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INSIDE THIS ISSUE

February / février 2005

Journal

Vol. 99, No. 1 Whole Number 710

contents

table des matières

FEATURE ARTICLES/ARTICLES DE FOND

RESEARCH PAPERS/ARTICLES DE RECHERCHE

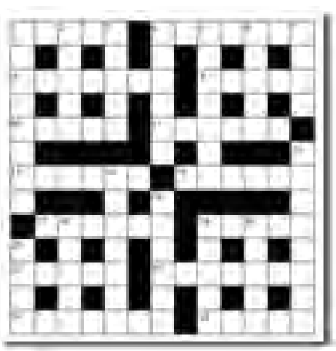
EDUCATION NOTES

COLUMNS/RUBRIQUES

Meteor and Aurora Detection Using Modern Video Technologies
p. 14

A Moment With… Dr. Douglas Gies
p. 40

Reflections
p. 10



Astrocryptic
p. 44

News Notes
p. 4

Cover:
Orbital Oddities: Sky Scan
Teaching radio astronomy in Alberta schools
p. 35

Editorial

by Maureen Okun (okunm@ml.bc.ca)

In a well-known passage from Mark Twain's *Adventures of Huckleberry Finn,* Huck and Jim gaze at the sky one night from their raft on the Mississippi and try to figure out whether the stars "was made, or only just happened." Huck is skeptical about their having been made because "it would have took too long to *make* so many." But Jim's rejoinder makes Huck doubt the validity of his own position: "Jim said the moon could a *laid* them; well, that looked kind of reasonable, so I didn't say nothing against it, because I've seen a frog lay most as many, so of course it could be done."

This segment is one of my favourite parts of the novel; I find our heroes' ingenuous ruminations charming and amusing. I'm less charmed and amused, though, when the same kind of thinking shows up in my classroom. True, none of my students has come up with anything quite like Jim's cosmology, I'm happy to say, but several have nonetheless used reasoning strategies similar to those exemplified by Huck and Jim's conversation.

I teach in the Liberal Studies program at Malaspina University-College on Vancouver Island. Our program takes students on a multidisciplinary excursion through the major works of Western culture. One component of that journey is a module on astronomy, in which we read works by Aristotle, Ptolemy, Copernicus, Galileo, and Newton. Our goals include enabling students to understand how methods of scientific inquiry have changed over time and how changing models of the Cosmos have had an impact on Western thought. But an impassable chasm opens up on the road to these intellectual destinations when students don't know or understand the basics of our current model of the Universe. I soon realized I'd have to change my approach to this module when some of my students told me, with confidence, that the Moon's phases are caused by the Earth's shadow and that the seasons vary as the distance between the Earth and the Sun varies. When, after some patient explaining on my part, one student asked, "If that way's south, which way is east?" I knew we had some backtracking to do.

Confusion about the cardinal directions is one issue; at least there's an uncertainty to work with. Mistaken assumptions about the workings of the world, however, are in some ways more serious because those who hold these assumptions often *know* they're right. A cup full of error must be emptied before it can be refilled with clear thought. I realized that these students, with their how-can-you-argue-with-it explanations of Moon phases and seasons, were, like Huck and Jim, reasoning by analogy. Without the means or motivation to embark on a long program of empirical study, Twain's heroes use their common sense to figure out what they don't know by drawing on their experience with what they do know: birds, frogs, and eggs, hence the logic of a star-laying Moon. Everyone has seen shadows fall

Journal

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

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and knows that the closer you get to something hot, the warmer you get. Why not apply this knowledge to the Solar System? It looks "kind of reasonable."

It's the "kind of" part that I have needed to chip away at in my teaching of this course. The prospect of such chiseling can be daunting when you're ready to talk about epicycles and the precession of the equinoxes and a student tells you he's looking forward to finding out what his horoscope is. This is one reason why belonging to the RASC is such a boon: I'm not the only one to have faced these problems, and members, including *JRASC* editor Wayne Barkhouse, have offered educational advice in this very periodical. Even better, because it's so comprehensive, is the RASC's most recent publication, Mary Lou Whitehorne's *Skyways: Astronomy Handbook for Teachers*. Although directed at teachers in the K-12 education system, *Skyways* is a treasure for this university instructor; many of my students clearly need elementary instruction in astronomy before they can fully understand and appreciate the significance of the Copernican revolution. The pages of *Skyways* are full of instructional suggestions, activities, and resources. And I was delighted to find a quotation from — you guessed it — *Huckleberry Finn* on the first page: "We used to watch the stars that fell, too, and see them streak down. Jim allowed they'd got spoiled and was hove out of the nest." Such "kind of" reason is just what *Skyways* is designed to address. Thanks, Mary Lou!

Correspondence
Correspondance

Spreading the Tomatosphere

I was very pleased to see your article "A Moment with Dr. Michael Dixon" in the October issue of the *Journal* (*JRASC*, 98, p. 207). As an astrophysicist and an educator my team and I had the pleasure of working with the Canadian Space Agency to create the Tomatosphere educational package for teachers, mentioned in the article. Tomatosphere has been a very successful classroom project throughout Canada and our educational team has enjoyed presenting this unique project to teachers and students across the country. The "real world" link between what scientists are discovering today and what our students, the scientists and astronauts of tomorrow, will be doing with those discoveries is an exciting topic indeed.

Dr. Thomas Stiff
York University

Cover Photo

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News Notes
En Manchettes

EXPEDITION ALPHA TO MARS

Over an intensive two-week period from November 27 to December 12, 2004, the Mars Society of Canada (MSC) recently conducted Expedition Alpha (ExAlpha) at the Mars Desert Research Station (MDRS) in Utah, USA.

The ExAlpha crew consisted of six trainees and three instructors. The trainees were doctoral candidate Ken Pizzolitto from the University of Waterloo's Kinesiology program, and the Waterloo chapter of MSC; graduate student Nick Wilkinson from the University of British Columbia's Mining Engineering program, and the Vancouver chapter of MSC, Randy Shelaga, aerospace engineering consultant, from Moose Jaw, Saskatchewan, Peter Reinwald, a machinist and trained EVA field work measurement observer from the Alberta Chapter of MSC; Graylan Vincent, graduate of University of Washington with dual B.Sc. degrees in Aerospace Engineering and Geology (the sole American on the crew); and Dustin Freeman, undergraduate aerospace engineering student at Queen's University in Kingston, Ontario, and founder of our new Kingston MSC chapter. The instructors on ExAlpha were veterans from earlier expeditions: Jean Lagarde, Mars Society founding member, served as commander for the first week (Phase One); Matt Bamsey, President of MSC and graduate student in aerospace engineering at CU-Boulder, also helped with training during the first weekend; and Melissa Battler, planetary geology graduate student at University of New Brunswick, and MSC Director of Events, joined the crew in the second week (Phase Two) as Research Program Manager.

Expedition Alpha was designed to train the crew in basic exploration techniques using the Scouting Exploration Methodology Study (SEMS) developed by Stacy Sklar and Rocky Persaud. SEMS is conducted with MSC's three Astronaut EVA Dataloggers. Training will also be given in work measurement techniques adapted from industrial settings by John Roesch of MSC Alberta Chapter to measure field science operational metrics; traverse path optimization; logistics and teamwork. The research program of ExAlpha consists of a scouting campaign of the MDRS area in search of biological concretions, as first discovered by Melissa Battler on Expedition One. These concretions are of similar size and characteristics to the "blueberries" concretions found by the Opportunity Rover on Meridiani Planum on Mars. The research program also aims to measure the operational modes of the scouting EVAs and physical work expenditure by the crew, as well as to optimize traverse paths for the given scouting campaign. This information will serve as a baseline set of exploration metrics tied to specific science goals (and thus to specific modes of investigation) that in the long term can allow expedition planning of science campaigns for Mars once similar metrics are measured for other science goals on our future research expeditions.

The ExAlpha Remote Science Team will consist of Rocky Persaud, a graduate student in planetary geology at the University of Toronto, founder of the MSC Expedition series, and MSC Vice-President of Research, Stacy Sklar, geology student at Northern Arizona University, Veronica Ann Zabala, geology student at Arizona State University, and Melissa Battler for the week before she joins the crew for ExAlpha Phase Two. Stacy, Veronica, and Melissa have in the past or are currently researching concretions at their respective universities.

Figure 1 — Expedition Alpha logo

ExAlpha will eventually be followed by future training expeditions (ExBeta, ExGamma, and so on). The goals of this series of expeditions is to develop a corps of skilled researchers and research assistants familiar with the basic field operations program from our research expedition series to allow MSC to conduct a long term program in field science operations studies; and provide the opportunity for more Canadians to experience what an MSC-run expedition is like. The field training program and the field research program of Expedition Alpha are described at the Expedition Mars `www.expedition-mars.org` web site. More information about Mars Society Canada is available at `marssociety.ca.`

CYPRESS HILLS DESIGNATED A DARK-SKY PRESERVE

The Cypress Hills Interprovincial Park is the first provincial park in both Saskatchewan and Alberta to be officially recognized as a Dark-Sky Preserve. This designation announced this past October acknowledges and protects the nocturnal environment, a part of the natural heritage of the provinces.

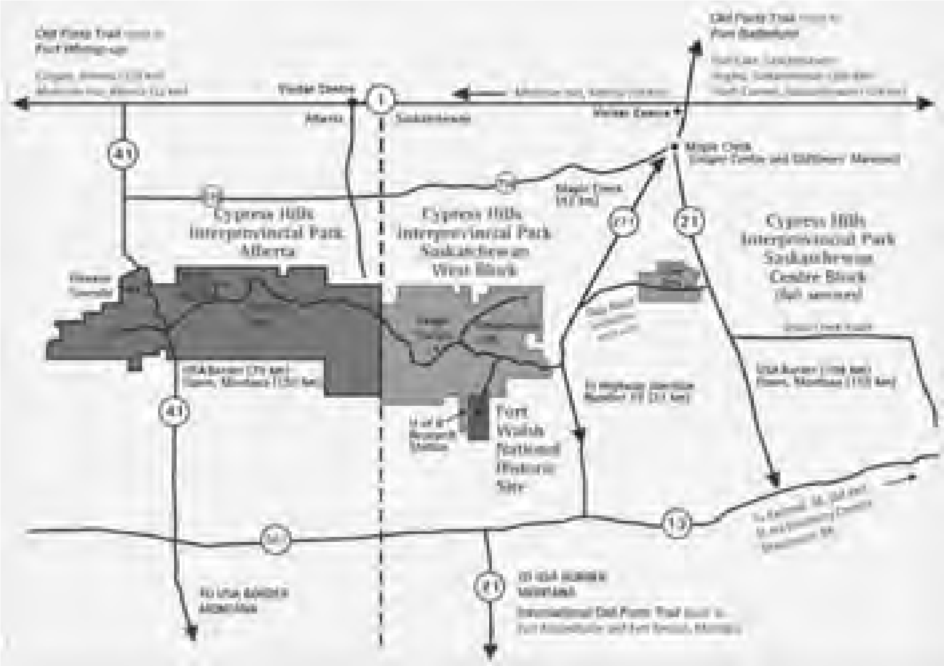

Figure 2 — The Cypress Hills Interprovincial Park straddles the border between Saskatchewan and Alberta.

Figure 3 — Dr. Arif Babul, University of Victoria, recipient of a prestigious Leverhulme Visiting Professorship.

The declaration was made by the governments of Saskatchewan and Alberta, responsible for managing Cypress Hills Interprovincial Park, and by Fort Walsh National Historic Site of Canada, in partnership with the Royal Astronomical Society of Canada (Calgary, Regina, and Saskatoon Centres) at a recent Canadian Parks Council meeting held in the park.

Establishing Cypress Hills Interprovincial Park as a Dark-Sky Preserve will be accomplished by using responsible lighting practices, including the use of fully-shielded luminaires, minimum light levels, energy-efficient lamps, aiming lights downward, and reducing lighting during nighttime hours.

"We are pleased to participate in this designation with the Government of Alberta, Parks Canada, and the Royal Astronomical Society of Canada, which will help to ensure the protection of nighttime darkness, an essential element of the ecosystem," Saskatchewan Environment Minister David Forbes said.

"Our continuing partnership with Saskatchewan and Fort Walsh will provide opportunities for the public to appreciate a starry sky, which is also an important aspect of our natural heritage, including the First Nations heritage surrounding constellations and related mythology," Minister of Alberta Community Development with responsibility for parks and protected areas Gene Zwozdesky said.

The designation will help to enhance visitors' appreciation of Cypress Hills Interprovincial Park with the night sky as part of the natural, historical, and cultural experience. It will also provide opportunities for new interpretive and educational programs, attracting more visitors, and adding economic benefits to the respective provincial and local tourism industries. Saskatchewan and Alberta both plan to work toward expanding the Dark-Sky Preserve program within their respective jurisdictions.

LEVERHULME VISITING PROFESSORSHIP

University of Victoria Cosmologist, Dr. Arif Babul, has been awarded a prestigious Leverhulme Visiting Professorship to be held jointly at the University of Oxford and the University of Durham in the UK.

"I am thrilled and honoured to be awarded the Leverhulme Professorship," says Babul, who in the early 90's held a NATO Science Fellowship at the University of Cambridge. "I am very excited to have the opportunity to renew my collaborations with colleagues in the UK and especially at Oxford and Durham, which are home to two of the top cosmology groups in the world."

A highly accomplished scientist, Dr. Arif Babul's innovative research and distinguished record of highly insightful publications have had a significant impact on recent developments in astrophysics. Babul studies how the Universe, emerging from the "fires" of the Big Bang in an exceedingly smooth state, evolved into the present richly structured network of galaxies that he poetically compares to "a 3-D sculpture of glistening spider webs strung with sparkling beads of morning dew." Of the myriads of cosmic forms and features, he is especially fascinated with the colossal cosmic entities known as clusters of galaxies. First discovered as gigantic swarms of galaxies held together by gravity, these systems are now recognized as huge reservoirs of super-heated X-ray emitting gas, and among the most massive — a mind-boggling equivalent of up to a million billion suns — concentrations of matter with gravity so strong that it can bend and distort light from distant background objects. A computer-generated cluster of galaxies can be found at the following link: visav.phys.uvic.ca/~babul/Arif/current_files/image001.png. Some fifteen billion years of cosmic evolution are captured in the snapshot. The final system is the result of gravity pulling together mass comparable to 10,000 billion suns as the Universe expanded after the Big Bang. This simulation was generated by Dr. Babul's collaborator, Thomas Quinn of the University of Washington, on a supercomputer running full-tilt for a week. A QuickTime movie showing the assembly of the cluster over fifteen billion years can be downloaded at visav.phys.uvic.ca/~babul/ART/Big_Galaxy_Cluster.mov.

Dr. Babul, originally from East Africa, came to Canada at the age of 10. He grew up in the Flemingdon Park neighbourhood of Toronto. He pursued undergraduate studies in Engineering Science at the University of Toronto, and received his doctorate in Astrophysical Sciences from Princeton University in 1989. He is presently a Professor of Physics and Astronomy at the University of Victoria and the Director of the Canadian Computational Cosmology Collaboration.

Administered by the Leverhulme Trust, the Leverhulme Visiting Professorships are intended to enable United Kingdom universities to host internationally distinguished academics from overseas. Scholars are nominated for the award by the universities in UK, and the overriding criteria for selection are the nominees' academic standing and achievement, and the potential for host institution researchers to benefit from the visitor's skills and expertise.

The Measure of the Earth — A Saskatchewan Diary

by Martin Beech (beechm@uregina.ca)

Sunday, June 20, 2004. Regina. It is 6 a.m. I am up and awake and ready to measure the world — literally. Today is a day for old daydreams to be made true, and it is a day for retracing shadows of the ancient past.

When I first learned as a young schoolboy how Eratosthenes had determined the size of the Earth by comparing the length of shadows cast at two different locations, I was enthralled. The concept was so very, very simple (as, indeed, are all leaps of genius, once explained) and yet it was also so powerful. I reveled in the shear audacity of the idea — from shadow lengths to the circumference of the Earth. Here was the stamp of human imagination, and here was the "measure in all things" as espoused by Horace.

It is 6:20 a.m. The weather, as per usual in Saskatchewan, is not cooperating; the sky is a uniform gray. The forecast, however, is for intermittent clear spells with perhaps an occasional shower. I have set up the first of the sundials in our back garden and Georgette (my wife) *will make one set of observations from there.*

The clock has just rounded 7 a.m. and I am traveling north out of Regina, heading for Star City, on highway number 6 (see Figure 1). *I will set up the second sundial there, and a better-named location from which to make my measurements I could not hope to find. The skies are still overcast and an intermittent light rain is falling.*

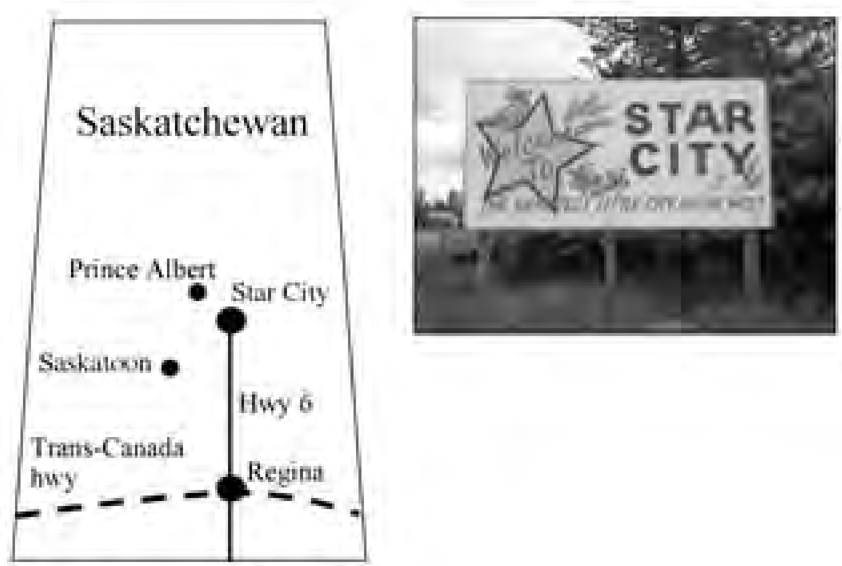

Figure 1 — Schematic map of Saskatchewan showing the sundial locations at Regina and Star City.

