for the variable, and even that is rather uninteresting since it is reasonably symmetric and much less skewed than that for δ Cep (contrary to the description of Percy & Rincón 1996). In short, while δ Cep seems to be the ideal target star for student observations, ζ Gem presents a challenge even for experienced observers. The author's observations for the latter Cepheid are available to those who are interested.

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DAVID G. TURNER is the Editor of the Journal of the Royal Astronomical Society of Canada, *and is also a professor in the Department of Astronomy and Physics (note the order!) at Saint Mary's University. He is a life member of the RASC, and has had a varied career that included a six-year stint as director of the Doran Planetarium at Laurentian University in Sudbury. He is also a founding member and honorary life member of the Sudbury Astronomy Club. When not observing the skies from his backyard in Cole Harbour, Nova Scotia, he uses what remains of his time to garden and to enjoy his collection of seventeen years of music from the Nova Scotia International Tattoo.*

Society News/Nouvelles de la société

NEW NATIONAL SECRETARY

Following the recent resignation of Raymond Auclair from the office of National Secretary (as a result of time pressures associated with his employment), the RASC welcomes Kim Hay of the Kingston Centre as the new Secretary for the Society. One of Kim's responsibilities is the *Society News* page in the *Across the RASC* section of the *Journal*. In Kim's words: "Since this is my first contribution to *Across the RASC* as your new National Secretary, I am extending an invitation to all Centres and members to come forward and to send me information on what is happening on the local level. Yes, there is the RASCList, which is a useful tool, and there is a national web site (`www.rasc.ca`). Not all members have access to the RASCList or have web access so in order to reach everyone it is necessary to include noteworthy items of national interest in the *Journal*. If you would like to contribute any information, please do so by sending me a note at kimhay@kingston.net. I would be glad to include any information in *Society News — Nouvelles de la société*."

SUMMER MEETINGS

There were two meetings of interest to RASC members held near the beginning of the summer. The 1999 annual meeting of the Canadian Astronomical Society • Société Canadienne d'Astronomie (CASCA) was held in Halifax, Nova Scotia, June 27–30, and was hosted by Saint Mary's University. *Journal* editor David Turner was chair of the local organizing committee. The Helen Sawyer Hogg public lecture was presented during the meeting on June 28, and featured Paul Chodas of the Jet Propulsion Laboratory speaking on "The Impact Threat and Public Perception." Paul's well-attended lecture discussed the methods of calculating asteroid orbits, specifically those for potential Earth colliding objects. A number of media interviews and appearances were held in conjunction with the lecture itself. Also speaking at the meeting was Stéphane Charpinet, who presented the Plaskett Medal lecture on "The Potential of Asteroseismology for Subdwarf B Stars." The Plaskett Medal is a joint award of CASCA and the RASC, and features a gold medal to the student who has produced the best doctoral thesis at a Canadian university in the previous two years. Stéphane, who is a French citizen, completed his Ph.D. thesis at the Université de Montréal.

Immediately following the CASCA meeting was *Partners in Astronomy*, a joint meeting of the Royal Astronomical Society of Canada (RASC), the Astronomical Society of the Pacific (ASP), and the American Association of Variable Star Observers (AAVSO), held in Toronto, Ontario, July 1–7 at the University of Toronto. The meeting was organized by John Percy, who chaired the local organizing committee. It was a well-attended meeting with lots of interesting paper displays, talks, and commercial booths, and featured a variety of astronomical events, including a three-day workshop for teachers, a Project ASTRO workshop to develop amateur-professional partnerships in astronomical research and education between astronomers and teachers, a session on the history of astronomy, and a family fair for children. The RASC General Assembly (GA) and the Society's annual meeting were also held as part of the meeting, in conjunction with a combined awards banquet. Culminating the General Assembly was the Ruth Northcott Lecture, presented by keynote speaker Geoff Marcy, who shared further information on the exciting discovery in April 1999 of three planets around Upsilon Andromedae.

The minutes for the two meetings of National Council held on July 1 and July 3 have been posted on the Web site by National Recorder Peter Jedicke. A message to all Centres is sent on the completion of the minutes, in order that Centres can obtain individual copies. Members not attached to a Centre who do not have web access should contact the National Office for information.

The summer months also feature many star parties that are attended regularly by members across the RASC. To name a few, in Canada there is the Mount Kobau Star Party, Nova East, Starfest, the Huronia Star Party, the Great Manitou Star Party, the Saskatchewan Summer Star Party, and the Alberta Star Party, and for our neighbours to the south there is the Syracuse Star Party and Stellafane, among others. If a star party in your area was omitted from this list, please send a note on the star party to Kim Hay (kimhay@kingston.net, or RR #2, Perth Road Village, Ontario, K0H 2L0) so that she may call attention to it prior to next year's event.