There is something wonderfully compelling about the astronomy practiced by the ancient Greek philosophers. Their Universe was simple, elegant, compact, and completely known — indeed, it was almost everything (elegant aside, perhaps) that our modern-day Universe isn't. In keeping with his time the calculation performed by Eratosthenes was new, bold, and highly imaginative. He began from the principle that the Earth was a sphere and from there through the application of elementary geometry, and three actual measurements, he derived the girth of our home world. Incredible!

Eratosthenes was born circa 275 BC in Cyrene, a then Greek city on what is now the North African coast of Libya. In later life he moved to Alexandria and distinguished himself as a librarian, philosopher, poet, and athlete[1]. No fragments of Eratosthenes' original writings concerning the measure of the Earth have survived to the modern era, but an account of his procedure is given by Clemodes in his *On the Elementary Theory of the*

[1]Eratosthenes was also a well-known and celebrated mathematician. Indeed Archimedes specifically records that Eratosthenes described an instrument capable of duplicating a cube, and that he also developed a set of rules for generating prime number tables — via the so-called sieve of Eratosthenes. In later life Eratosthenes lost his eyesight and, refusing to live if he could not read, he committed suicide in 194 BC.

Heavenly Bodies. Clemodes explains that Eratosthenes' method made specific use of observations relating to the altitude of the Sun[2]. In particular Eratosthenes noted that in Syene (now the city of Aswan) the Sun was directly overhead at noon on the day of the summer solstice, while in Alexandria, some 5000 stades to the north, the Sun was 1/50 of a circle away from the zenith[3]. With these pieces of information, admittedly none of which, as far as we know, were actually measured by Eratosthenes, he was able to determine that the Earth had a circumference of 252,000 stades[4].

It is 9:34 a.m. I have just arrived in Watson, over half way to Star City. The weather is beginning to improve. I can at last see clear breaks of blue sky.

It is 10:33 a.m. and I have stopped for coffee at Melfort. I am now just a few tens of kilometres from Star City, and the wind is howling. Dirty-gray and ominous heaps of cumulus clouds cover most of the sky — but clear breaks are visible. During the past hour the Sun has occasionally blazed out from between clouds, but typically for just a few tens of minutes. The weather isn't perfect, but we should be able to work around it. Cell phone contact with Regina indicates that it is clear and sunny there.

It is 11:45 a.m. and I am standing by my car. It is parked on a diagonal in an attempt to act as a windbreak. The sundial has been set in place and its base has been leveled (see Figure 2). *I am situated some 10 km north of Star City, at a roadside turnoff. It is a desolate spot; the wind is gusting over the open fields and the verge-side grasses are rippling and bending wildly in its path. I catch my breath — now for the first measurement. I call through to Regina and the first simultaneous twin marking of sundial shadow lengths is achieved at 11:47 a.m.*

Figure 2 — The portable sundial as setup near Star City.

It is 11:55 a.m. and a brooding mass of dark cloud has moved overhead. A heavy rain has begun to fall and the sundial has just been blown over by a tremendous blast of wind. I rush to get the sundial safe inside the car — I don't want its wooden frame to get wet. Oh, well, no one said that measuring the Earth was going to be easy. We have one data set already, and moving the sundial is not a great problem since it is shadow lengths that we are measuring, not relative shadow motion. I have moved the car to place it as a better windbreak.

It is 12:22 p.m. The rain has cleared away, the wind has dropped to a whisper, and we have just successfully completed another simultaneous shadow length measurement. The air is pungent with the smell of rain-washed earth. It is as if a deep and refreshing breath has been drawn in by the land with the exhalation held back, for just a few short minutes, in order to stay the invigorating enjoyment of the moment. I can't help but feel that this must be something like the astronomy of the ancients: out on the land, feeling and sensing the solid Earth beneath one's feet.

It is 2:00 p.m. A steady rain has begun to fall and I am now ready to head for home. We have gathered simultaneous shadow length measurements at 1:00, 1: 12, and 1:43 p.m. A good haul of data points — I hope.

It is 6:26 p.m. Home! The drive back has been long and bothersome. I am tired. A check of the odometer reveals a distance of 287.8 km between the Regina sundial station and that at Star City[5]*. I will rest for an hour and then turn to the numbers.*

Table 1 is a summary of the measured shadow lengths and resultant Sun altitudes from Regina and Star City. For the purpose of measuring the Earth, it is the difference in Sun altitudes, α, that is important.

The essential geometry of the measurements made at Regina and Star City is shown in Figure 3, and just as Eratosthenes would have calculated it, the circumference of the Earth is given by the formula

$$\text{Circumference} = 2\pi R_{\otimes} = (360 / \alpha) \times D\,(\text{km}),$$

where *R*≈ is the Earth's radius and *D* is the distance between Regina and Star City in kilometres. From my car's odometer

[2]See James Evans, *The History and Practice of Ancient Astronomy* (OUP, Oxford, 1998, pp.63-66). While Eratosthenes' calculation was based upon measurements supposedly gathered at noon on the day of the summer solstice, the calculation can be made on any day of the year. In addition to using the Sun to determine the latitude difference between two observing locations, one can also use star altitudes at their lower culmination. Posidonius *ca.* 100 BC, for example, used observations of the bright star Canopus, as seen by observers at Rhodes and Alexandria, to deduce that the Earth's circumference was some 240,000 stades.

[3]The 1/50th of a circle measurement is equivalent to 360 / 50 = 7.2 degrees.

[4]Stades are a well-known problematic unit in the sense that they have no standard. Zdenek Kopal in his *Widening Horizons* (Taplinger Publishing, New York, 1970, p. 18) argues that 1 Stade is equivalent to about 1/6th of a kilometre. If this conversion is correct then the radius of the Earth as deduced by Eratosthenes is of order 6317 km.

[6]This is the northing distance. I have taken off the easterly distance from Melfort to the Star City turnoff. Technically the observations should be made from locations that are on the same meridian, but a small offset to the east for the second station is not of major concern for the calculation presented here.

Time (CST)	Shadow length (mm): Regina	Altitude (deg.)	Shadow length (mm): Star City	Altitude (deg.)	α (deg.)
11:47	92.5	59.81	103.0	57.06	2.75
12:22	85.0	61.87	94.0	59.41	2.46
13:00	81.5	62.86	91.0	60.22	2.64
13:12	81.5	62.86	92.0	59.95	2.91
13:43	86.5	61.45	95.5	59.01	2.44

Table 1 — Sundial shadow lengths and Sun altitudes from Regina and Star City. Each sundial has a gnomon of length 15.9 cm, and the tangent of the Sun's altitude is simply the ratio of the gnomon and shadow lengths. The sixth column shows the difference in the Sun's altitude as measured at the two locations; ideally the difference should be a constant.

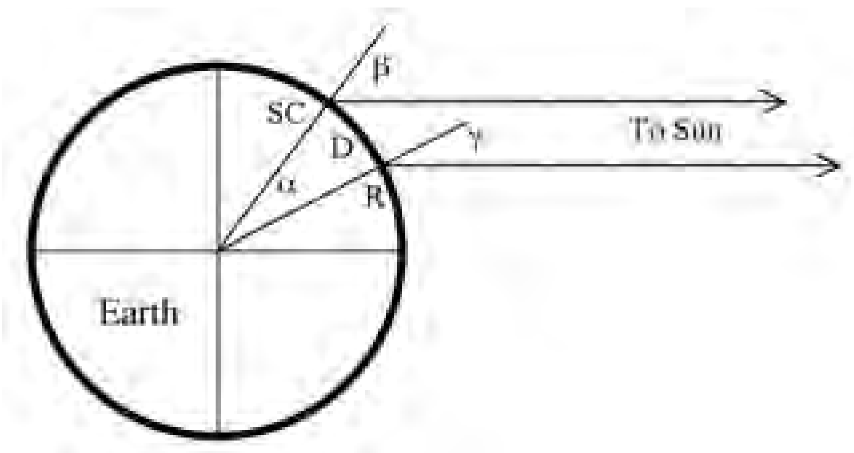

Figure 3 — The geometry for finding the size of the Earth from shadow length measurements on sundials at two locations a known distance D apart. The angle $\alpha = \beta - \gamma$ corresponds to the difference in the latitudes of the two observing locations; R and SC correspond to the locations of Regina and Star City where the angles γ and β are measured respectively.

I have $D = 287.8 \pm 0.2$ km. From column six in Table 1, I also have α (deg.) = 2.62 ± 0.12. These numbers combine to give an estimate of the Earth's radius of $R_{\otimes}$ = 6294 km, with a formal uncertainty[6] of 4.6%. The RASC *Observer's Handbook* gives the Earth's mean radius as 6371 km.

10:25 p.m. Well, not so bad a day's outing. Have measured the size of the Earth to within a few percent of its "correct" value, and completed, finally, one of those adventures planned many long years ago.

Martin Beech teaches astronomy at Campion College, The University of Regina. He has reached the age where many of the planned adventures of youth will have to wait in perpetuity; others, however, are being actively pursued.

[6]The uncertainty in the circumference is $\Delta C / C = \Delta D / D + \Delta\alpha / \alpha$, where we estimate ΔD = 0.2 km, and where $\Delta\alpha$ = 0.12 from the values presented in Table 1.

Percival Lowell, Lowell Observatory, and Pluto

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

This issue we have an interesting pair of anniversaries: February 18 is the 75th anniversary of Clyde Tombaugh's discovery of the planet Pluto at Lowell Observatory in 1930; and March 13 is the 150th anniversary of the birth of the founder of that observatory, Percival Lowell, almost exactly 75 years earlier in 1855.

Percival Lowell

Percival Lowell (1855–1916) came from a prominent Boston family and benefited from an education at Harvard. Graduating in 1876, he traveled to Korea and Japan to advance his family's business interests. He performed diplomatic services for the Korean Special Mission to the United States and wrote several books about East Asia. Following that, he turned his attention to astronomy, which he undertook without formal training. From 1902, he was a nonresident professor of astronomy at the Massachusetts Institute of Technology. His brother Abbott became President of Harvard, and his sister Amy was a poet and critic, receiving the Pulitzer Prize for poetry in 1926.

Lowell became fascinated with Mars and the possibility that intelligent beings inhabited the planet. He used his personal fortune to build a well-equipped, high-altitude observatory near Flagstaff, Arizona in 1894. Built atop the 2100-metre Mars Hill, the observatory included a 0.6-metre Clark refractor at which Lowell made countless observations of Mars, including features that he believed were artificial canals. (This telescope is now a U.S. National Historic Monument.) Lowell's views on Mars have been discredited by modern observations, but the myth of life on Mars lives on. The recent findings of the Mars rovers supporting the view that Mars once had flowing water have enlivened the debate.

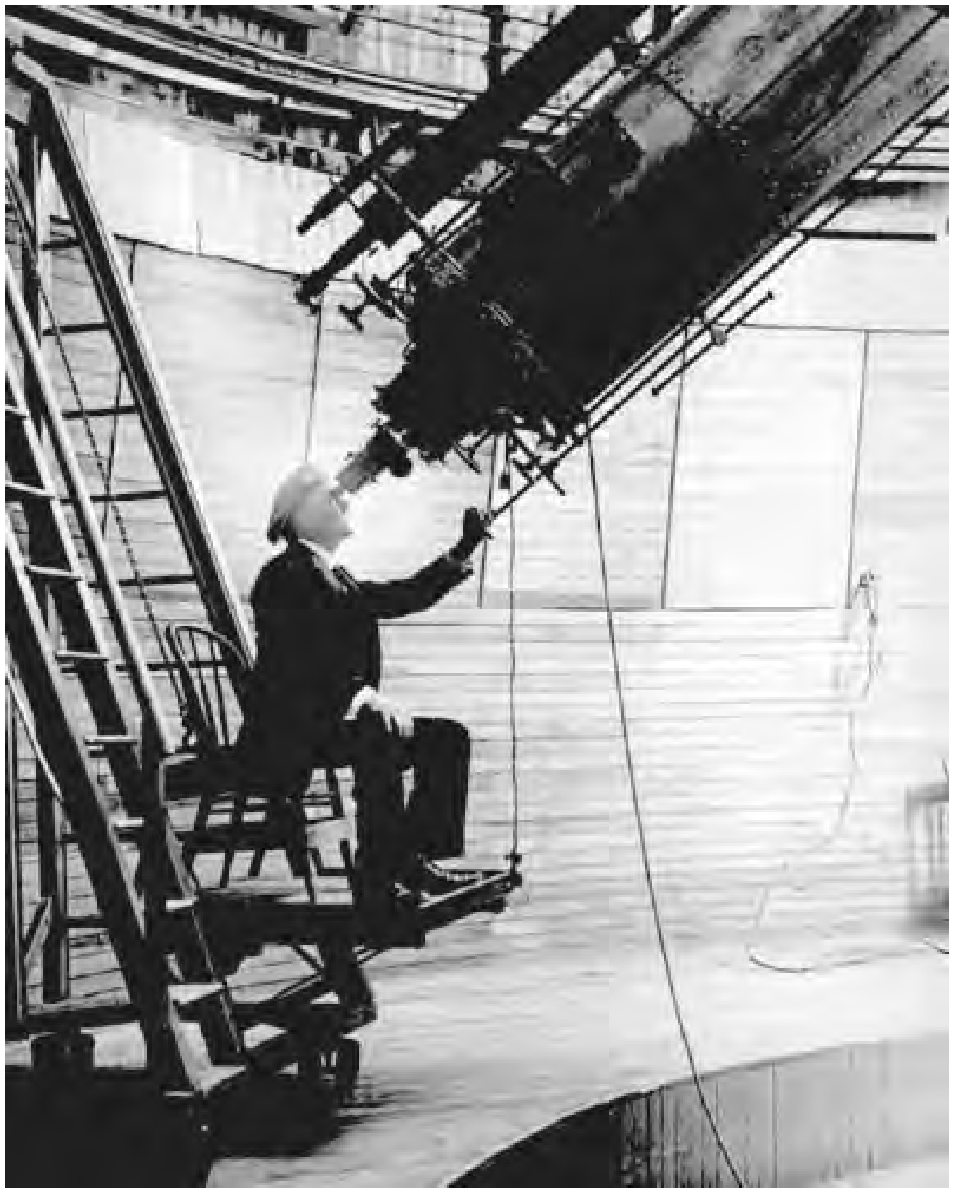

Figure 1 — Percival Lowell (1855–1916), wealthy and accomplished American amateur astronomer, at his Clark refractor.

In the July 2004 issue of *Sky & Telescope* magazine, Thomas A. Dobbins and William Sheehan argue that the details Percival observed on the face of Mars could have been a peculiar interaction of the telescope, the eye, and the brain. As a result of image-enhancing algorithms, similar features are evident in some recent digital images of Mars. Although the canal features are not physical, they are reproducible visual effects that Lowell dutifully recorded in his notes and sketches. (See the August 2003 issue of *JRASC* for an example of Lowell's findings.)

The Discovery of Pluto

Another favorite project of Lowell was the search for Planet X. He was trained as a mathematician, and he was convinced that the motion of Neptune indicated the existence of a trans-Neptunian planet. The searches began in 1905. Lowell himself was unsuccessful in locating the planet he believed to exist: the honour went to Clyde Tombaugh (1906–1997), a young self-taught astronomer who came to work as an assistant at Lowell's observatory in 1929. After about a year of painstaking effort, Tombaugh discovered Pluto as a magnitude 15 speck on a pair of photographic plates on February 18, 1930, fourteen years after Lowell's death.

Tombaugh actually exposed the discovery plates on January 23 and 29, but he discovered the apparent motion of Pluto among the stars of Gemini over the 6-day interval by carefully aligning the plates in an optical viewing device known as a "blink comparator." By rapidly alternating the view between the plates, the tiny star-like speck that was Pluto appeared to jump back and forth between its positions on those dates. The photographic search was always conducted in the region of the sky opposite the Sun, to maximize the apparent retrograde motion of any planetary object against the distant background stars. From its rate of angular motion, Tombaugh was certain that the new object was beyond the orbit of Neptune. He continued to make observations for about a month, and the discovery of PLuto (capitalization intentional!) was announced on March 13, the 75th anniversary of Lowell's birth.

Ironically, the mass of Pluto turned out to be less than 1/5 that of the Moon, too small to have the desired gravitational effect on Neptune. Although Tombaugh's search strategy was successful, the discovery was somewhat accidental. After the discovery of Pluto, Tombaugh received a scholarship to the University of Kansas, earning a bachelor's degree in 1936 and a master's degree in 1939.

Lowell Observatory Today

Other achievements at Lowell Observatory include: discovery of the expansion of the Universe; co-discovery of the rings of Uranus; and the continuing search and discovery of numerous near-Earth asteroids, comets, Kuiper Belt Objects (KBOs), and extra-solar planets. Observatory astronomers are conducting an extensive study of the photometric stability of the Sun, which is relevant to the global-warming debate. (For those who keep back issues of *JRASC*, there is more to read on this in the August 1999 *Second Light* and December 2001 *Reflections* columns.)

The latest educational project is the 4.3-metre Discovery Channel telescope (DCT), to be operated in partnership with the Discovery Channel. The DCT will be used primarily to accelerate the discovery of KBOs that orbit the Sun beyond Pluto. Find out more at `www.lowell.edu/`.

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

Weighing the Lowest Mass Stars

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

The most important property of a star is its mass, yet that often is very difficult to measure directly. Its luminosity can be determined by measuring the brightness and knowing the distance, but unless a star has a companion, its mass usually is estimated through a device known as the "mass-luminosity" relation. This is a fancy term for the rough relationship between a star's mass and luminosity. Now Laird Close, of Steward Observatory at the University of Arizona (originally from Ottawa), and his colleagues there, in Germany, Spain, and Chile, have measured the mass of a very-low-mass star. They find that the standard mass-luminosity relation overestimates the mass of such objects by a factor of about 2.5, at least when the star is young. This also means that some of the young, cool objects previously identified as brown dwarfs are more massive, and therefore the frequency of brown dwarfs and giant planets in clusters has been overestimated.

The mass-luminosity relation has its origins in the Hertzsprung-Russell diagram. This diagram plots stars' spectral type (or equivalently, their surface temperatures) against its luminosity. The "main sequence" is a band of normal — not giant — stars stretching from the brightest and hottest to the dimmest and coolest. The H-R diagram has been a very useful tool for professional astronomers for almost 100 years, because — once it has been calibrated with some known masses — it can be used to estimate masses of other stars, and their distances, from just a picture and a spectrum. The low-luminosity end of the H-R diagram has been very poorly calibrated, because of the difficulty in observing those stars, so it is constrained only by the theory of stellar structure.

Mass is the single most important quantity for most stars because that determines the temperature and pressure of the gas at the centre, through the self-gravity of all the hydrogen in the star. The temperature and pressure regulate the rate at which energy is generated, as hydrogen fuses to form helium. The end of the main sequence is determined by the point at which hydrogen can no longer fuse, although in young low-mass objects, known as brown dwarfs, deuterium fuses down to lower temperatures. Deuterium is hydrogen with a neutron in the nucleus, and it fuses more readily than normal hydrogen.

The physics of fusion is quite well understood, the central temperature and pressure fairly well understood, but the atmospheres of low-mass stars are very poorly understood indeed, which allows for a lot of uncertainty in the mass-luminosity relation. Hot stars have only ionized elements in their atmospheres, which are not particularly efficient at absorbing photons from the surface. What astronomers call the "radiative transfer" problem is quite simple to resolve.

When a star becomes very cool, however, molecules and even dust can form in its atmosphere, enormously complicating the job of figuring out what its true total (bolometric) luminosity is. An everyday analogy to illustrate the problem can be seen looking at our Sun through the atmosphere. When the Sun is high in the sky, some of the blue photons are scattered out of the line of sight (enough to make the sky blue), but the Sun appears white. When it is setting, the light has to travel a much longer path through the atmosphere, encountering many more molecules and dust grains, which effectively remove all of the blue photons — therefore the Sun appears red. The Sun itself is the same, but what we see has changed. A related process happens to the low-mass stars. We know approximately how much total energy has to come out (from theory), but the wavelengths at which it comes out varies dramatically according to what is in the atmosphere.

This is why an absolute calibration of the mass-luminosity relation is so important. I mentioned earlier that the only time astronomers can measure directly a star's mass is when it has a companion, like in a binary star system. Close and his companions have developed a new adaptive-optics camera that, when mounted on the Very Large Telescope in Chile, enabled them to find a very-low-mass star orbiting the star AB Doradus. The companion (AB Dor C) is more than 100 times fainter than AB Dor A, and only 0.156 arcseconds away. At the distance of AB Dor, that's just 2.3 AU from the star (about the distance of the asteroid Vesta from the Sun). An interesting sideline to the main story is that the *Hubble Space Telescope* tried — but failed — to detect the companion, whose presence was expected based on tiny wobbles in AB Dor's position on the sky. This underscores the power of adaptive optics and large ground-based telescopes!

Using the published data on AB Dor's wobbles, the observed position of the companion, and the mass of AB Dor, Close was able to determine that the companion's mass is a tiny 0.09 solar mass, or about 94 Jupiter masses, which is just above the level of a brown dwarf. He then obtained a spectrum to determine very precisely the star's spectral class, which turns out to be M8. Through a rather complicated process, he finds that the predicted mass for such a star with the age of AB Dor C is a factor of 2 lower than its measured mass. This means that the heavily hyped free-floating cluster planets may well be misidentified low-mass brown dwarfs.

The final conclusion drawn by Close is that his work illustrates the danger of using theory that has not been calibrated by observation — a lesson that should be learned by one and all, whatever your field.

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.*

FROM THE PAST AU FIL DES ANS

A REMARKABLE AURORA ON AUGUST 7, 1906.
FROM NOTES TAKEN AT SHEBESHEKONG, SIXTEEN MILES NORTH-WEST OF PARRY SOUND

While watching the sky this evening a brilliant display of Aurora took place, beginning at 8.50. Streamers of beautiful light green shot up to about 40°. At first they changed rapidly, flashing up occasionally to a point near the zenith, no color but green being visible, but after a time they settled down to a large arch of glowing light without any visible motion. The arch extended from north-west to north-east, and at its centre was about 20° above the horizon. At 10.30 it was still visible. At the time the Aurora began, a large bow of light appeared in the north-east, seeming to spring up from the Aurora, and gradually but slowly extended upwards across the sky to the zenith and down to the west until it reached the horizon. It was from 3 to 4 degrees in width, came up in the north-east through the Dolphin, crossed the Milky Way at about right angles slightly south of the zenith, and slightly south of the head of Cygnus, covered Corona Borealis and Arcturus and extended westward to where Venus had been two hours before in the ecliptic.

When it began in the north-east it had the appearance of a bright tail of a comet but much wider. It looked like a long extended cloud lighted up by the Sun, very much brighter than the Milky Way. It had no motion, but remained in the same position all the time. It arched the whole sky without a break. Breaking up first in the zenith it gradually but slowly dissolved, and at 10.30 had disappeared.

Whether this phenomenon had any connection with the weather or not I cannot say, but it rained all night on the 9th and all the next day, the 10th.

by J. McEachren
from *Journal*, Vol. 1, p. 42, January-February 1907.

METEOR AND AURORA DETECTION USING MODERN VIDEO TECHNOLOGIES

BY

MARTIN CONNORS
Athabasca University
Electronic Mail: martinc@athabascau.ca

MIKKO SYRJÄSUO
University of Calgary
Electronic Mail: mikko@phys.ucalgary.ca

PETER BROWN
University of Western Ontario
Electronic Mail: pbrown@uwo.ca

AND ERIC DONOVAN
University of Calgary
Electronic Mail: eric@phys.ucalgary.ca

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ABSTRACT. It is now possible to inexpensively monitor the night sky using video technologies, and both amateurs and professionals can contribute to science by doing so. Two night-sky events that illustrate this were detected from Athabasca, Alberta, and coincidentally took place at local times on October 1 of the years 2002 and 2003. The 2002 event was a bright aurora detected by a "meteor" camera, which we describe in terms of current auroral theory. The 2003 event was an unusual fireball recorded both by the automated meteor camera and by a new auroral camera. We suspect that this was a rare Earth-grazing fireball, but the position in the sky and lack of other instrumental records do not allow us to determine this or the orbital parameters with great accuracy. The planned THEMIS research network of auroral cameras should secondarily contribute to bolide research, and gaps in its coverage could be filled by amateurs. Equipment used for automated detection of meteors is described in sufficient detail that others could build it.

RÉSUMÉ. La technologie actuelle des caméras vidéo permet de surveiller le ciel nocturne de façon continue à des prix modiques. Ceci permet aux amateurs comme aux professionnels de contribuer à la science. La nuit du 1er octobre nous a livré des surprises les deux années consécutives de 2002 et 2003. En 2002 une aurore boréale intense a été detectée par une caméra d'observations des météores. Nous expliquons ce phénomène suivant la théorie actuelle des aurores. En 2003 un bolide extraordinaire a été enregistré par cette même caméra (à Athabasca, en Alberta) et par une nouvelle caméra d'observations des aurores. En ce cas il s'agissait probablement d'un bolide frôlant l'atmosphère sans tomber, mais d'après les données disponibles il n'est pas possible d'en être certain, ni de déterminer avec précision son orbite. Nous concluons néanmoins qu'un réseau de caméras pour la recherche des aurores boréales serait utile aussi pour localiser des bolides. Nous donnons ici suffisamment de détails sur nos caméras de détection automatisée des bolides pour que ceux qui désirent entreprendre des recherches sur les bolides ou tout simplement enregistrer les phénomènes du ciel nocturne puissent les construire eux-mêmes.

1. Introduction

Meteor observing with automated cameras has a long history in Canada. MORP (Meteorite Observation and Recovery Project; Halliday *et al.* 1978) used sophisticated film-based cameras to determine orbits of meteors and to aid in finding meteorites. Similarly, aurora photography and motion picture recording has been in use for a long time with custom built (Brown *et al.* 1976) or specialized image intensifier cameras (Trondsen & Cogger 1998). Simple tape-based video recording equipment for the purpose of studying bright meteors was recently discussed in this *Journal* (Connors *et al.* 2003). We have found that the low-cost equipment used in those meteor cameras was also excellent for monitoring bright aurorae. Overall, the cost of monitoring the night sky has dramatically declined over the decades, due largely to improvements in technology. Specifically, low-powered, sensitive detectors are commercially available and inexpensive lenses allow a wide field of view. We will show here that use of computers and digital video further decreases the cost, and importantly also the effort, of running a sky monitoring network. Video techniques at various levels of sophistication can be used for monitoring meteors and aurorae, blurring the distinction between amateur and professional efforts.

The scientific motivations for bolide and for auroral observing differ. Bolides are of interest largely since they may produce meteorites. Good observations from the ground can allow the fall zone to be accurately determined, facilitating finding them. The observations also allow the orbit to be determined, giving valuable information about the origin of these rare samples from space (Wasson 1985). The recent Neuschwanstein fireball and meteorites are a good example, with intriguing questions raised by the orbit's similarity to that of the well-known Pribram meteorite (Spurny e*t al.* 2003). While bolides are rare, aurorae are commonly seen in the large part of Canada lying in the auroral zone. However, many fundamental facts about the physics behind the aurora remain mysterious (McPherron 1995). Questions yet to be answered include the origin of the auroral arc itself and the larger framework in which aurorae occur, particularly the most active and dramatic ones associated with the auroral "substorm."

We illustrate the various detection methods by discussion of an auroral event detected by meteor cameras, and of a meteor event detected by both a meteor camera and an auroral camera. These events each took place on October 1, MST. The auroral event took place in 2002, while the meteor was detected in 2003. We will first give a brief discussion of the aurora relative to the current knowledge of auroral phenomena and theory. Analysis of the meteor event, to the extent possible based on images from only one location, follows.

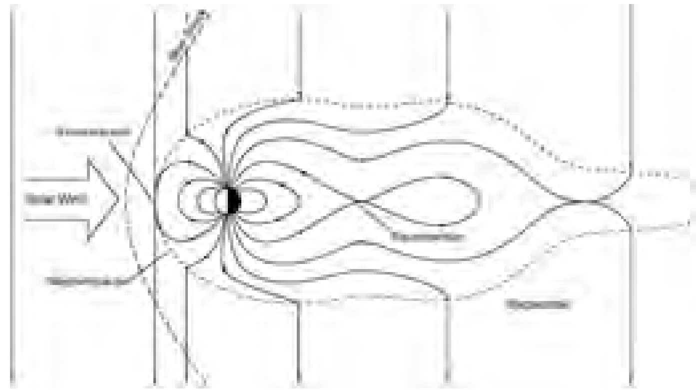

Figure 1 — Earth's magnetosphere and the solar wind, with magnetic field lines shown as solid lines with arrows. The solar wind compresses Earth's magnetic field on the (sunward-facing) dayside (left), and stretches it out into a magnetic tail on the night side (right). Energy can be stored in the magnetotail and unloaded into the near-polar atmosphere (often in substorms) to cause aurorae. The dominant physical process, reconnection, is not discussed in this article, but is thought to be most effective when the solar wind magnetic field points southward, as shown in this highly schematic diagram. Courtesy United States Geological Survey.

2. October 1-2, 2002: Aurora Detected with a Meteor Camera

Auroral activity is the indirect result of energy injected into near-Earth space by the solar wind. This thin gas typically carries about 20 particles cm^{-3}, of which half are electrons and half protons (hydrogen ions). Usually some other elements are also present. It flows past Earth at speeds typically approaching 500 km s^{-1}. The interaction with Earth is partly due to the fact that the solar wind also carries a magnetic field, and this interaction is strongest when that field at least partly points southward. Much of the energy is stored in a comet-like magnetic tail, the magnetotail, on the opposite side of Earth from the Sun (see Figure 1). Changes in the magnetic configuration can result in energy flowing into the near-polar regions, producing aurora. Often this takes place in a process known as a substorm. The exact details of substorms are not understood; however, they are usually divided into growth, expansive, and recovery phases. These correspond respectively to periods of storage of energy, its explosive release, and subsequent reconfiguration.

Figure 2 shows the northward-pointing part of the magnetic field embedded in the solar wind on October 1-2, 2002, as measured by the *ACE* (Advanced Composition Explorer) solar wind probe, located at the L_1 Lagrange point between the Sun and Earth. Early in the universal time (UT) day (from 0 to 3 UT on the figure) of October 1, the magnetic field pointed northward, as shown by positive values in the figure. Referring to Figure 3, which shows the magnetic field measured on the ground at Yellowknife in northern Canada, the period corresponding to northward magnetic field as measured in the solar wind by *ACE* has very flat traces. It is well known, and will be clear from discussion below, that the aurora produces a magnetic field. These flat traces, with little magnetic activity, in turn indicate little auroral activity at that time. However, after the solar wind magnetic field started to point southward (around 3 UT), as indicated by negative values in Figure 2, the magnetic field on the ground became

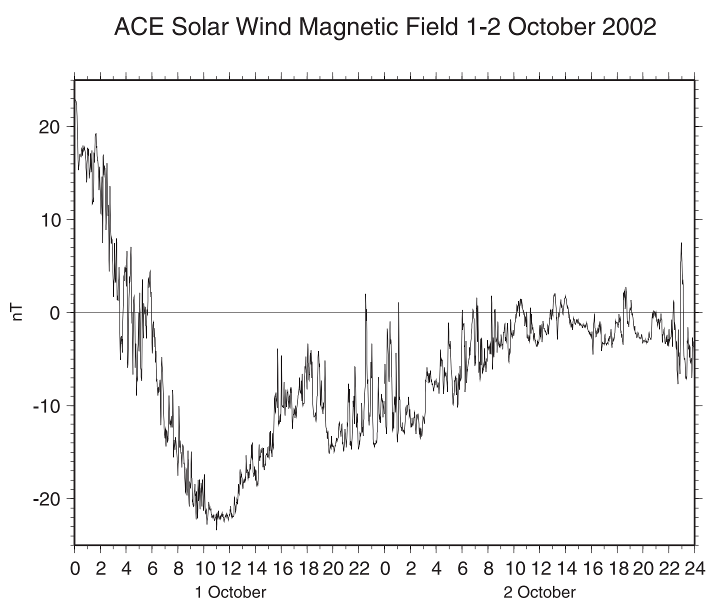

Figure 2 — Solar wind magnetic field as measured by the *ACE* satellite on October 1-2, 2002 (UT), plotted against UT (in hours) on the two days. The unit of magnetic field strength is nanotesla (nT). The northward component only is shown. The magnetic field affecting Earth is delayed by the approximately one hour that the solar wind takes to travel from *ACE* to the magnetosphere. Courtesy UCLA solar wind data centre.

disturbed, as indicated by all three traces of Figure 3. Noting that the increased magnetic activity is closely tied to the solar wind magnetic field turning southward supports the idea that the interaction of the solar wind with Earth is strongest under those circumstances. Comparing Figure 2 to Figure 3, it can be noted that the relative changes in magnetic fields at Yellowknife are much larger than those at corresponding times in the solar wind. This is largely due to solar-wind energy being stored near Earth: much of it is released impulsively in substorms, and the large electric currents they produce near some point on the ground (Yellowknife in this case) can cause a much larger magnetic field than those present in the solar wind to "drive" the system. For example, the large changes at 13:30 UT, in all components of the magnetic field shown in Figure 3, indicate the onset of the expansive phases of a substorm.

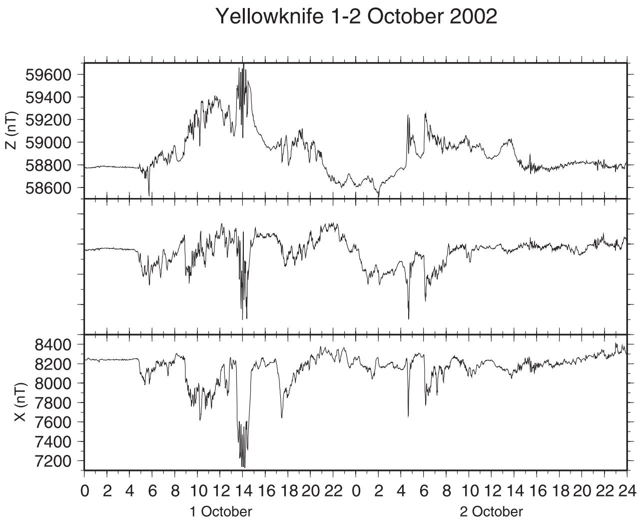

Figure 3 —Magnetic field at Yellowknife on October 1 and 2, 2002 (UT). *X* is the geographic northward and horizontal part of the magnetic field, *Y* the eastward and horizontal part, and *Z* the vertically downward part. At this latitude Earth's magnetic field is directed almost vertically downward, so *Z* is much greater than *X* or *Y* and approaches the total field strength of about 60,000 nT. Courtesy NRCan.