SUMMER SKY EVENTS

Many RASC members had front row seats to the solar eclipse of August 11, 1999, and most were able to view the Perseid meteor shower if they were fortunate enough to be without clouds. Images from the solar eclipse expeditions will be included in future issues, if possible. Check the *Observer's Handbook* or the *RASC Calendar* for information on forthcoming astronomical events.

CONGRATULATIONS TO…

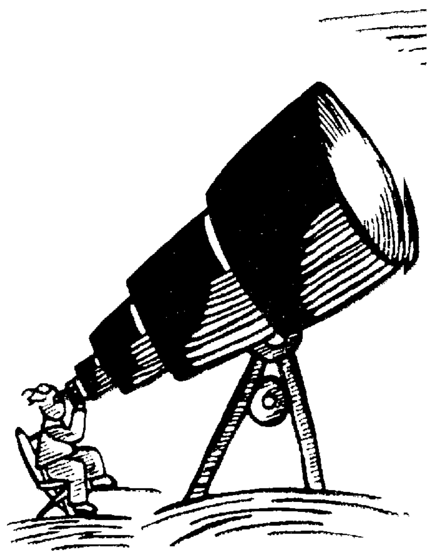
…R. O. Christie (Saskatoon Centre), John Douglas (Ottawa Centre), Charles Johnston (Montreal Centre), Marc Dumais (Toronto Centre), Doug Angle (Kingston Centre), and Richard Weatherston (Sarnia Centre), who were awarded Messier Certificates at the Annual Meeting of the Society.

…Randy Klassen (Vancouver Centre), Mark Viol (Toronto Centre), and Ken F. Roung (Windsor Centre), who were awarded NGC Certificates at the Annual Meeting of the Society.

IN PASSING…

…Fred Troyer (Toronto Centre), Ed Kennedy (Saskatoon Centre), and Peter Sim (Calgary Centre). The Society sends its sincerest sympathies and tributes to family members, Centres, and friends of the above RASC members, who passed away in recent months.

Ask Gazer



Dear Gazer:

Here is my vote in favour of Gazer. I guess that also makes it a vote against Mr. Astronomy Man. You may still ask your own questions (and answer them as well), since I am sure they would be more intelligent, interesting, and entertaining than the ones I am about to ask.

After watching the movie Contact *last year, I could not help wondering about something. From my little corner of the universe (northwestern BC, just south of the Alaska Panhandle), Vega is a circumpolar star. In winter it sparkles above the northern horizon; in summer it is almost directly overhead. In* Contact, *as the American astronomers are tracking the alien signals coming from Vega, the comment is made that Vega will be setting soon and Australia will be picking up and monitoring the signal. My question is: How could astronomers in the southern hemisphere monitor a northern circumpolar star, such as Vega, using ground-based radio telescopes? Am I missing something?*

My second question: What I thought was an April Fools' joke appears to be fact. Someone has been able to slow the speed of light. If it is truly possible does it now mean that warp speed (going faster than the speed of light à la *Star Trek) is now also possible? — or is all of the west coast rain rotting my brain?*

Confused on the Wet Coast

Dear Confused:

Your first question caught me by surprise, as I also saw *Contact* and did not notice anything out of the ordinary. But then, I do not recall that particular conversation in detail. Like you, I first thought that you had stumbled upon one of those errors that are common to science fiction movies and television shows. One of my all-time favourites was a made-for-television movie about an asteroid that was going to hit the Earth. You may have seen it; the "solution" was to deflect it by firing laser beams at the asteroid from orbiting shuttles. Need I say more? If you really want to learn of the entire range of scientific errors that can occur in the entertainment industry, I would direct your attention to a book called *The Nit-picker's Guide to Star Trek*. In it, you will find all manner of violations, not only of the laws of physics as we know them now, but also of the laws of physics as they are understood in the 24th century.

Still thinking that an error had been made, I went back to check the novel upon which the movie was based. Surely the author, Carl Sagan, would not have made such an error. But there it was in print — Australia. So much for the theory that movie scriptwriters had used artistic license to make the other location sound more exotic. There was only one thing left to do — ask the editors for funding to go to Australia and do some investigative journalism. Gee, I'm not sure which of them started laughing first. It was worth a try.

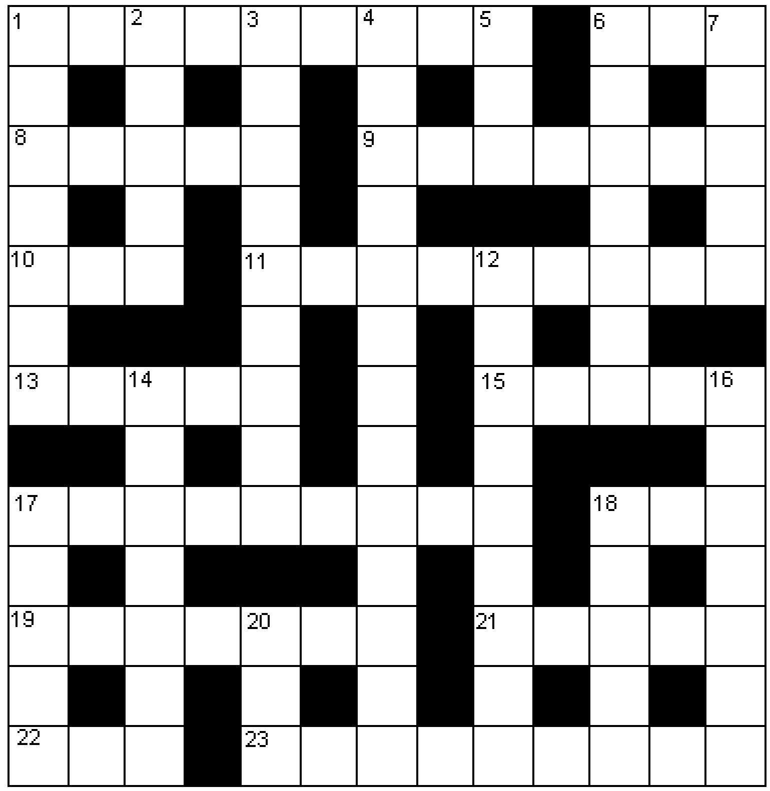
I had to do it the cheap way… boot the computer, call up a sky simulator, and lay in a course for California. Vega is high in the sky, so the next step was to start advancing the clock until Vega was just about to set. Done. Now we are off to Australia, but just where in Australia is the Jet Propulsion Lab's dish? The program I am using has a preset location for the "Australian National Radio Observatory" that looks like a good bet. Checking on the map, I see that is about halfway from Canberra to Siding Spring… close enough! Now, centre on Vega and, there it is — 14° above the horizon and setting, but still visible for an additional two-hour period.

For a more mathematical argument, one could look at Vega's declination, which is about +39°. That means that it is circumpolar if your latitude is north of 51° N (90° – 39°), and it can never be seen if your latitude is less that 51° S. As long as you do not live in Tierra Del Fuego or Antarctica, you can at least get a glimpse of Vega at some time during the year.

Your second question is more difficult to answer, as I am unsure of the "technique" for slowing light to which you refer. The speed of light, having a value of about 300,000 km/s, is the *fastest* speed at which light can travel, and that occurs in a vacuum. In other media, such as water, glass, and ionized gas, light travels more slowly. In an ionized gas, for example, it is possible for charged atomic particles to travel faster than light, but only faster than the speed of light in that medium. While that does lead to an interesting phenomenon — Cherenkov radiation — it does not mean we have to worry, any time soon, about warp core breaches.

Astrocryptic

by Curt Nason, Halifax Centre



ACROSS

1 Black hole source on the little highway to McCaffery's planet and eggs (9)
6 Compete for life at Mont Megantic (3)
8 Oddly, an old name in light diffraction experiments (5)
9 Bet started with a bad nickel that his IR star was in Orion (7)
10 Mesons hold the secret to a facility in Chile (3)
11 Apes Lyrae variables with four year periods (4,5)
13 Make a smooth transition from the latter half of Betelgeuse (5)
15 Cosmologist famed in predicting periodic Kelvin temperatures (5)
17 Tear barge apart in homage to Ursa Major (5,4)
18 Spica presumably contains a polar lid (3)
19 One small company rips apart from the Antares region (7)
21 The last nebula in Athens (5)
22 It's news to Dickinson, and way over my head (3)
23. Coles rent unusual astronomy books and telescopes from them (9)

DOWN

1 Oculars appear huge around the beginning of the year at the poles (7)
2 Dog star or planet? (5)
3 Warped T-ring, like the one from Alpha Centauri (5,4)
4 Stellar mnemonic begins to confuse Bohr, failing Electrical Engineering (2,2,1,4,4)
5 In mid-March, follow it through Bootes to Virgo (3)
6 A simple cell in current affairs (7)
7 Marine raptors nearly finished Rutherford (5)
12 I spy order that is Delta Ophiuchi's (3,6)
14 His reflector design turned a little energy into a bad orgy (7)
16 Use axle pin to get your point across (7)
17 Stellar components took ages to develop solar beginning (5)
18 Fifty race around frantically to set up on these nights (5)
20 Little muscle in the heart of Vulpecula (3)

The All Splendours, No Fuzzies Observing List (part 2 of 4)

by Alan Whitman, Okanagan Centre (awhitman@vip.net)

This is the winter section of a new observing list that attempts to include all of the finest splendours in the entire sky. No featureless fuzzies are included. The 145 sights in the complete list are the best that there are. Almost a quarter of the wonders are visible with the unaided eye, and, except for the few close double stars, all objects on the list can be seen under ideal conditions with a 4-inch telescope. The descriptions of the objects, however, reflect the larger apertures widely in use, as well as the advent of nebular filters. Readers knowing the originator of the popular name of any object should please advise me so that proper attribution can be made in the final installment. The spring list will appear in the February issue.