Substorms have varying lengths and characteristics. The one mentioned above, starting at 13:30 UT on October 1, lasted about 1.5 hours and ended relatively abruptly as observed at Yellowknife. By examining Figure 3 more closely, we can note some general information about substorms and Earth's magnetic field to give background for the specific event discussed below. Earth's magnetic field may be conveniently measured in nanoteslas (nT). The total field in Canada averages about 60,000 nT and much of it is directed vertically downward. Thus the values indicated for the *Z* (vertically downward) part of the magnetic field approach the total value. The 13:30 UT substorm produced about a 10% change in the horizontal parts (*X* and *Y*) of Earth's magnetic field, but only about a 2% change in the total field, since the change in *Z*, relative to its large magnitude, was small. We noted above that magnetic activity observed at the ground increased when the solar wind *Z* component (Figure 2) became negative. This substorm took place while this was still true, and there was no obvious change in the solar wind magnetic field at the time the substorm started. This supports the concept that the energy release after storage is often through an internal and possibly chaotic process not closely linked to "triggers" in the solar wind. The details of triggering, or lack thereof, are controversial and will not be further discussed here. We now proceed to discuss the substorm that took place at 04:24 UT on October 2, 2002 and was recorded by the meteor camera at Athabasca.

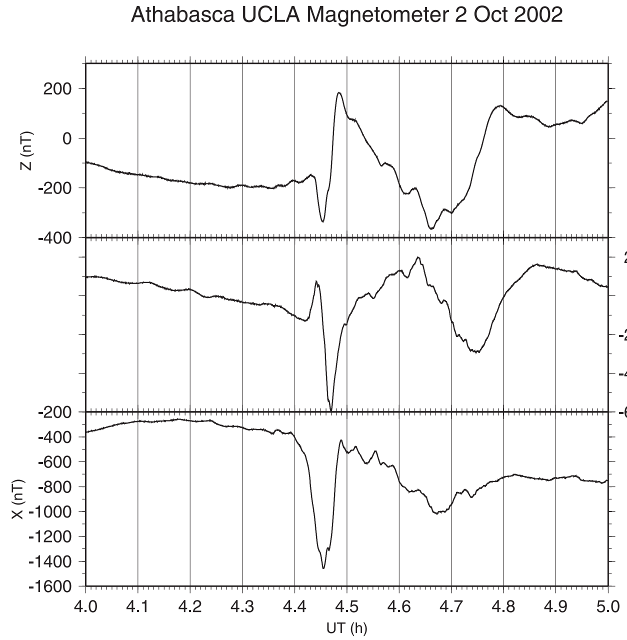

Figure 4 — Magnetic perturbations at Athabasca on October 2, 2002 (UT). Components of the magnetic field are as in Figure 3 but in local magnetic coordinates (in which a compass would point northward). The negative change in the northward component starting at 4.4 UT (4:24) indicates the onset of a magnetic substorm.

Figure 4 presents magnetic data from the Athabasca University precision magnetometer. The most notable feature is the large decrease (by about 1000 nT) of the *X* (northward) part of the magnetic field at 04:24 UT on October 2, 2002. This is a substorm onset signature, much as described above. The other components of the local magnetic field at Athabasca were affected by this onset also. We note that that the *Z* (vertically downward) component did not initially change at the time of large *X* field change. This indicates that the initial electric current associated with the auroral onset was overhead, since a current directly overhead does not create a vertical magnetic field. A closer examination shows smaller changes in the magnetic values in the hour preceding the onset, and a pre-onset decrease in *X* starting at 04:12 UT. These are associated with the growth, or energy storage, phase of the substorm. We now examine the visual light auroral signatures of this substorm, and their relation to the magnetic changes. The automated meteor camera system (described below) was set for very high sensitivity on this date and captured many frames. Some of these are shown here in Figure 5: all were placed together in sequence to make a video clip of the auroral event, which was also useful in our analysis.

In Figure 5, frame (a) shows pre-onset auroral activity. These faint aurorae were recorded at 03:45:15 UT, during a depression in the *X* magnetic component, known as a "bay." The end of the bay is visible in Figure 4 where the *X* component is initially rising (until about 04:10 UT). Such a bay (the overall depression in this one was about 200 nT) often accompanies dynamic but faint aurorae. The next frame, taken at 04:00:18 UT, shows the situation after formation of a single homogeneous arc in the south. The appearance of this arc

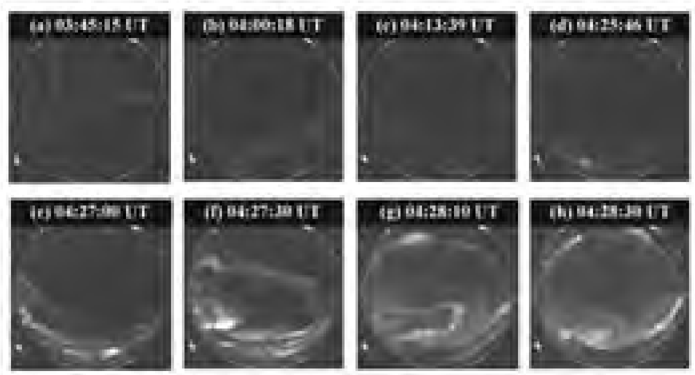

Figure 5 — Frames captured by an automated meteor camera at Athabasca on October 2, 2002 (UT), with times given in UT. These record the auroral event of that evening. South is at bottom, west at right as would be seen by a person facing southward. Lights around the edge are university building lights.

a) 03:45:15: Pre-onset activity during magnetic bay of 200 nT.
b) 04:00:18: Formation of single homogeneous arc to south.
c) 04:13:39: Precursory activity.
d) 04:25:46: Breakup arc in southeast.
e) 04:27:00: Westward traveling surge has passed south of Athabasca. Poleward border arc system intruding from east.
f) 04:27:30: Near extreme *X* perturbation, poleward border arc system has steadily moved northward, and is seen above the centre of the image. The box has picked out the brightest region of moving aurora.
g) 04:28:10: After extremal *X* perturbation, poleward border intensification slightly east of north.
h) 04:28:30: PBI has now moved to west of north. Second PBI in NE (explains double *Z* perturbation at Yellowknife).

coincided with the magnetic bay starting to decrease in strength. In the next frame (c), taken at 04:13:39 UT, the homogenous arc has moved further south but become fainter. Aurora also is seen to the north of the arc and is brighter in the east. The next frame (d), taken at 04:25:46 UT, shows the initial brightening associated with the expansive phase of this substorm. This brightening started up to two minutes after the start of the steep decline in magnetic field marking onset. Substorm timing is very controversial (Liou *et al.* 2002; Baker *et al.* 2002) and plagued by "aliasing" effects, often due to images being taken less frequently than the timescales in the events they are meant to depict. In this case we can claim that the intelligent camera actually caught the exact moment of the breakup arc. In the worst case, we find that the breakup arc was not present in the previous image, taken at 04:24:58 UT, while this image was taken at exactly 04:25:46 UT. Close examination of Figure 4 leads us to claim that the magnetic onset was very close to 04:24:00 UT. Clocks for the camera were set using Network Time Protocol (NTP), accurate to much better than a second. Those for the magnetometer were set using continuous Global Positioning System (GPS) monitoring, with even better precision. Thus the observation of a difference in onset time is not likely due to clock error.

The location of the breakup arc also tells a lot about the substorm process. It is in the southeast. This indicates, first, that the auroral activity was concentrated east of the meridian of Athabasca, a conclusion supported by noting that magnetic stations to the east recorded a longer-duration magnetic event. Indeed, this is expected, since it is known that substorm onsets result from energy stored in the magnetotail of Earth, and this region is overhead roughly at midnight. This event took place in the late evening hours at Athabasca, thus midnight would have been toward the east. A further implication of the southerly location of the brightening, relative to Athabasca, is that the initiation of onset was very close to Earth. Magnetic field lines from Athabasca can be traced out into the magnetosphere and get to be only about five Earth radii away. Thus the earliest stages of this substorm expansion took place even closer to Earth than this.

The fifth selected frame, Figure 5(e), shows how the initial brightened region has traveled westward, passing south of Athabasca. This frame was exposed at 04:27:00 UT and many intervening frames allow verification that the bright region moved smoothly westward. This leads to identification with the "westward traveling surge" (Marklund *et al.* 1998). That feature has been identified with strong upward electric currents moving along magnetic field lines. The evidence of this can be seen in the *Y* component negative perturbation near this time in Figure 4. If a near-vertical, upward flowing electric current is south of the magnetic detection station, a negative (westward) perturbation is expected, as seen there. This frame also features a new auroral arc system intruding from the east. This appears to be associated with the northern border of the aurorae. Inspection of intervening frames indicates that it moved smoothly northward. Such expansion is typical of the "bulge" region of an auroral substorm expansive phase as seen from satellite images (Liou *et al.* 2002), with the direction of motion as expected when west of the main activity. The satellite images are usually not spaced closely enough in time to allow verification that the motion is smooth. While we cannot see the entire picture with our limited field of view, our rapid exposure rate allows us to see the smoothness of the motion, using frames not shown here.

Frame (f) was taken only 30 seconds after frame (e), yet the aurorae appear very different. The surge feature in the southwest has dimmed and the southerly arcs are now in three distinct bands. A possible new westward traveling surge is coming in from the east. This is the brightest feature, and the motion-detection system has drawn a box around it to indicate so. This very active time was also that of the most extreme magnetic perturbation. The poleward border-arc system has steadily yet rapidly moved northward, with some westerly motion as well.

Another 40 seconds later, as shown in frame (g), there has again been dramatic change in the auroral configuration. The magnetic perturbations were already decreasing at this time, yet the southern aurorae remained bright and active. An interesting feature is the bulge in the rather distinct northern arc system. This may be identified as a poleward border intensification (PBI), a relatively recently recognized form of auroral activity. In this frame it is located slightly east of north. Rostoker (2002) noted a tendency for PBIs to follow substorm onset. The last frame (h) was exposed only another 20 seconds later, and the PBI has now moved to west of north. Intervening frames (not shown) allow us to know that the motion across the north was smooth. A second PBI is apparent in the northeast. Figure 3 shows that Yellowknife, 900 km north, had a similar magnetic *X* perturbation to that observed at Athabasca, but at 04:30, several minutes later. Since we have shown, and it is well known, that polar expansion takes place, one might conclude that the same current system had moved north and crossed over Yellowknife. This is known to happen (Connors 1998) but did not in this case. The auroral video, with its range of view extending to near Yellowknife, shows that instead the similar signatures arose from opposite borders of the auroral display, one an expansive phase onset, one a PBI. Since expansive phase and PBI magnetic signatures arise from different physical origins (Connors 1998; Rostoker 2002), the video record is a vital adjunct to avoiding confusion in interpreting magnetic data.

We have discussed this auroral event in some detail and it is in some ways prototypical, although it took place on a very rapid timescale. Visual observers could expect to see many of the features discussed. We have shown the advantages of a motion detection system in that it may respond to bright auroral features as needed. We note that this sequence of activity would be difficult to decipher based on magnetic records alone. We now proceed to a meteor event where images from an auroral camera complemented the results from the meteor camera.

3. October 1, 2003 (MST) Fireball

Authors MC and MS were testing auroral video instruments from inside the newly constructed Athabasca University Geophysical Observatory on the evening of October 1, 2003, and set off automated imaging sequences on the THEMIS (Time History of Events and Macroscale Interactions during Substorms; see below) black and white imager and an experimental colour auroral imager. They then took a break to watch the fairly weak aurora in progress and to observe Mars with a telescope, from east of the observatory. Looking up at 23:38 Mountain Daylight Time (MDT), they saw a bolide in the western sky, which traveled so slowly and lasted so long that it was possible to run to the west of the building and see the entire event. The object was greenish in colour, cast shadows, and faded without any evidence of fragmentation. No sound was heard and the object was close to the horizon. Remarkably, it was later verified that the bolide lasted over 20 seconds.

Since the meteor camera instrumentation is online, it was immediately possible to link up to the Athabasca meteor camera (which was on top of the nearby main building of the university) and verify that many exposures were automatically taken. It was also rapidly verified that the all-sky THEMIS system captured the event, while the colour camera under test, with a more restricted field of view, did not. Unfortunately, the other cameras of the northern Alberta fireball network were, for various reasons, not operational, meaning that we have video observations from only one location for this unique event. Several visual reports came in, allowing us to determine that the object flew nearly over Valleyview, about 200 km northwest of Athabasca, but these were too few and of too low quality to allow us to adequately supplement our instrumental data and determine the exact path of the fireball. The quality of images and unique means of acquiring them led us to determine just how much information we could extract from the data set.

Figure 6 shows the fireball in a composite made using five frames from the THEMIS imager. The imaging rate was one frame per five seconds, and the exposure time was one second per image. As captured on these frames, the meteor was trailed due to its motion. The sensitivity of the device is shown by the fact that the Milky Way and stars to at least fourth magnitude are visible. Ironically, this is extremely important in bolide detection. Even though bolides of interest are typically of at least −8 magnitude and easy to detect with almost any instrument, calibration on stars is needed to allow directional information to be deduced. It at first appears as if the extreme sensitivity of the THEMIS

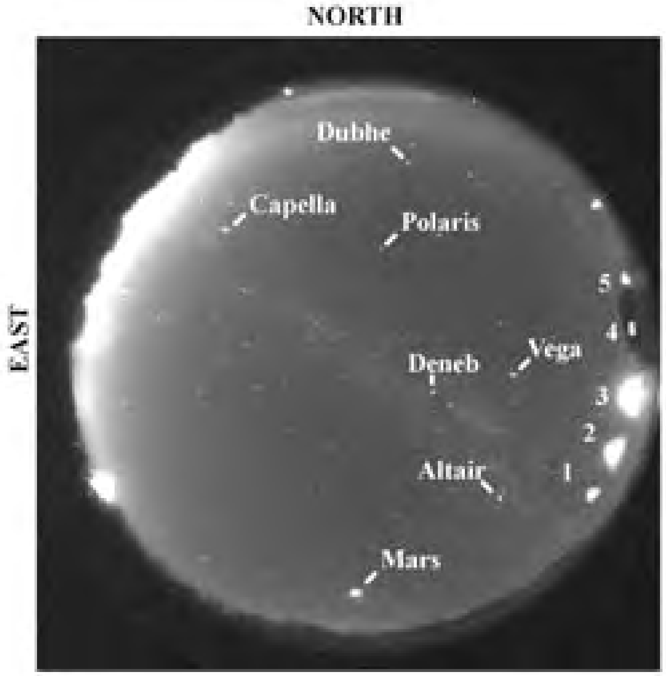

Figure 6 — Annotated all-sky image from THEMIS camera. Positions of the meteor are indicated by numbers, with times in Mountain Daylight Time zone: (1) start — approximately 23:38:15; (2) brightened meteor with the trail widened by blooming; (3) brightened meteor, at this time casting shadows, at least −8 magnitude; (4) passing behind tree; (5) fading out *ca.* 23:38:35. The light beyond position 5 is on the horizon. The camera is fairly well aligned with north at top, west at left. Selected celestial references are marked and the Dipper to the right of the "pointer" star Dubhe, with the handle pointing toward a ground light but with Arcturus invisible, having set. The Milky Way crosses the image diagonally. Limiting magnitude is beyond 4. This image is a composite made by retaining the maximum value at a given pixel from each of the five frames, to enhance visibility of the meteor.

camera has acted against an application for bolides, since the very bright bolide (and also Mars) "bloomed" and became quite wide in the image. Here another aspect of THEMIS comes into play: it has a 16-bit digitizer, giving a very wide dynamic range. This allows rescaling to show only the sharp path of the bolide. This has been done in Figure 7, where only the brightest objects remain visible and the bolide's path is a set of narrow lines. The one-second, precisely timed exposures allow two angular position measurements per image along these lines (beginning and end). One can calibrate from the images with dim stars visible and transfer the calibrations to the rescaled images since the geometry remains the same. By sad fate, this bolide was so low that even the images with many stars do not have many near it, making position estimates worse than they would have been had it been higher. As noted, the automated meteor-detection system also functioned very well in detecting this bolide. Figure 8 shows 22 of its images co-added, each detected automatically. A small box surrounds the meteor in each image, placed by the detection system to indicate where motion occurred. The contrast is low in this type of co-adding, but Mars and some horizon lights are visible. This camera had been pre-calibrated so that directions could be determined immediately once the location of the meteor was measured on each image. Once

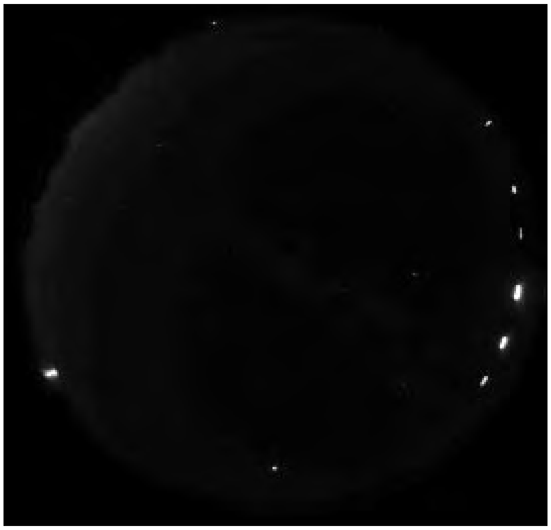

Figure 7 — Rescaled THEMIS bolide image. As in Figure 6, but the intensity has been reduced to allow the path of the bolide to be most clearly seen. Mars, horizon lights, and the brightest stars remain visible.