WINTER OBJECTS:

(Objects that I have never seen are indicated at the start of each seasonal list, but none of the ten unobserved objects happen to be in the Winter list.)

N.B. All catalogue numbers not preceded by alphabetical letters are NGC numbers. except double stars.

ID	Con	Type	RA (2000)	Dec (2000)	Mag.	Size	Remarks
Pleiades	Tau	OC	3:47.0	+24:07	1.2	120′	=M45; NE; Merope RN is L-shaped
32	Eri	Dbl	3:54.3	−02:57	4.5,6.1	7″	Topaz, blue-green
Hyades	Tau	OC	4:20	+15:38	0.8p	400′	NE; very large, V-shaped
1851	Col	GC	5:14.1	−40:03	7.3	11′	CC II
h3752	Lep	Dbl	5:21.8	−24:46	5.4,6.6	3.5″	Gold, blue; GC M79 36′ ENE
LMC	Dor	G-SBm	5:23.6	−69:45	0.6p	432′	NE; many EN and Cl inv
M38	Aur	OC	5:28.7	+35:50	6.4	21′	OC 1907 and M36 adj
M1	Tau	SNR	5:34.5	+22:01	8.4	6′	Lord Rosse's Crab Nebula
M42/43	Ori	EN	5:35.4	−05:27	4	66′	Orion Neb NE; Trapezium Mlt inv; greenish-gray; 16-in: reddish-brown areas DN inv; RN 1973+ adj
2070	Dor	EN/OC	5:38.6	−69:05	8.2	40′	NE; Tarantula Neb in LMC
2024	Ori	EN	5:41.9	−01:51	—	30′	Flame Neb; with branching dl
M37	Aur	OC	5:52.4	+32:33	5.6	24′	Ri: 150 st
M35	Gem	OC	6:08.9	+24:20	5.1	28′	NE; Ri; OC 2158 and IC 2157 adj
8	Mon	Dbl	6:23.8	+04:36	4.4,6.7	13″	Yellow, blue
2237	Mon	EN	6:32.3	+05:03	—	80′×60′	Rosette Neb; UHC reveals DN inv; NE OC 2244 inv
M41	CMa	OC	6:47.0	−20:44	4.5	38′	NE
M50	Mon	OC	7:03.2	−08:20	5.9	16′	
2392	Gem	PN	7:29.2	+20:55	8.3	0′.2	Clown-Face Neb; blue-green
Alpha Gem	Gem	Mlt	7:34.6	+31:53	2.0,2.9	3″.9	Castor: A white, B blue-white; C m 9.1 at 73″
M46	Pup	OC	7:41.8	−14:49	6.1	27′	Ri M46 has PN 2438; NE OC M47 adj
k	Pup	Dbl	7:38.8	−26:48	4.5,4.8	9″.9	Both white
M93	Pup	OC	7:44.6	−23:52	6.2	22′	
2451	Pup	OC	7:45.4	−37:58	2.8	45′	Orange c Pup inv; Ri OC 2477 adj
2516	Car	OC	7:58.3	−60:52	3.8	30′	NE
Zeta Cnc	Cnc	Mlt	8:12.2	+17:39	5.6,6.0	0.″8	Three yellow st; C mag 6.0 at 5″.8
M44	Cnc	OC	8:40.1	+19:59	3.1	95′	NE; Beehive cluster; many Mlt
IC 2391	Vel	OC	8:40.2	−53:04	2.5	50′	NE; bright st
IC 2395	Vel	OC	8:41.1	−48:12	4.6	8′	
Iota Cnc	Cnc	Dbl	8:46.7	+28:46	4.0,6.6	30″	Yellow, blue
M67	Cnc	OC	8:50.4	+11:49	6.9	18′	

Abbreviations used

A = component A of a double or multiple star
adj = adjacent
B = component B of a double or multiple star
B = (with number) Barnard's catalogue of dark nebulae
C = component C of a multiple star
CC = concentration class for globular clusters, from I to XII
Cl = cluster(s)
cn* = central star of planetary nebula
Dbl = double star
dl = dark lane in galaxy or emission nebula
DN = dark nebula
EN = emission nebula
G = galaxy (with type)
GC = globular cluster
IC = Index catalogue
-in = inch (as in "8-in," meaning a telescope of 8-inch aperture)
inv = involved
LMC = Large Magellanic Cloud
M = Messier catalogue
m = visual magnitude
Mlt = multiple star
NE = visible with the naked eye
Neb = nebula
NGC = New General Catalogue
OC = open cluster
OIII = An Oxygen III nebular filter ([O III]) is recommended
p = photographic magnitude
PN = planetary nebula
Ri = rich in stars
RN = reflection nebula
SMC = Small Magellanic Cloud
SNR = Supernova remnant
st = star(s)
UHC = A filter passing both [O III] and Hydrogen Beta is recommended
Var = Variable Star

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Most deep-sky data are from *NGC 2000.0*. For the few facts not available from *NGC 2000.0*, the following *Observer's Handbook* 1999 lists were used in this order of preference: *Galaxies: Brightest and Nearest* by B. Madore (for the dimensions of elongated galaxies and for LMC and SMC data), *The Messier Catalogue and The Finest NGC Objects* by A. Dyer, *Nebulae* by W. Herbst, and *Star Clusters* by A. Moffat.

Double star co-ordinates, magnitudes, and separations are from the *Observer's Handbook 1999*, when available. Guide 7.0 software by Project Pluto was used for the remaining doubles, except that the separations for wide pairs are taken from *Burnham's Celestial Handbook*.

Retired weatherman Alan Whitman is now a full-time amateur astronomer. His other interests include windsurfing on the Okanagan Valley's lakes, hiking and skiing on its mountains, and travel. He invites observing reports for use in this column from experienced amateurs who have largely completed their Messier list.

Scenic Vistas:
Going Where Few Have Gone Before

by Mark Bratton, Montreal Centre (mbratton@generation.net)

> *"...the greatest thrill must be the occasion when one locates and identifies a completely new and 'unlisted' object for oneself. In such a case — to be the first and only person to have observed that object visually — is truly a unique feat of discovery."*
>
> Kenneth Glyn Jones in the Webb Society's *Deep-Sky Observer's Handbook, Volume 6: Anonymous Galaxies*

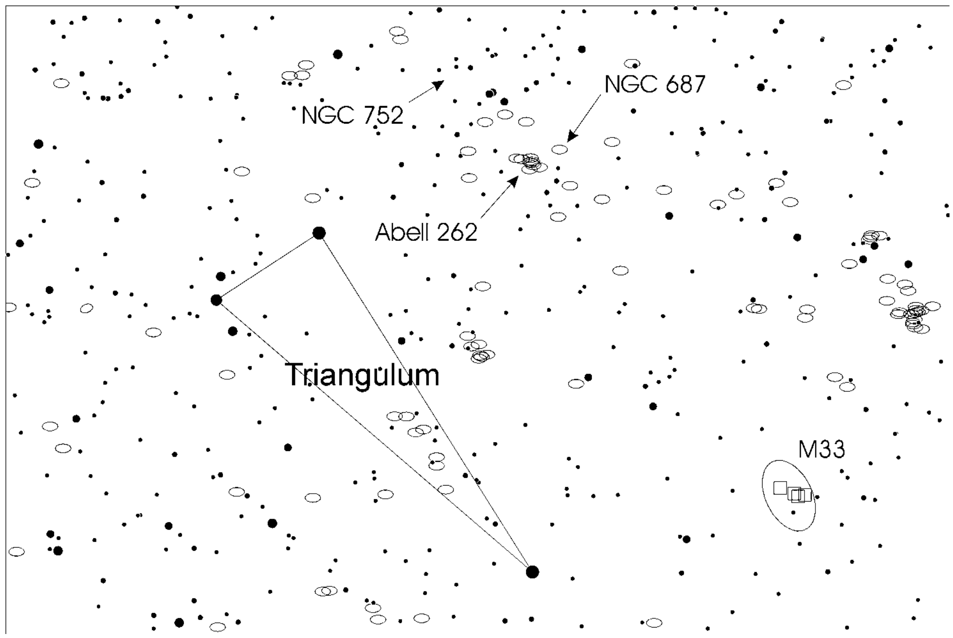


Fig. 1. A 10° high finder chart for NGC 687 showing stars to magnitude 8.5. The target galaxy, MCG 6–5–17, is just to its lower left (see figure 2). ECU Chart prepared by Dave Lane.

The great visual observers of the late 18th and 19th centuries, Marth, the Herschels, d'Arrest, Copeland, Stephan, and Bigourdan to name a few, did a pretty thorough job of mining the sky for deep sky wonders. Using reflectors and refractors that were state-of-the-art for their day, these astronomers swept up successively fainter and fainter objects, the overwhelming majority of which were galaxies. By the 1880s, so many objects had been found that J. L. E. Dreyer was charged with the task of organizing and publishing a definitive catalogue of that work. The result was the *New General Catalogue of Clusters and Nebulae*, a mammoth work that listed 7,840 objects, distributed over the entire sky from pole to pole.