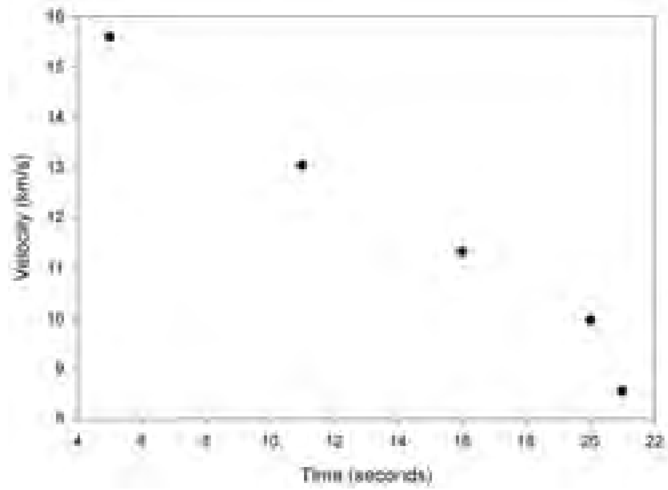

Figure 9 — Speed of the October 1, 2003 bolide based on THEMIS camera images and rough (visual) ground observations. Time within the event is given at the bottom.

again, however, the low elevation of the meteor acts against accuracy, since the uncertainty in positions is great near the horizon due to curvature of the mirror used (Connors *et al.* 2003).

Despite the good performance of the imaging systems, we have instrumental records from only one location for this event. The placement on the images available was about the worst possible. Combination with the few eyewitness reports did not produce a good data set to work with. Nevertheless, we used the measured astrometry from the THEMIS camera with astrometric reduction procedures similar to those described by Connors *et al.* (2003), in combination with two eyewitness records, to compute an approximate trajectory. The extremely long angular path of the fireball as measured by the THEMIS imager does aid somewhat. From the duration of the event alone it is clear that the entry angle must have been very shallow — our formal solution suggests a best-fit entry angle of 4 degrees, with an error of the same order. This is comparable to the entry angle of the Peekskill fireball of October 9, 1992 (Brown *et al.* 1994). The geodetic azimuth of the radiant was found to be 202 ± 12 degrees; *i.e.* the fireball traveled from the SSW to the NNE. Combined with the visual observations, those from the THEMIS imager allow approximate speed measurements to be made along the trail, as shown in Figure 9. The earliest speed was from 15-16 km s^{-1} and the last, near the end point at t = 21 s, was just over 8 km s^{-1}. The height at the last point was approximately 50 km. As fireballs usually remain luminous until end velocities of ~4 km s^{-1} (Borovicka & Kalenda 2003) we suggest this implies that the object completely ablated by this point. The approximate decelerations observed along the path are consistent with a dynamic mass (*cf.* Connors *et al.* 2003) of order 100 kg at the mid-flight portion of the trail. The pre-atmospheric orbit is uncertain due to the large range of possible azimuth/altitudes for the radiant. Nevertheless, we can attempt to deduce the nature of the object. Orbits may be characterized by their Tisserand parameter, T, a quantity indicating the relation to the planet Jupiter. This parameter largely depends on the eccentricity e and semimajor axis a of a body (and to some extent on its orbital inclination). In addition, while orbits may evolve through time, if their change is primarily due to interaction with Jupiter, which is usually the case, the Tisserand parameter will change little despite possibly large changes in each of a and e. We leave the formula for T to a reference (Weissman *et al.* 2002) but note that a small a and low e result in a large value, while larger a and e result in a small value. For asteroidal orbits, generally T exceeds 3, while for cometary orbits, typically with higher a and e, T is less than 3 (Levison 1996). Thus T can be used to distinguish the likely origin, as an asteroid or a comet, of a body (such as this meteor) whose a and e have been determined, even roughly. We accordingly computed T for a series of orbits using combinations of altitude, azimuth, and speed in the respective ranges altitude = [2,10], azimuth = [10,36], and v_∞ = [12,26]. Figure 10 shows the range of T as a function of speed

Figure 8 — Twenty-two co-added meteor camera images of the October 1, 2003 bolide, from an automated meteor camera at Athabasca. Boxes are around each detected image, and Mars is clearly visible near the bottom. The horizon is surrounded by lights from this camera's position on the roof of the university. At upper right, computer-generated time stamps have been obliterated by co-adding; the large inverted time stamp at bottom has also been affected and in addition is inaccurate.

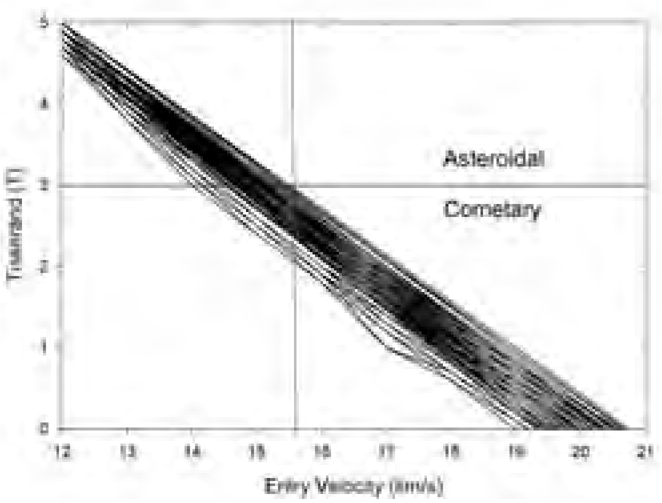

Figure 10 — Tisserand parameter for various possible orbits of the October 1, 2003 bolide.

for all altitude, azimuth combinations. The highest entry speed that has $T > 3$ and thus would correspond to an asteroid is $V_\infty = 15.6$ km s^{-1}. Our earliest measurements of the speed of the meteor give between 15 and 16 km s^{-1}, so that in most likelihood the object was a small asteroidal body. Table 1 outlines the range of probable orbital elements given our large range of altitude and azimuth combinations for the radiant and assuming $v_\infty < 15.6$ km s^{-1}. These are comparable to those of many known near-Earth asteroids with aphelion in the asteroid belt. Although this meteor was likely an unusual Earth-grazing fireball, we note that a not particularly unusual asteroidal orbit is needed to produce such an event. Since we have also concluded that it likely ablated completely, it would not have left the atmosphere as was the case for the famous daylight Earth-grazing fireball (Ceplecha 1994) of August 10, 1972.

Table 1. Heliocentric orbit of October 2, 2003 fireball (J2000.0)

Semimajor axis	a	< 2.7 AU
Eccentricity	e	0.3-0.65
Perihelion distance	q	0.97-1.0
Aphelion distance	Q	2.5-4.5 AU
Argument of perihelion	ω	0-14°
Longitude of ascending node	Ω	8.6°
Inclination	i	< 9°

Due to having good data at only one station, we are unable to say much more about this particular fireball. However, the good performance of the imaging systems leads us to believe that, as more automated fireball detection systems come into use, along with a continental network of auroral cameras (see below), much useful data about bolides will be obtained. We now describe some of the equipment used.

4. Instrumentation

Here we give a description of the imaging instrumentation used to detect sky events. These are possibly outside of the aims of the original designers since we find aurora cameras detecting meteors and vice versa. Given patience and luck, ordinary video cameras can be used to detect bolides and produce quantitative results (Connors *et al.* 2003). We have also used modern commercial video and still cameras to capture motion pictures of aurorae, with very good results. The most recent cameras will even give good colour rendition. Experimentation in this field could be very rewarding for amateurs. We have found that tape-based systems, used to detect rare events, need many tape changes and lead to the operator losing sight of the final goal. Here, we concentrate on systems that would be in place semi-permanently and produce images directly in digital form on a computer. Although vast amounts of data are produced, the operator attention required is reduced, and the viability and reliability of monitoring is increased.

The original Sandia cameras use a video camera pointing down toward a convex mirror, and are described and illustrated in a previous *Journal* article (Connors *et al.* 2003). To make an automated version, the video stream was fed to a *Hauppauge Win-TV* card of the sort readily available in computer stores. These cards cost well under $100 Cdn. They were placed into computers running various free versions of the Red Hat Linux software distribution. The *Hauppauge* cards have good software support. Initially we attempted to use *ATI* brand cards, but the Linux support was poor. We found that Pentium computers running at 100 MHz were sufficient for automated detection, although they are heavily burdened by the detection software. We attached the computers to a network and used Network Time Protocol to synchronize their clocks. The motion detection software is simply called "motion" and we suggest that interested readers search the web for the latest version, or for similar software. Specialized meteor detection software is also referred to in the 2003 *Observer's Handbook* (Hawkes 2002). We note that we use a version of the motion software to monitor our observatory for intruders (while recording the results offsite) and that it works well with a webcam. Thus a very low-budget bolide detection system could be made with a webcam-based, rather than a video, system. Calibration of such a system might be problematic, however, due to low sensitivity.

We suggest that amateurs wishing to build a meteor camera consult the recent article by Gamble (2004) and consider an upward-pointing camera under a clear dome. Such domes appear to be available in hobby stores for approximately $2, although proper housing design to include ventilation and heating for use in Canada may need some work. An example of such a design is shown in Figure 11, in use in the recently installed University of Western Ontario fireball network.

Figure 11 — Upward-looking Rainbow lens system under a clear dome, as installed in the University of Western Ontario bolide network.

This system is based on "Rainbow" lenses and specialized electronics known as "Sentinel," similar to what is described in the Gamble article. We have tested the Rainbow lenses to give satisfactory all-sky coverage when used with the PC-164C low-light video camera available (for under $200 Cdn) from `www.supercircuits.com`. It can use 12V power taken from the data logging PC's floppy disk connectors, but should not be used with a wall power supply unless it is known to be well regulated. The PC-164C and other inexpensive cameras are described in telescopic and wide-field astronomical applications by Horne (2003). It may further be of interest to readers contemplating studying aurorae that it is now relatively inexpensive to build a magnetic detection system. Details are provided by Bredeson & Connors (2004).

The cameras used in the THEMIS project are more costly, but still within the price range of dedicated amateurs. We have noted above that questions relating to timing of events in substorms remain contentious. With a major aim to resolve these questions, THEMIS is a NASA MIDEX (mid-size Explorer class) mission involving a constellation of magnetospheric satellites and one of the most ambitious ground-based observing programs in the history of space science. More details are available at `sprg.ssl.berkeley.edu/themis/` and `aurora.phys.ucalgary.ca`. The THEMIS cameras combine a *Starlight Xpress MX716* astronomical CCD-camera (*ca.* $2000 Cdn: see `www.starlightccd.com`) with custom-built optics costing about $3500 Cdn. The all-sky optics were manufactured by Keo Scientific (`keoscientific.com`) and consist of a fish-eye lens and telecentric lens elements providing a fast f/0.95 optical system. These cameras capture images of the night sky at five-second intervals with an exposure time of one second. The THEMIS ground-based camera network with 16 cameras in Canada and 4 in Alaska will be fully operational by 2006, with locations as shown in Figure 12. The field of view shown for each camera is for meteor heights of typically 50 km. They will be larger for aurorae, which are at 100 km or above, and in most cases provide overlap between nearby cameras. Due to the large amount of data produced, it will be useful to use software to help recognize various aspects of the auroral display (Syrjäsuo *et al.* 2001). The THEMIS project should, in addition to providing highly detailed coverage of auroral activity over the continent, give much-needed instrumental data allowing falls of meteorites to be found and orbits to be determined.

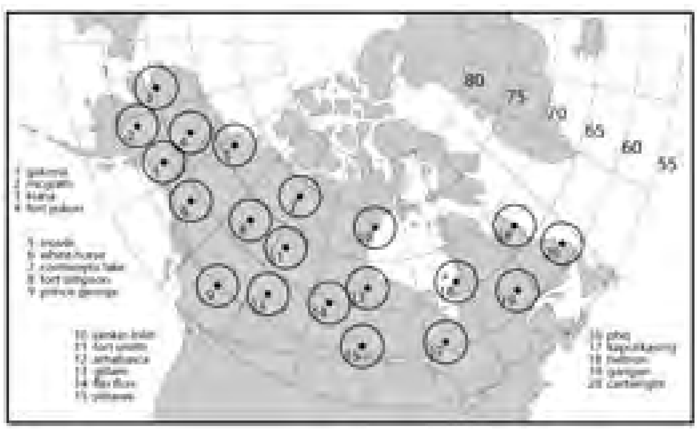

Figure 12 — THEMIS ground station coverage of Canada and Alaska. Much of Canada will be covered with imagers taking exposures every five seconds at night, with the data centrally accessible in real time. This should produce useful data for determining orbits and fall zones of bolides, in addition to the main aim of recording details of aurorae on a continental scale. Station names are shown around the map with numbers corresponding to those on the map. In all cases the station names correspond to those of the nearest geographical location: for station *pbq* this is an abbreviated form standing for Poste de la Baleine, Québec.

5. Discussion

We have shown examples of an aurora detected by cameras originally designed to detect meteors and vice versa. Clearly, new technologies are enabling novel approaches to studying sky phenomena over Canada. We have described reasons to continue such studies and stress that there remain unanswered questions where simple equipment can provide answers, particularly if many units can be networked together. We are unable to show here the compelling visual results of night sky video, and encourage readers to find out for themselves by building such equipment.

Acknowledgements

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Martin Connors
Centre for Science
Athabasca University
Athabasca AB T9S 3A3
Canada

Mikko Syrjäsuo
Department of Physics & Astronomy
University of Calgary
Calgary AB T2N 1N4
Canada

Peter Brown
Department of Physics & Astronomy
University of Western Ontario
London ON N6A 3K7
Canada

Eric Donovan
Department of Physics & Astronomy
University of Calgary
Calgary AB T2N 1N4
Canada

Martin Connors is an Associate Professor at Athabasca University and Canada Research Chair in Space Science, Instrumentation, and Networking. He recently opened the Athabasca University Geophysical Observatory, which primarily does auroral studies.

Mikko Syrjäsuo is an Alberta Ingenuity Fellow in the Department of Physics and Astronomy of the University of Calgary. His main interest is the application of computer vision to auroral research, but during field trips he often brings a camera for auroral photography and a telescope, just to make sure it is cloudy.

Peter Brown is an Assistant Professor and holds the Canada Research Chair in Meteor Science at the University of Western Ontario. He has recently started the NEAPS (Near-Earth Asteroid Physical Studies) program using the UWO Elginfield 1.22-m telescope.

Eric Donovan is an Associate Professor in the Department of Physics and Astronomy of the University of Calgary. He is active in many aspects of auroral and magnetospheric research and is the Principal Investigator of the NORSTAR project. He was recently named as a Canada Research Chair.

CANADIAN THESIS ABSTRACTS

Compiled by

Melvin Blake (mblake@mail.pari.edu)

High Precision Optical Interferometry and Application to Be Stars, by Christopher Tycner (tycner@astro.utoronto.ca), University of Toronto, Ph.D.

A new technique for calibrating optical long-baseline interferometric observations is developed where both the calibration corrections and the source characteristics are obtained from the observations of a program star. This calibration technique can only be applied to certain classes of objects, such as emission line sources or binary systems, where the parameters describing the characteristics of the source have different functional dependence than the calibration parameters. To demonstrate its effectiveness, the technique is applied to observations of four different *Be* stars obtained with the Navy Prototype Optical Interferometer. The interferometric observations utilize measurements obtained simultaneously in many spectral channels covering a wide spectral range, where only two channels contain a strong signal due to the circumstellar envelope in the Hα emission line. The calibrated observations in Hα allow modeling of the circumstellar envelopes of all four stars with circularly symmetric and elliptical Gaussian models. The best-fit model parameters are then combined with similar results for other *Be* stars, already published in the literature, to study the relationship between the Hα emission and the physical extent of the Hα-emitting circumstellar region. For the first time, a clear dependence of the net Hα emission on the extent of the circumstellar region is demonstrated. These results are consistent with an optically thick line emission that is directly proportional to the effective area of the emitting disk. Within the small sample of stars considered in this analysis, no clear dependence on the spectral type or stellar rotation is established, although the results do suggest that hotter stars might have more extended circumstellar regions.

Chromospheric Activity Induced by Short-Period Planets: A Search for Modulation of Ca II H & K Emission, by Evgenya Shkolnik (shkolnik@physics.ubc.ca), University of British Columbia, Ph.D.

I have detected the first strong evidence of magnetic interaction between an extrasolar planet and its parent star.
Of the >100 extrasolar planets discovered to date, approximated 20% of them are "51 Peg"-type with a Jupiter-mass planet orbiting within 0.1 AU. The systems with the tightest orbits (P_{orb} < 5 days) offer the best opportunity to observe a tidal or magnetic interaction between the planet and its parent star. Stellar chromospheric activity could be modulated in two ways. For magnetic interaction, the modulation is predicted to be at the orbital period with enhancement near the sub-planetary point ($\varphi = 0$). Tidal interaction would stimulate activity with a period of $P_{orb}/2$ with enhancements near both $\varphi = 0$ and 0.5.

The Ca II H & K line reversals at 3968 and 3933 Å are the best chromospheric activity indicators visible from the ground. I observed the H & K emission cores of five Sun-like stars with short period planets: τ Boo, HD 179949, HD 209458, 51 Peg, and υ And. I acquired 10 nights of high resolution (≈ 110,000), high S/N (~ 500) data at the Canada-France-Hawaii Telescope over three semesters: August 2001, July and August 2002. The superb quality of the data yielded differential radial velocities to better than 20 m s^{-1}. Fitting known orbital parameters such as period and velocity amplitude to the radial velocities, I determined updated ephemerides and accurate orbital phases.