Unfortunately for Dreyer, the discovery of objects did not stop, for publication of the *Catalogue* occurred simultaneously with the development of astrophotography as a powerful new tool in astronomy. Although occasional discoveries were still made visually, it now became the turn of astrophotographers, principally Max Wolf at Heidelberg. They uncovered nebulae that were very often beyond the capabilities of visual observers using even the most powerful telescopes. In response, Dreyer issued two *Index Catalogues*, supplements to the *New General Catalogue*, which tabulated the additional discoveries. In 1908, when the second *Index Catalogue* was published, the total number of known, deep sky objects stood at 13,226. In the twentieth century, these catalogues have been used by amateur astronomers as guides to their own personal voyages of discovery through the universe.

It was not until after the publication of the Palomar Observatory Sky Survey in 1956 that serious cataloguing of galaxies resumed. The difference at that point was that the work was done by astronomers studying and measuring photographic plates of the night sky. Almost without exception, the objects were so faint that they had never been seen before by human eyes. The reference works that resulted were the *Catalogue of Galaxies and Clusters of Galaxies*, the *Morphological Catalogue of Galaxies*, and the *Uppsala General Catalogue of Galaxies*. While they were intended as tools for professional astronomers, over the years a small number of advanced amateur astronomers acquired these works and used them to expand the frontiers of visual astronomy. They realized that some of the objects were relatively bright, bright enough to be seen visually if one knew exactly where to look for them. The objects in question had escaped detection in the 19th century because the observing techniques in use allowed small objects at the threshold of visibility to go undetected. Thus was born the observation of the so-called "anonymous" galaxies.

The galaxies are called anonymous primarily because they are not listed in the *New General Catalogue*, so their existence is not known to the average amateur astronomer. Additionally, the objects are seldom plotted on the star

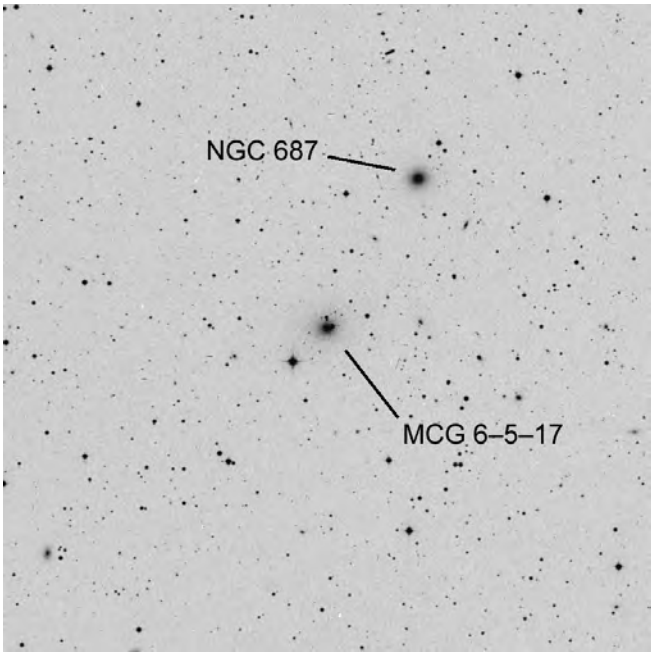


Fig. 2. A 25 arc-minute field of NGC 687 and MCG 6–5–17 from the Digitized Sky Survey[1].

charts commonly available to the amateur community. It is usually necessary to use telescopes with apertures in excess of 30-cm, under very dark skies, to have any hope of detecting this class of object. Needless to say, patience and determination are necessary prerequisites for this type of observing.

Although I have not actively pursued such objects, over the course of the last four years I have been fortunate enough to observe about a half dozen anonymous galaxies with my 15-inch Tectron reflector. Although the objects are detectable, I can vouch for the fact that they are faint, challenging objects — except for one. That object, known as MCG 6–5–17, is located in the constellation Andromeda, at the outskirts of the galaxy cluster Abell 262.

I observed it on the evening of December 2–3, 1994, a night when I rated the seeing as 4 (on a scale of 10) with a limiting visual magnitude of +5.2. In my notes I wrote: "This is a very bright, compact object, looking like a nebulous star. It is located northeast from a mag. +9 field star. NGC 687 (a galaxy of visual magnitude +12.3) can be placed in the same high power field, as it is located less than 10 arcminutes to the northwest. The outer envelope, though consistently visible, is overwhelmed by the bright core, which appears offset to the west."

The Webb Society's *Deep Sky Observer's Handbook, Volume 5: Clusters of Galaxies* lists the photographic magnitude of MCG 6–5–17 at +13, leading me to believe that the galaxy should be visible in an 8-inch telescope, and possibly in a 6-inch in the hands of a skilled observer. Because of the object's small size, the observer should carefully identify the field at medium magnification and then use the highest power available to aid in identification. Observing the galaxy with a small aperture telescope would place the observer in very select company indeed. It is located at R.A. $01^h\ 50^m.0$, Dec. +36°.5. NGC 687 is plotted on Chart 92 of Uranometria 2000.0. Any takers?

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, *which was scheduled to be published in the U.S. by Discovery Books this past summer.*

[1]Based on photographic data of the National Geographic Society — Palomar Observatory Sky Survey (NGS-POSS) obtained using the Oschin Telescope on Palomar Mountain. The NGS-POSS was funded by a grant from the National Geographic Society to the California Institute of Technology. The plates were processed into the present compressed digital form with their permission. The Digitized Sky Survey was produced at the Space Telescope Science Institute under US Government grant NAG W-2166. Copyright (c) 1994, Association of Universities for Research in Astronomy, Inc. All rights reserved.

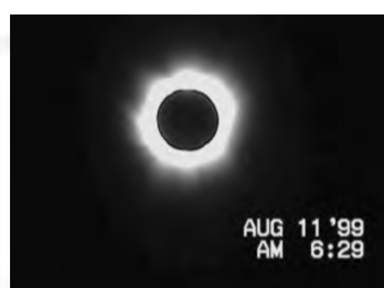
A SUMMER ECLIPSE...

A gallery of dramatic images contributed by our members

The Earth eclipses the Moon eclipsing the Sun!
(Photo by Mary Lou Whitehorne)

Astronomy enthusiasts made extraordinary efforts to catch the last total eclipse of the century and the millennium. These pages capture some of the images made by RASC members at various altitudes ...

Below and along the bottom of the next three pages: The progression of the eclipse as witnessed from the air. (video Images by David Lane)



"Luck was with us because, as totality approached, a large opening in the clouds settled directly overhead. We observed totality in clear skies. The number of prominences visible was stunning — a pink necklace around the entire black Moon. Less than an hour later, it was totally overcast again. If there is a finite amount of luck allotted to every eclipse chaser, I think we might have used ours up."

(Photos: Randy Attwood taken on the road in France)

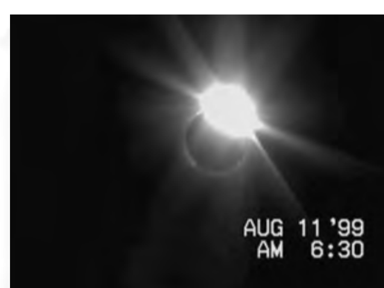
Eclipse image taken from a Piper Navajo at 9000 feet over the Atlantic. 300 mm lens on a Nikon F3 at f11, 1/1000 second on ISO 1600 film.

(Photo by Clint Shannon)

A secondary image of the partially eclipsed Sun shown below the windshield glare of the real thing. Taken from a Piper Navajo at 9000 feet over the Atlantic. (Photo by Ian Anderson)

Eclipse chasers know no limits when their quarry is in sight!

A collection of images from the eclipse flight out of Halifax showing the assembled group and their trusty plane, and culminating in the moment when they eclipse-hungry astronomers were able to observe and shoot the action over the North Atlantic.



Reviews of Publications
Critiques d'ouvrages

The Deep Sky: An Introduction, by Philip Harrington, pages 272, 15.5 cm × 23.5 cm, Sky & Telescope Observer's Guides Series, Sky Publishing, 1997. Price US$24.95 paperback. (ISBN 0-933346-80-8)

Good travel guides have a special way of compelling us to visit other places, without exhausting our curiosity before we get out the door. Unlike other forms of writing, the travel guide presents half of an experience that is only completed when the reader finds himself in the very place that is being written about. Names and locations are then married to first hand impressions, resulting in a synthesis of internal and external landscapes.

In practical astronomy, an observer's guide can perform a similar function. It alerts the observer to an array of potentially interesting objects, without divulging so much information (verbally or graphically) that seeing the objects through the eyepiece feels redundant.

That is the approach taken by Philip Harrington in *The Deep Sky: An Introduction*, one of a series of compact but informative guides from the publishers of *Sky & Telescope* magazine. Over the course of the book Harrington circumnavigates the celestial sphere, hopping from double stars to clusters to galaxies, all within easy reach of a medium-sized (20-cm) backyard telescope. More than 300 objects are listed here, representing all regions of the sky except the extreme south (*i.e.* declinations below −60˚). The list is impressive and the choice of objects intriguing, including many interesting and accessible targets that are unfamiliar even to seasoned deep sky observers.

Roughly the first quarter of the book consists of a quick primer on the deep sky, including what types of objects can be found there, the various ways in which they are named and catalogued, and the tools astronomers use to observe them. While concisely presented, it is standard fare for any general guide to amateur astronomy. Of greater interest to those who are just starting to venture into the deep sky is a chapter that Harrington devotes to the special challenge of observing faint, diffuse objects, as well as some tips on how to record observations of them.