Night-to-night modulation of the H & K emission was observed in four of the five stars. Our two standards, τ Ceti and the Sun, showed no such variability. Three of the four "active" stars did not appear to show a correlation between activity and orbital phase. However, HD 179949, the star with the tightest planetary orbit (P_{orb} = 3.093 days), repeatedly showed a 2.5% enhancement in the Ca II K emission leading the sub-planetary point by 0.17 in phase. A decrease was observed when the planet was behind the star. The activity persisted for 108 orbits (or 37 stellar rotations). This is the first detection of magnetic interaction between a star and its giant planet, as well as a first glimpse of an extrasolar planetary magnetosphere.

As an exaggerated example of enhanced chromospheric activity induced by a companion, I observed ER Vul, an RS CVn binary system with P_{orb} = 17 hours. Using the same setup at the CFHT, I obtained Ca II H & K spectra with nearly complete phase coverage. This system shows increased activity near the sub-binary longitudes of both components. There is also evidence of Ca II emission from between the two stars.

Observations of κ^1 Ceti, an active single dwarf star, show periodic H & K activity modulated by the stellar rotation (P_{rot} = 9.4 d.) with an enhancement level of ≈ 7%. The stimulating mechanism for its activity is unknown and may be evidence of a yet-unseen, nearby companion.

Synthèse spectrale de jeunes populations stellaires dans l'ultraviolet lointain, by Anne Pellerin (apelleri@phy.ulaval.ca), Université Laval, Ph.D.

Le but de cette thèse était de développer et tester la technique de synthèse spectrale évolutive aux longueurs d'onde de l'ultraviolet lointain. Jusqu'à récemment, cette technique n'était appliquée qu'à des données au-delà de 1200 Å. Le lancement du satellite *FUSE* en 1999 a permis d'explorer le domaine de l'ultraviolet lointain (900-1200 Å) avec une grande résolution spectrale. J'ai donc utilisé les spectres du satellite *FUSE* de 228 étoiles chaudes de type *O* et *B*, de 24 galaxies à sursauts de formation d'étoiles et de quatre galaxies Seyfert. Dans un premier temps, j'ai caractérisé le comportement des profils de raies stellaires en fonction du type spectral, de la classe de luminosité et de la métallicité des étoiles. Les raies O VI λλ1031.9, 1037.6, S IV λλ1062.7, 1073.0, 1073.5, P V λλ1118.0, 1128.0 et C III λ1175.6 ont été identifiées comme étant des indicateurs stellaires potentiellement intéressants pour la synthèse spectrale. Le domaine de longueur d'onde inférieur à 1000 Å couvert par *FUSE* montre aussi des signatures stellaires mais qui sont peu intéressantes pour la synthèse en raison de la contamination interstellaire. J'ai ensuite créé une bibliothèque de spectres *FUSE* qui a été intégrée au code de synthèse *LavalSB* afin de produire des spectres de synthèse dans l'ultraviolet lointain pour diverses populations stellaires théoriques. Il s'est avéré que les raies de P V et de C III sont d'excellents indicateurs d'âge, de métallicité et de fonction de masse initiale de la population stellaire, tandis que les raies de O VI et de S IV ne sont pas aussi efficaces. La comparaison des spectres *FUSE* de galaxies avec les spectres synthétiques a révélé des âges entre 2.5 et 18 millions d'années pour un large éventail de métallicités. On trouve aussi une forte dominance du mode instantané de formation stellaire. Ce travail a aussi permis d'estimer quantitativement l'extinction interne et les masses stellaires impliquées dans les sursauts. La synthèse des raies de l'ultraviolet lointain s'est avérée beaucoup plus précise que la synthèse à λ > 1200 Å en raison de la résolution spectrale exceptionnelle de *FUSE* et parce que les raies stellaires n'ont pas de profils saturés, même aux métallicités élevées. Les propriétés physiques globales des 24 galaxies à sursauts ont aussi été étudiées dans leur ensemble afin de mieux décrire le phénomène des sursauts de formation stellaires.

Education Notes
Rubriques pédagogiques

EXPLORING THE ASTRONOMY OF ANCIENT EGYPT WITH SIMULATIONS I: THE SUN, MOON, AND MILKY WAY

BY

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

Many of the creation myths and religious concepts of ancient Egypt are related to the cycles of celestial objects. While there are few original sources that describe the techniques or the observational results of Egyptian astronomy, the Egyptians did follow a lunar calendar at least as early as 3000 BC. From about 2800 BC onwards they also made systematic use of a yearly cycle of 365 days. They carefully monitored the heliacal rising of Sirius. They divided the night into 12 equal parts with "hours" that varied in length with the seasons.

The goal of this article is to investigate aspects of Egyptian astronomy by combining the available archeological information with a variety of computer simulations of the Egyptian sky in the third millennium BC. If we could travel back in time and look over the shoulder of an Egyptian priest as he made his observations, we might be able to gain a better understanding of the fundamentals of Egyptian astronomy. The article is divided into two parts. Part I includes simulations to investigate Egyptian observations of the myth of *Nut* and the rebirth of *Ra,* winter solstices, the beginning a lunar month, and the 25-year lunar cycle. Part II includes simulations to investigate characteristics of the heliacal rise of Sirius, and the use of decans to mark the hours of the night.

Simulations and Ancient Astronomical Practices

Astronomical events can be accurately simulated with relative ease, using low-cost planetarium programs such as *Starry Night*[1] . With such programs, complex mathematical calculations[2] are carried out automatically and results are displayed graphically. Simulations allow you to view a virtual sky in any particular direction, at any particular time, in any particular geographical location. In addition, simulations of ancient astronomical events can:

- provide insights into the methods employed by ancient astronomers,
- provide useful data about the events that were observed,
- provide the ability to make sets of virtual observations that can stretch over hundreds, or even thousands, of years.

A Brief Introduction to Ancient Egypt

Egyptian astronomy was closely tied to the religious and social life of their civilization. A review of the basic characteristics of this civilization provides a background for exploring their astronomical techniques and observations.

The Egyptian civilization prospered from at least 3500 BC until 55 BC, when Egypt became a Roman province. The ancient Egyptians created public monuments and temple complexes. They created works of art and complex tomb structures. They recorded many of their thoughts and actions in hieroglyphic script on papyrus scrolls. Unfortunately, most of these works have been lost through the ravages of time: decay and erosion, vandalism, religious and political cleansing, and looting. Fortunately, Egypt's dry climate has helped to preserve some of these structures, artifacts, and scripts. Archeologists and scholars have analyzed surviving material to construct political, social, economic, and technological models of life in ancient Egypt.

The scripts and artifacts related directly to astronomy are scarce and often fragmentary. Most of our knowledge of Egyptian astronomy is derived from about two-dozen sources, as summarized by von Bombhard (1999). The available evidence suggests that Egyptian astronomical knowledge was based on relatively simple, but systematic observations. Much of this knowledge was integrated into the social and religious life of ancient Egypt.

The Geographical Setting

The Egyptian civilization flourished along the Nile River valley. The Nile and its tributaries form one of the world's longest river systems. However, it is the last 1200 km, from the first cataract at Aswan (24°N) to the Nile delta (31°N) that formed the heart of ancient Egypt. In this region, the Nile flows basically from south to north. Annual floods of the Nile brought sediments from the interior of Africa that left fertile mud flats for farming along the valley and across the Nile delta. The surface of the Nile provided a natural highway from one end of Egypt to the other. Prevailing winds drove sailboats towards the south, while river currents carried boats north again.

The annual flooding of the Nile was a major event in Egypt, until the construction of the Aswan dam across the Nile in 1970. Monsoon winds from the Atlantic swept across Africa in early spring and deposited vast amounts of water in the mountains of Ethiopia. This water collected in the headwaters of the Nile and by midsummer floods began in the Nile valley. In a typical year, the flood crested about eight metres above the low water mark

[1] *Starry Night* is a computer program produced by Imaginova Canada Ltd., `www.starrynight.com`.
[2] Such as those included in *Astronomical Algorithms,* by J. Meeus, 1991.

as it flowed by Cairo in late August. Typically, the flooding lasted through September (James 1979).

The Political Background

The economy of Egypt was based on agriculture and new wealth gained through trading and conquest in Nubia to the south, and in Palestine and Syria in the northeast. Pre-dynastic Egypt consisted of the separate states of Upper Egypt (south) and Lower Egypt (north). The earliest records suggest that Upper and Lower Egypt were first united about 3050 BC under the rule of King Narmer. The politics during the next 3000 years did not flow smoothly. There were palace intrigues with new dynasties replacing the old approximately once every 100 years. There were internal revolts and invasions from without. However, a religious social class and the temple complexes they administered were more stable, and many survived for thousands of years, such as those at Aswan, Thebes, and Heliopolis.

The Religious Background

> "...the world began as a watery chaos called *Nun,* from which the Sun-god *Ra* emerged on a mound. By his own power he engendered the twin deities *Shu* [air] and *Tefnut* [moisture], who in turn bore *Geb* [earth] and *Nut* [sky]. *Geb* and *Nut* finally produced *Osiris* [god of the underworld], *Isis* [wife of Osiris and mother of *Horus*] and *Seth* [brother of *Osiris* and god of violence], and *Nephthys* [sister of *Isis*]. ...the universe [is] represented as a figure of the air-god *Shu* standing and supporting with his hands the outstretched body of the sky-goddess *Nut,* with *Geb* the earth-god lying at his feet" (James 1979, p. 145)[3].

The religious beliefs and practices of ancient Egypt were complex, and varied from place to place, and from one era to another. The following concepts were usually involved:

- a pantheon of gods led by *Ra,* the powerful Sun god, was represented by celestial objects,
- cycles of birth and death were represented by the rising of celestial objects in the east and the setting of celestial objects in the west,
- it was possible for mortal souls to join the gods among the stars,
- the gods followed a perilous nightly journey through the underworld, or *Duat,* from the region of death at the western horizon towards the region of rebirth at the eastern horizon.

Some Basic Concepts in Egyptian Astronomy

The association of celestial objects with gods, and the cyclic behaviour of celestial objects, formed the basis for Egyptian astronomy.

- The Egyptians preferred to make observations on the eastern horizon, the region of rebirth.
- The year was divided into three seasons based on the activity of the Nile river: four months of inundation, four months of planting and growth, and four months of harvest.
- Ancient calendars were based on the cycles of the Moon and were used to determine the dates of important festivals and to determine dates within a particular annual cycle. Historical dates were defined by the number of the year in the reign of the current Pharaoh.
- The heliacal rise[4] of Sirius in July was an important annual event. It marked the beginning of another cycle in the flooding of the Nile.

Simulations with Starry Night

The specific procedures for using the *Starry Night* program to create each of the following simulations are provided in the appendix.

Simulation I: *Nut* and the Birth of *Ra*

One of the oldest Egyptian myths describes the beginning of *Nut's* pregnancy at the vernal equinox and rebirth of *Ra* at the winter solstice. Wells (1996) contends that this myth has an astronomical foundation. *Nut,* the sky goddess, is associated with the Milky Way. At the vernal equinox, the Egyptians would have seen *Ra* set in the west and as the sky darkened, the mouth of *Nut* would be briefly visible before it followed *Ra* over the horizon. The consumption of *Ra* would have occurred below the horizon. Nine months later, near the winter solstice, the figure of *Nut* rises feet-first in the east a few hours before dawn, and as the Sun rises *Ra* is reborn. Wells also claims that this association was most pronounced at about 4500 BC, suggesting that this may be the date of origin for this myth.

The astronomical conditions related to this myth can be simulated using the steps provided in Simulation I, in the appendix. After following these steps, the western horizon is seen, just before sunset near the date of the vernal equinox in 3000 BC. The Sun can be seen near the intersection of the ecliptic and the celstial equator. The Milky Way forms the body of *Nut,* and the constellation of Gemini marks her mouth. At the vernal equinox her arms are stretched over her head towards the western horizon.

In the *Time Bar* step [forward] 10 minutes at a time to observe *Ra* setting in the west followed by the upturned mouth of *Nut.* Below the horizon, according to the myth, *Nut* swallowed *Ra* and was thus impregnated. To observe how this annual event changed over the centuries reset the time to 6:50 p.m. and change the date first to April 18, 3500 BC; then to April 22, 4000 BC; and finally to April 26, 4500 BC. As you move to vernal equinoxes further back in time, the Sun can be seen to move a little closer to Gemini just before sunset.

To view a simulation of the birth of *Ra* at a winter solstice shift the date to January 6, 2999 BC; set the time to 6:50 a.m.; and in the *Button Bar* switch the view to the East. Above the horizon at the left of your screen the figure of *Nut* can be seen rising feet first. The constellation of Cygnus marks the pelvic region. At the bottom right, the Sun is just below the horizon. Step [forward] 10 minutes at a time. The Egyptians would have seen the legs of *Nut* rising upward in the eastern sky, and then fade as *Ra* rose above the horizon a little further to the south.

To observe how the appearance of the celestial birth of *Ra* changed over the centuries: reset the date first to January 6, 3500 BC; then to January 6, 4000 BC; and finally to January 6, 4500 BC. At earlier winter solstices the legs of *Nut* can be seen to move to a more vertical position.

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[3]The italics and contents of the square brackets have been added for clarification and emphasis.

[4]The heliacal rising of a star is the annual date on which the star can first be seen again in the east, just before sunrise.

Assuming, as Wells explains, that the Egyptians had a flexible approach to the concept of insemination, then the Egyptian creation myth can be represented by correlations between the positions of the Milky Way and the Sun. The Egyptians saw *Ra* reborn in a yearly cycle, as well as in the daily cycle of night and day. There is some indication that the myth and astronomical events were more closely aligned at dates earlier than 3000 BC. However, on the basis of these simulations it would be difficult to assign a specific date for the origin of the myth.

Simulation II: Observing the Winter Solstice

In theory, determining the date of a winter solstice from horizon measurements is a simple procedure. All you need is a fixed observation post, a level wall facing east, and an assistant. To make an observation, you ask your assistant to move a marker along the top of the wall until it corresponds with the position of the rising Sun. When the day arrives that the southernmost position of the marker has been reached, you have determined the date of the winter solstice. The date of an ancient Egyptian winter solstice can be determined in a similar manner by observing the simulated sunrise on successive mornings.

Follow these steps to become familiar with the Sun's annual motion along the eastern horizon:

- Use the setup procedure outlined in Simulation II in the appendix.
- Play time [forward] in the *Time Bar* to observe a time-lapse movie showing the rising Sun on successive days, on the eastern horizon at Thebes during 3000 BC.
- Watch the movie through the equivalent of several years as the Sun cycles from north to south, and back again. With the time set at 6:00 a.m. each day, the Sun also cycles above the horizon during the longer summer days and below the horizon during the shorter winter days, as the Earth follows its elliptical orbit around the Sun. Combining these two motions, the Sun's position traces out the shape of an analemma on the celestial sphere.
- Note also that the Sun rises due east about the time of the equinoxes.

The date of an ancient winter solstice can be determined as follows:

- [Stop] the action as the Sun approaches its southernmost position.
- From the *Time Bar* select *Sunrise*, point at the Sun, push [control], and record the Sun's azimuth.
- [Step forward] another day, select Sunrise and record the Sun's azimuth again.
- Repeat this process, day-by-day until the Sun's azimuth reaches a maximum value for that year.

For the year 3000 BC, this procedure leads to January 5 as the likely date for the winter solstice.

Notice that near the date of the solstice, the azimuth angle of the Sun changes less than 0.01° a day. An Egyptian priest might have anticipated the date of the winter solstice and announced it on a given day, but observationally the priest would have been unable to confirm that the winter solstice had been reached until several days after the event had occurred. Also notice that this is a YES/NO observation; a priest would either declare that the Sun had risen at its southernmost position on a given day, or that it had not. In the above simulation, there is no attempt to determine the hour of the day when the solstice was reached. If the Egyptians had counted the number of days between successive winter solstices they could have estimated the length of the year to be approximately 365 days. However, since it is difficult to determine the precise day of a solstice with this technique, there would have been some uncertainty associated with this estimate.

Using horizon measurements to determine the date of a solstice contains a systematic factor involving the latitude of the observer. At the latitude of Luxor, 26°N, the date of a winter solstice obtained using horizon measurements is about seven days earlier than the date of the true solstice.

Pebble-in-a-Jar Technique

Counting the number of days between celestial events would have required a procedure for recording dates and the counts of days. A pebble-in-a-jar technique is proposed as one of the simplest possible counting procedures. Using this technique, an Egyptian priest would have placed a pebble in an empty jar on the day an event, such as a winter solstice, was observed. A pebble would be added each day until the next occurrence of the event. The jar would be labeled with a date such as "year 5 in the reign of Cheop." Counting the number of pebbles in the jar would have provided a measure of the length of time between the events. Saving the jar of pebbles would preserve the count for future reference. If pebble-in-a-jar counts were continued for tens, or even hundreds, of years, the results could be averaged to obtain a more accurate estimate of the number of days between celestial events. This type of averaging would be very effective since observing errors would tend to cancel rather than accumulate over time.

Lunar Calendars

> "Like all ancient peoples, the proto-dynastic Egyptians used a lunar calendar, but unlike their neighbours they began their lunar month, not with the first appearance of the new crescent in the west at sunset, but rather with the morning when the old crescent of the waning moon could no longer be seen just before sunrise in the east" (Parker 1974, p. 52)

The lunar year consisted of 12 lunar months. Since 12 lunar months average just 354 days, at two-or-three-year intervals an extra month was inserted to keep the seasons and feasts in place. Evidence for this type of calendar suggests that it was in use in Egypt before 3000 BC.