The meat of the book is Harrington's list, broken down into four, lengthy chapters, which move chronologically from spring through summer, fall, and winter objects. Devoted Harrington readers will recognize much of the material in the chapters as an expanded, repackaged version of his articles for *Sky & Telescope*. The beauty of the guidebook format is having all of that information in one place, easy to reach and conveniently portable.

Within each season, Harrington further subdivides his objects into constellations, which appear alphabetically. It takes some practice to figure out where in the book different constellations will turn up. For example, is Hercules a spring or summer constellation? In this book it turns out to be a summer object. A simple list of constellations at the beginning of each chapter would have made things easier in this regard.

The section on the objects themselves make for interesting reading. In good guidebook fashion each one typically merits about 15 lines of text, which is just enough to get you heading for your telescope. If you want to learn more after seeing the objects for yourself, you will soon be looking for a bigger book. What makes this guide unique is the personal touch Harrington frequently works into his descriptions. Sometimes he recollects seeing an object in a memorable circumstance, such as a star party. Often, he gives voice to the impressions of other observers he has met, some well known, some just plain folks.

Apart from the standard Messier objects and other deep sky splendors, Harrington includes a selection of novel targets from a personal list that he dubs "STAR" — short for "Small Telescope Asterism Roster." Such targets are distinctive patterns of stars that turn up in the eyepiece from time to time, with shapes that range from triangles to horseshoes to small dogs. Harrington began a list of such objects when working on his guide to binocular observing, and the list has since been augmented by the readers of *Sky & Telescope*.

The final thirty pages of the book comprise a miniature sky atlas, representing the locations of objects listed in the guidebook among the constellations. Unfortunately, there is no handy system of cross-references identifying to which map to turn in order to find a particular object. The reader is left flipping back and forth through the pages, matching up lists and maps by constellation and then pinpointing objects the hard way.

That inconvenience makes the book something less than it could be — a fully self-contained atlas of the deep sky. Instead, it makes a good addition to an observer's reference desk, offering an excellent resource for the stargazer who has run out of new things to look at.

Ivan Semeniuk

Ivan Semeniuk is book review editor of the Journal.

NightWatch: A Practical Guide to Viewing the Heavens, Third Edition, by Terence Dickinson, pages 176, 27 × 28 cm, Firefly Books, 1998. Price $29.95 paperback. (ISBN 1-55209-302-6)

Sometimes what makes a book remarkable is the realization that once upon a time people had to get by without it. For astronomy hobbyists, that is certainly true of Terry Dickinson's *NightWatch*. Looking back at the selection of practical astronomy manuals before 1983 — the year *NightWatch* was first published — one wonders how anybody managed to find the sky at all.

Of course there were thousands of us that did. But we did it by cobbling together scraps of useful information from an assortment of poorly produced field guides, nineteenth century British handbooks, and cryptic sky charts that bore little resemblance to the real thing. In those primitive times, beginners had nothing much to fuel them but their own boundless enthusiasm as they plowed through pages of incomprehensible numbers and leaden prose.

In contrast, *NightWatch* succeeds by presenting the universe in a logical, accessible and thoroughly engaging format. From the solar system to the deep sky, it is a complete package, inexpensive, and conveniently laid out. For those whose explorations of the night sky predate the first edition, reading *NightWatch* is not unlike flying the Concorde to a place were only mule trains once ventured. As an all-inclusive and reliable introduction to observing the heavens, it is the undisputed best way to go.

Users of the third edition will benefit from all the features that made the original *NightWatch* a hit, along with several improvements, mainly to the book's visual lay-out and graphics. Nearly all of the photographs have been updated, including some stunning full-page shots of Comet Hale-Bopp and the summer Milky Way, photographed by the author. The addition of colour to the line drawings that accompany each seasonal sky map makes them easier to use, and the familiar deep sky charts have an improved typeface and contrast that enhances their readability in the field. The book's signature spiral ring binding is retained, allowing users to fold the cover back for convenience while observing.

Much of the content of the text, as well as the original twelve-chapter format, remains unchanged. However, in the new edition the information is laid out in a more user-friendly way. The difference is particularly evident in the chapter on stargazing equipment. Now the reader can easily pick out the relevant details on everything from "trash telescopes" to focal ratios to selecting the right pair of binoculars, without scanning through pages of text. More than ever, this chapter of *NightWatch* should be required reading for anyone interested in purchasing a telescope, no matter how large or small.

NightWatch belongs on every amateur astronomer's bookshelf, but in a place that that puts it within easy reach. After years of leafing through its large, square pages I am still amazed at just how much useful information they contain. Even more impressive, the sizable quantity of facts they contain in no way cramps the book's comfortable, loose-fitting style. *NightWatch* **is** backyard astronomy — not condensed, but carefully distilled — in this edition, better than ever.

Ivan Semeniuk

Ivan Semeniuk is book review editor of the Journal.

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