The Lunar Calendar in Upper Egypt

In Upper Egypt, the annual flood of the Nile was regarded as the most vital natural event and the helical rising of Sirius was used to regulate the insertion of the extra lunar month. The twelfth month was named for the rising of Sirius. Whenever the heliacal rising of Sirius occurred during the last 11 days of its month, an extra month was added to the year. The cult centre for Sirius was on the island of Elephantine, near the first cataract of the Nile at Aswan.

The Lunar Calendar in Lower Egypt

The ancient lunar calendar in Lower Egypt was keyed to the ceremony celebrating the rebirth of *Ra*, at the winter solstice. The chief cult centre for *Ra* was established at Heliopolis, just north of modern Cairo. (Wells 1996, p. 34)

Simulation III: The Beginning of the Lunar Month

The Egyptians marked the beginning of the lunar month on the morning when the old crescent of the waning moon could no longer be seen in the east, just before sunrise. This moment might be considered the beginning of the regular celestial union of the Sun and the Moon before the start of the next lunar cycle.

The observational task of the Egyptians was straightforward: "On this day, is the Moon observable before sunrise, or not?" Each morning, the waning Moon moves closer to the Sun, has a narrower crescent, and is more likely to be lost in the glare of the Sun. The optimal condition for viewing the last remnant of the waning Moon occurs when the Moon is just above the eastern horizon, with the Sun just below the horizon. Morning civil twilight lasts until the Sun is within 6° of the horizon (*Observer's Handbook 2004,* p. 113). A typical celestial object needs to be at least 5° above the horizon to be visible (Schafer 2000). A difference in altitude of 11° between the Sun and the Moon corresponds to a lunar illumination of about 2% and occurs about 1.5 days before a new Moon. For the purpose of this simulation, the beginning of a new lunar month is declared on the first morning that the separation between the altitudes of the Sun and the waning Moon falls below 11°. Since the Moon moves about 12° a day relative to the Sun, this date can be clearly defined on most occasions. Choosing an altitude-separation standard of 11° facilitates the search for simulated dates for the beginning of Egyptian lunar months. The only ambiguity occurs when the difference in altitudes is close to 11° just before sunrise. If the actual Egyptian altitude-separation standard was the equivalent of a few degrees larger or smaller, then for ambiguous cases, their dates would have tended to be one day earlier, or one day later.

Refer to the setup for Simulation III in the appendix. Check the altitude[5] of the Sun and Moon for January 27, 3000 BC at 8:20 a.m. Would a new lunar month begin on this day, the previous day, or the next day? To answer that question, [Step forward] in time until the Sun is just more than 6° below the horizon. If at that moment the altitude of the Moon is more than 5°, then the new lunar month has not yet begun. Continue to advance the date by one day and repeat the altitude checks. In this case, the Moon is just outside the 11° altitude-separation standard on January 29, but is clearly inside it on January 30. In this simulation, the new lunar month would have begun on January 30.

Skip ahead 28 days to February 27, 3000 BC and determine the date for the beginning of the next lunar month. You may have to step forward or backward a day or two. And you may have to run Time [forward], or [backward], a few minutes until the Sun is just more than 6° below the horizon.

The Egyptians could have estimated the average length of the lunar cycle using the pebble-in-a-jar technique and then averaged the results over a number of cycles. Again, any errors would tend to cancel out rather than accumulate.

Simulation IV: The 25-Year Lunar Cycle

The Egyptians made systematic lunar observations over extended periods of time and discovered an intriguing 25-year lunar cycle. From modern observations it is known that one lunar cycle lasts 29.530,589 days (*Observer's Handbook 2004,* p. 28). Multiplying, one finds that 309 lunar cycles last 9124.952 days. If it is assumed that a solar year has exactly 365 days, then 25 solar years consist of 9125.000 days. The difference between 309 lunar cycles and 25 solar cycles of 365 days is less than an hour and ten minutes. This means that every 25 years the Moon will be in the same phase, at the same time of day, on the same day of the year, in the same part of the sky, with the same stellar background!

One might think that extensive observations would be required to detect such a cycle. However, the observations the Egyptians made to detect the beginning of a new lunar month provided most of the needed information. The last remnant of a waning Moon fixes the phase, the moment before sunrise fixes the time of day, the eastern horizon fixes the location in the sky. The only extra information needed is the day of the year on which a new Moon occurs, within a 365-day calendar. There is clear evidence that the Egyptians used a 365-day calendar for civil functions (Depuydt 1997). The Egyptian year also included a number of annual festivals. Suppose that during one year a particular festival happened to occur on the same day as a new Moon, and that this coincidence was recorded. The next year, on the day of the same festival there would not be another new Moon. Nor would there be the next year, nor the next year after that. But 25 years later, there would again be a new Moon on the same day as the original festival. If records were kept for more than 25 years, then it would have been possible for an astute ancient Egyptian archivist to discover that a new Moon had also occurred on the same day in the calendar, 25 years previously. With a little more research the archivist would have discovered a 25-year cycle for new Moons at other festivals. One can try to imagine the excitement that would have accompanied this discovery of a new 25-year cycle, within the other celestial cycles of the gods.

The setup for Simulation IV is provided in the appendix. The date of January 30, 3000 BC has been chosen to display the beginning of a new lunar month. Note that the Moon is in the constellation of Aquarius. To test the reality of the 25-year cycle, advance the Julian Day by 9125 days (from JD 625701.68055 to JD 634826.68055)[6]. After this jump in time, note that the Sun and the Moon are still in essentially the same positions. You can use the *Forward* and *Back* buttons at the left of the *Button Bar* to cycle back and forth between these two dates. The 25-year cycle is impressive, but not perfect. Each time that you jump forward or backward 9125 days, the stellar background does shift a few degrees.

Summary

The four simulations described above provide insights into possible ancient astronomical practices. In Simulation I, the myth of *Nut* and the annual rebirth of *Ra* was illustrated using the annual motion of the Milky Way across the sky. The simulation can also be used to

[5] An accurate measure of the altitude of an object can be found by placing the cursor on the object, and pushing the [control] key. The difference in altitude between two objects can be estimated using the *angle separation* cursor.

[6] 0.68055 is the fraction of a day that corresponds to 7:20 a.m. in Egypt.

examine Wells' contention that this myth originated about 4500 BC. Egyptian observations of solar and lunar cycles were probably based on simple YES/NO observations. In Simulation II, the counting of whole days between winter solstices, and the averaging of results over several years, would have led to an estimate of 365 days for a solar year. Simulations III and IV illustrate how Egyptian observations of the new Moon, combined with records of feast days over several decades, could have led to the discovery of a 25-year lunar cycle, within a 365-day calendar system.

If you have access to a planetarium program such as *Starry Night,* you are encouraged to work though these simulations. Take your time. Repeat a simulation several times and experiment with variations. Try to visualize yourself observing the crisp desert sky in ancient Egypt while pondering the cycles within cycles that were created at the beginning of time.

Part II includes simulations of the heliacal rise of Sirius, and of measuring the hours of the night with the "decans."

Appendix

The *Starry Night Pro 5.0* program used in these simulations has many options that let users customize its features. The options suggested below have been selected to facilitate investigations of the astronomy of ancient Egypt. Similar options can be implemented with other planetarium programs. In *Starry Night,* the *Tool Bar* refers to the uppermost horizontal tool bar. Just below that is the *Time Bar.* The *Button Bar* is a third tool bar that can be displayed just under the *Time Bar.* The *Side Pane* is a vertical set of option menus that can be accessed down the left side of the screen.

General Settings for Simulations in Ancient Egypt

From the *Tool Bar* select:

- File > Preferences > Number Formats: Change all the positional angles to dd.ddd° format to simplify the comparison of angle sizes.
- File > Preferences > Cursor Tracking: Check *Show info in upper* left and *When the control key is down.* These choices will minimize unwanted pop-up information. If do you point at an object with the cursor and at the same time push the [control] key, a listing of that object's properties are shown in the upper left of the screen. This information includes the object's altitude and azimuth.

View: Check *Hide Horizon.*

View > Alt/Az Guides > Options: Check *Local equator (horizon line)* and set the colour to red. Check *Background grid,* set the colour to pink and the Spacing to *Medium* (the altitude grid lines are then 20° apart, starting at ± 10°).

View > Celestial Guides > Options: Check *Celestial equator* and set the colour to green. Do not check any other items.

View > Ecliptic Guides > Options: Check *The Ecliptic* and set the colour to blue. Do not check any other items.

View > Solar System: Check *Planets-Moons.*

View: Select *Show Button Bar* and then select *E* for East.

Options > Viewing Location > Latitude/Longitude: Set Latitude to 26°N, Longitude to 33°E, Time Zone to +3h, and DST off. Then *Add Location to List as Thebes, Egypt.*

Options > Viewing Location > List: Select *Thebes* and push *Set Location.*

From the *Time Bar* select:

- The *Hand* tool and use it to move the red horizon line so that it is about a third of the way up the screen.
- Set the *Time and Date* to 6:00 a.m., January 1, 3000 BC.
- Set the *Time Flow Rate* to 1 minute.

Under File > Save as => Save all the above settings as ANCIENT EGYPT.

Simulation I: *Nut* and the Birth of the Sun

Open the file for ANCIENT EGYPT.
From the *Tool Bar* select:

- Options > Stars > Milky Way: Set the brightness to maximum and select *Visible Spectrum* for a realistic portrayal of the Milky Way. Selecting *Molecular Hydrogen* will make it easier to locate the Milky Way, but the correlation with the figure of *Nut* is made more obscure.

From the *Button Bar* select: Constellations.
In the Time Bar:

- Set the *Time and Date* to 6:50 p.m., April 15, 3000 BC (close to the vernal equinox). Note that at the time of the equinox the Sun is at the intersection of the green celestial equator and the blue ecliptic plane.
- Set the *Time Flow Rate* to 10 minutes.

Simulation II: Observing the Winter Solstice

Open the file for ANCIENT EGYPT.
In the *Time Bar* set the *Time Flow Rate* to 1 day.

Simulation III: The Beginning of the Lunar Month

Open the file for ANCIENT EGYPT.
In the *Tool Bar:* View > Solar System: Select *Planets-Moons.*
In the *Side Panel:* Find: the Moon. This step labels the Moon and makes the new Moon much easier to locate.
In the Time Bar:

- Set the *Time and Date* to January 27, 3000 BC at 7:00 a.m.
- Set the *Time Flow Rate* to 1 minute.

Use the *Hand* cursor to raise the horizon to about a third of the way up from the bottom.

Simulation IV: The 25-Year Lunar Cycle

Repeat the setup for Simulation III, but set the Date to January 30, 3000 BC and from the *Button Bar* select: Constellations.

Note that at the right of the *Time and Date* window there is a pop-up menu with an item *Set Julian Day.* Selecting this item allows the user to change the Julian Day . Changing the Julian Day[7] produces corresponding changes in the *Time and Date* window.

[7]See the *Observer's Handbook 2004,* p. 52, for a definition of Julian Dates.

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William Dodd has a M.Sc. in astronomy and a D.Ed. in computer applications. He is a retired mathematics teacher with a particular interest in the fundamental and historical aspects of astronomy.

Society News/Nouvelles de la société

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

National Council Meetings & RASC Happenings

A New Year, and new beginnings! I trust that everyone got all their astronomical presents they asked for and if not, well there is always next year!

Since our last exchange in news, we have had one National Council meeting on October 30, 2004 in Toronto. At this meeting it was announced that Ms. Heide Debond, National Recorder, was stepping down from this position. At the meeting, Mr. Peter Jedicke, (President) thanked Ms. Debond for all the hard work she has done for the Society and wished her well for all her future endeavours. A round of applause was given for her.

Ms. Debond also wrote a note to the members of Council and thanked them all for letting her have the opportunity to work with a great group of astronomers and friends.

The Nominating Committee has asked that anyone who wishes to take on the job of National Recorder contact them. There is also a job description located on the Society Web site in the Private section.

The Society presently finds itself in a significant deficit situation, and there is no simple solution to this problem that will restore long-term financial health, but also allow the Society to undertake worthwhile initiatives that support its mandate. It is not the intent that the Finance Committee takes over the usual responsibilities of other Society Committees, but that this committee will consult extensively with the appropriate Committees.

A new Special Committee, called Task Force 21, was formed from Motion NC04402 for the purpose to study, to develop, and to propose options for Council's consideration to help to ensure the long-term financial security of the Society given the reality of the current annual deficit; taking the Society's current revenue model into account, suggest changes to improve the Society's financial outlook including ways to give Council the flexibility to fund projects and initiatives in addition to services to individual members, including (but not limited to) the following:

- Study and propose ways to reduce the cost of delivering current member services.
- Study the cost/benefit of delivering more member services via the Internet.
- Study ways to market our current products and publications better.
- Investigate new sources of on-going revenue.
- Study and, if necessary, propose changes to make the Society's governance model more effective.

The committee is comprised of: the President (Chair), Chairs (or committee member designated by the Chair of each Committee) of Constitution, Education, Finance, Information Technology, Membership and Promotion, Observing, and Publications Committees, members of Executive Committee, three others appointed by Council, and two others appointed by the committee. Its mandate will be for one year, and extended by Council, if need be. For more information on this issue, please go to `www.rasc.ca/membersonly.htm`.

We have another National Council meeting coming up on February 26, 2005 again in Toronto. All reports for the meeting will be placed on the National Web site, `www.rasc.ca` in the Private members' section for you to read on the Society's affairs.

International Astronomy Day is coming up in April where Centres celebrate with mall displays and public events. The International Astronomy Week is from April 11-17; for more information visit, `www.rasc.ca/ctivities.htm` or contact Bruce McCurdy, the RASC Astronomy Day Coordinator, at `bmccurdy@telusplanet.net`.

Our next big event will be the 2005 General Assembly being held on May 20-23, 2005 weekend. It will be held in beautiful Kelowna, British Columbia, and hosted by the Okanagan Centre. You can be kept up to date by visiting `www.ocrasc.ca/ga.html`. If you have never been to a General Assembly, it is a wonderful way to meet fellow members, talk astronomy, learn about the National Society itself, and take in the local sights of the area.

Sad News

On a sad note, the Executive and members of the RASC wish to extend to Mr. James Edgar (publications proofreader, and Regina Centre Member) our sympathies on the loss of his mother in late November 2004.

Greybeard Nostalgia: That Sagging-scope Feeling

by Alan Whitman (whitmans@vip.net)

Here is an extreme example of that sagging-scope feeling. My first telescope was a refractor with a *one-inch* non-achromatic f/30 objective lens (I kid you not) that I bought at the age of 14 from an ad in a comic book. There were five telescoping cardboard tubes — the refractor looked like a cartoonist's idea of a telescope! The cardboard tubes sagged in an arc, so I fastened wooden rods to the 30-inch long tube to stiffen it. (I should have become a urologist.) Despite the extreme focal ratio, there was still a *lot* of false colour with that *single* lens f/30 objective, so I wrote back to the US comicbook ad and included my hard-earned $8 or $10 for the optional achromatic objective "for those who demand exceptional performance."

With my new 1-inch f/30 achromatic objective, my stiffened tube, and the single eyepiece provided (25× according to my logbook) the scope worked pretty well on the Moon, revealing many, many lunar craters and mountains. (Old Galileo would have died from envy to have had such a fine scope!!) But balancing a 30-inch long tube on the porch railing didn't work very well for the planets (Saturn was only elliptical at 25× when the planet dashed through the shaking tube's small field of view) and I was vaguely aware that even-more-expensive telescopes than mine had mountings to hold them steady. So one afternoon I independently invented the alt-azimuth mount, with a clamp to hold it to the porch railing. The handmade mount worked pretty well except that when the straight-through refractor was aimed too high, my head was on the porch floor. Even for an enthusiastic 14-year-old who had just discovered the Universe, that position cramped my style, not to mention my neck.

Do you remember those solid ditch-crossings that driveways used to have, made out of 8 × 8 timbers? I spiked a 2 × 4 to the crossing's timbers and clamped my handmade alt-azimuth mount to the top of the 2 × 4. The whole apparatus took only a couple of afternoons of trial and error to perfect. Decades later I had a strong sense of *deja vu* when I saw a photograph of the mount that a teenage Leslie Peltier had crafted for his first scope, "The Strawberry Refractor." (I have never understood why the owners of department store scopes on shaky mounts don't just fix the problems, instead of giving up so easily.) With my new rock-solid mount (dampened by a ton of driveway gravel!) the 1-inch showed me Saturn's ring (singular) and one Jovian belt at 25×. Captivated, I sketched the changing positions of Jupiter's Galilean moons nightly for a year or more. The 1-inch refractor found Uranus and shortly afterwards I saw Uranus with the unaided eye from my first dark site, an Albert County, New Brunswick maple sugar camp that I worked at over Easter vacation (free in exchange for unlimited sampling of the maple products).

The 1-inch found Vesta, Ceres, and a sunspot, unfiltered on the setting Sun. (Don't try that at home! The after-image was a tad bright and long-lasting and I tried solar projection the next day.) That first scope split seventeen double stars (the closest being beautiful gamma Andromedae and gamma Delphini), and revealed four open clusters, one globular (M13 of course), one nebula (the Great Orion Nebula), and one galaxy (M31). Its field of view was too tiny to show M33, but I did see the Triangulum Galaxy with my Dad's simple 4× field glasses.

After six months of observing with the 1-inch refractor, aperture fever struck when I happened upon the Moncton public library's copy of *Sky & Telescope* magazine and drooled over the *Unitron* ads. The *Unitron* on the back cover of *Sky & Telescope* that Johnny's parents bought him to keep him away from the television was way beyond a young Canadian paper-boy's yearly income, but I began purchasing an alt-azimuth mounted 60-mm *Tasco* refractor that was featured in a little one-eighth page ad. This was on the lay-away plan, so every couple of months I would mail my paper-route earnings off to a friendly lady in San Diego and each time she would write me a short but encouraging note acknowledging receipt of my funds and advising the size of the ever-decreasing balance (not that I didn't know the sum to a penny) that stood between me and The Cure for Aperture Fever.

A 60-mm f/12 *Tasco* achromatic refractor was a quality telescope in 1962 (after I added a sock full of weights to the front end of the tube to balance it properly). The new trophies now mounted quickly in my logbook.

In the fall of 1963 Jupiter's disk reached 50″ in diameter at that perihelic opposition. The *area* of Jupiter's disk in October 1963 was about 125 percent of the area that Jupiter's disk will reach at its mediocre opposition this year. I was now 17 years old, was the only serious amateur astronomer in New Brunswick as far as I knew, and I had my prized 60-mm achromat. There were no larger telescopes available to me to observe with.

All of the authorities (*Sky & Telescope*, the *Observer's Handbook, etc*) said that at least a 3-inch refractor was needed to see shadow transits of the Jovian moons. I didn't have a 3-inch refractor, nor did I know anyone who owned such a wonderful scope. I did have a good 2.4-inch refractor that had split mis-matched alpha Piscium at 2.0″, almost at Dawe's Limit, and split Castor, then near periastron and at only 1.9″, right at Dawe's Limit. And I had read that the 1963 opposition of Jupiter was the closest for many decades to come.

There were probably an unusual number of nights of superb seeing that autumn in Atlantic Canada. (I don't know because my logbook back then just recorded what I saw, not the seeing and transparency.) Anyways, my 60-mm *Tasco* refractor at 117× showed Ganymede's shadow in transit on Oct 5/63 and Nov 17/63, Io's shadow in transit on Oct 18/63 and Nov 19/63 (the latter event was seen without foreknowledge), and even Europa's small shadow on Dec 2/63 and also at the next opposition on Jan 28/65.

On Oct 18/63 I followed Io as it approached Jupiter and could still see Io as a bright point against Jupiter's dark limb for several minutes *after* transit ingress. My logbook was full of doubt about this observation because the authorities of the day said that a 4-inch refractor was needed to see Jovian satellites in transit. But, of course, none of these adult experts had ever seriously observed Jupiter with a 2.4-inch refractor at a perihelic opposition — why would they waste a superb night doing that since they owned 4-inch and larger refractors? I didn't have access to a larger scope, but I was an experienced observer by the fall of 1963.

When Io's shadow followed Io that night I could see the shadow in transit at 55× in addition to 117×. Detail on Jupiter was the NPR, NEBn, NEBs, STB, and SPR. (The SEB was not visible in my scope that autumn — the planet was dominated by an unusually wide NEB, which was doubled in some longitudes, and the NEB had darker patches within it on some nights.)

At the next opposition in 1964-65 I was seeing bays and projections on the equatorward-side of the NEB and SEB with the little refractor. The Great Red Spot was much more obvious in those years than it is today, although in appeared brown instead of red in the 60-mm scope.

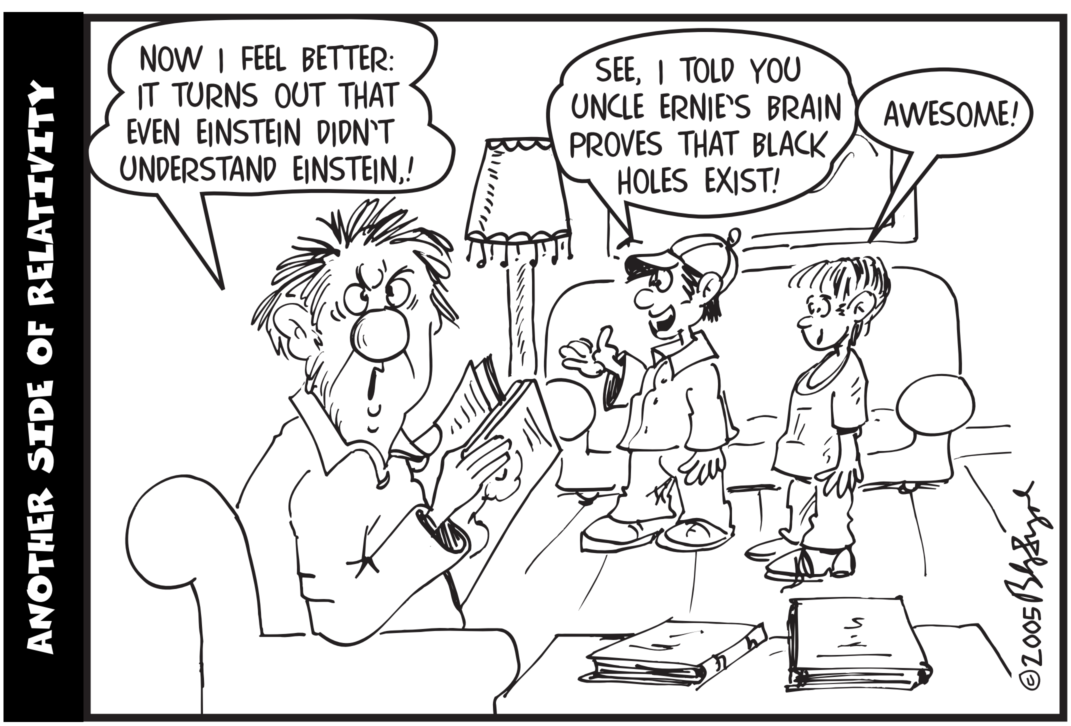
In 1964, when I reported my observations of shadow transits with a 2.4-inch refractor during the recent perihelic opposition of Jupiter to the editor of the *Observer's Handbook*, I was ignored. The *Handbook* continued to say that a 3-inch refractor was needed.

In the early or mid-'80s I reported my 1963 observations to the *Handbook's* editor again and this time the section on Jupiter was amended to say something wishy-washy like "some observers have reported seeing shadow transits with a 60-mm refractor."

About 1996 I wrote Roy Bishop, then-editor of the *Observer's Handbook*. The *Handbook* was then finally revised to say "The tiny black shadow can be particularly evident if it is cast on one of the bright zones of Jupiter. This phenomenon sometimes is evident in a good 60-mm refractor under good seeing conditions." (The quote is from the 1997 *Handbook*.)

Perehelic oppositions effectively increase your telescope's aperture. Combine that with an upgrade from a "comic book scope" to a "department store scope" and my *Tasco* earned a place in my heart, perhaps enhanced by its sad ending in a little flood (just deep enough to drown my loyal observing companion) in a Vancouver basement apartment a few years later.

Forty years on, Alan Whitman is convinced that a 1-metre scope would cure his aperture fever.



Jordanian Astronomical Society Glimpses a Challenging Crescent

by Mohammad Odeh, Jordanian Astronomical Society (modeh@jas.org.jo)

Introduction

The Jordanian Astronomical Society (JAS) pays great attention to crescent observations, where in 1999 JAS established, in cooperation with the Arab Union for Astronomy and Space Sciences (AUASS), the Islamic Crescents' Observation Project (ICOP). ICOP now has more than 170 members from 51 different countries. The members of ICOP observe the crescent monthly and report their result to the head of ICOP in Jordan, where the results are added directly to ICOP's Web site (`www.jas.org.jo/icop.html`). Thus, the visitor to the Web site can read the results of crescent observations from different parts of the world each month.

Results of Observation

As usual, JAS made all the preparations required to observe the new crescent of March 2004, where the New Moon occurred on Saturday, March 20, 2004, at 22:40 UT. To know the possibility of seeing the crescent, JAS observers use the software *Moon Calculator* prepared by Dr. Monzur Ahmed, adopting Yallop criteria. The possibility of seeing the crescent on Sunday, March 21, 2004 in the world appears in Figure 1. In this graph there are four curves; countries located in curve A (small rectangles) were able to see the crescent easily by naked eyes; countries located in curve B (small stars) could see the crescent by naked eyes providing there were optimum atmospheric conditions. Countries located in curve C (small vertical lines) should use optical aid

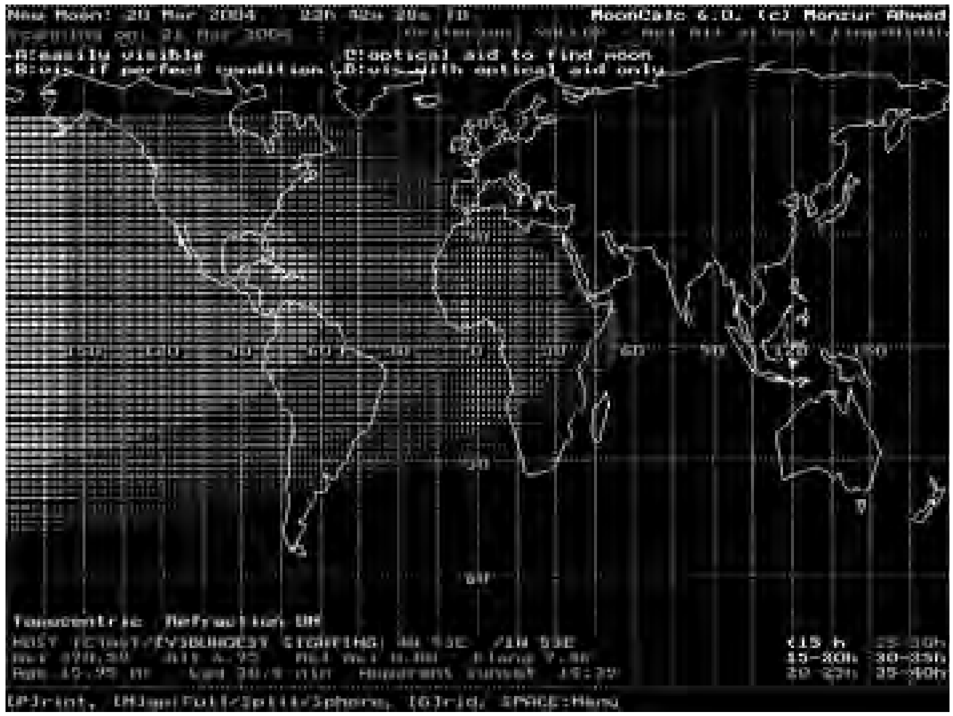


Figure 1 — This graph shows the possibility of seeing the new lunar crescent on Sunday, March 21, 2004 from the whole world. Where the areas located under small dots are able to see the crescent by optical aid only, this includes the extreme western parts of the Arabian Peninsula, eastern and some southern parts of Africa, and some southern parts of Europe. Areas located under small vertical dashes are able to the see the crescent by optical aid at first and then by naked eyes; this includes the central parts of Africa, some parts of the Atlantic Ocean, some northern parts of North America, and some southern parts of South America. Areas located under small stars are able to see the crescent by naked eyes under perfect atmospheric conditions; this includes parts of western Africa, major parts of the Atlantic Ocean, eastern and northern parts of North America, central parts of South America. Areas located under small rectangles are able to see the crescent easily by naked eyes; this includes southern and western parts of North America, northern parts of South America, and major parts of the Pacific Ocean. Other parts of the world are not able to see the crescent even by optical aid. This graph was generated using the software *Moon Calculator* by Dr. Monzur Ahmad adopting Yallop criteria at best time.

at first, after that the crescent might be seen by naked eyes. Countries located in curve D (dots) must use an optical aid in order to see the crescent. Jordan is just outside the last curve, and thus seeing the crescent from Jordan on Sunday, 21 March is a real challenge!

The JAS team of observers consisted of three members; Dr. Tarek Katbeh, Mustafa Abdul-Khalek, and Yousef Al-Farran. The team headed to Ash-Sharah Mountains, which is one of the highest mountains in Jordan, 220 km to the south of the capital Amman near a city called Ash-Shoubak. The coordinates of the location are:

Longitude: 35:30 E
Latitude: 30:24 N
Elevation: 1646 m
Time Zone: UT+2.

The team reached the summit of the mountain at 16:50 LT, equipped with a telescope having the following specifications:

Meade 10-inch LX200 GPS
Diameter: 254 mm
Focal Length: 2500 mm (a focal reducer f/6.3 was used, so the actual focal length was 1600 mm)
Eyepiece: *Meade* Super Plossl 56 mm
Magnification: 28.5×.

Katbeh was able to do the alignment for the telescope during daytime within 10 minutes only! The observers pointed the telescope towards Venus, Mercury, and Mars just to check the accuracy of the alignment, and in every test the object was field-centred.

The calculations showed that the Sunset at the elevation of the observing location would occur at 17:56 LT, however, the Sun disappeared beyond the far horizon at 17:54 LT. Then, the coordinates of the Moon were entered into the telescope and it moved automatically towards the Moon. After about five minutes of trying to glimpse the crescent, Katbeh was the first to glimpse the extremely thin crescent at 18:00 LT. "It was extremely thin, and I could notice the brightness differences from one part to another! Moreover, it was not lit at certain parts," Katbeh described the crescent.

When the crescent was first seen through the telescope at 18:00 LT, the following topocentric values were:

Moon's Altitude: 4.3 degrees
Sun Altitude: −3.0 degrees
Relative Altitude: 7.3 degrees
Elongation: 8.2 degrees
Relative Azimuth: −3.8 degrees
Moon Age: 17 hours and 18 minutes
Geocentric Moon Age: 17 hours and 19 minutes
Moonset minus Sunset: 35 minutes.

Apart from the JAS team, another two residents were invited to share this observation, and both of them could see the crescent through the telescope. The team tried to see the crescent by binoculars and naked eyes but they couldn't see it.

Actually, this was not the first time JAS succeeded in seeing such a challenging crescent. For example on March 18, 1999, JAS was able to see a 20-hour crescent! Details about that observation and a photo for the crescent can be seen at `www.jas.org.jo/hej19.html`. Also on September 10, 1999 JAS did its most interesting crescent observation so far; a full report with a photo of the crescent can be seen at `www.jas.org.jo/jucres.html`. In addition, difficult crescent observations were done on October 10, 1999 (`www.jas.org.jo/raj20.html`) and on April 10, 2000 (`www.jas.org.jo/muh21.htm`). However, the youngest crescent observed by JAS was on August 19, 2001, with an age of 13 hours and 36 minutes only! A full report about this observation can be seen at `www.jas.org.jo/jut22r.html`.

Back to the crescent of March 21, 2004. JAS has added all the reports of ICOP members at `www.jas.org.jo/icop/saf25.html`. The visitor to this page will find also that I've tried to observe the crescent using 7 × 50 binoculars from the Acropolis in Greece. However, Greece was also outside the curve, and thus I couldn't see the crescent. In addition, the crescent was not seen by ICOP members in each of the following countries: Brunei, Iran, Kuwait, Saudi Arabia, Algeria, South Africa, and Nigeria. ICOP members in the USA confirmed seeing the crescent on that day.

We take this opportunity to invite interested persons to join us in ICOP, where we always welcome any observer to share crescent observations with us. More information about ICOP can be obtained from `www.jas.org.jo/icop.html`.

Mohammad Shawkat Odeh is Chairman of the Crescent and Mawaqeet Committee of the JAS, and Vice-Chairman of the Crescent, Calendars, and Mawaqeet Committee of AUASS (Arab Union for Astronomy and Space Sciences). He is also Chairman of Islamic Crescents' Observation Project (ICOP).

Sky Scan

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

Karma police
Arrest this man
He talks in maths
He buzzes like a fridge
He's like a detuned radio
Radiohead — *Karma Police*

I told you they were out to get me.

I'm not being paranoid (this time); they actually *were* out to get me. The story from my perspective began in late 2001, with a phone call from Dave Cleary, then a rising star in the Edmonton Centre executive and our most, uh, visible radio astronomy buff. Dave's brainchild, the Sky Scan Science Awareness Project, was a plan to share this under-appreciated branch of our science with a much broader audience. He had already assembled a volunteer steering committee (see Figure 1), obtained seed money of $5000 from the RASC Edmonton Centre, arranged program and infrastructure sponsorship from the University of Alberta's Department of Physics, and acquired a small three-year grant from the Natural Science and Research Council of Canada (NSERC). The next step was to hire a part-time educator to actively spread the word. The committee wanted somebody with an astronomy and public education background who was available to do contract work, and for better or worse I was their first choice. The school-year project would nicely complement my summer contract at Odyssium Observatory, and I was happy to take on the new challenge of talking radiohead.

After some research on where to focus our limited resources, we soon found an excellent fit between what we could deliver and the requirements of the new Grade 9 science curriculum. Inspired by the Pan Canadian Science Project and introduced in the fall of 2002, the new curriculum has as its general theme "Science, Technology, & Society" (Dodd 2002). A key upgrade was a new unit called Space Exploration, a long-overdue second astronomy unit being introduced into the Alberta curriculum, and one with considerably more teeth than the existing Grade Six Sky Science unit. One of its components is astronomy across the electromagnetic spectrum. Indeed, the cover of one of the new textbooks features the Parkes Radio Observatory in Australia, recently immortalized by the movie "The Dish."

Figure 1 — Sky Scan key personnel. Although formally at arm's length from the Society, the project relies heavily on RASC members. Here from L to R, Dave Cleary, Project Leader; Robert Rolf, Technical Adviser; Dr. Doug Hube, Science Advisor; Bruce McCurdy, Education Development Coordinator. Steering committee members not shown include Sid Shugarman, Science Consultant to Edmonton Public School Board, and Guy Almberg, Antenna Guy.

If astronomy can be a difficult subject to teach because it's not "hands-on," radio astronomy is doubly so because it's not even "eyes-on." At our initial workshops and in-services, we quickly found that many Science 9 teachers were apprehensive about presenting this unit due to negligible personal expertise in these areas. So we in Sky Scan resolved to present them with a helpful resource. Given the precarious state of school finances in supposedly rich Alberta, this had to be offered at no cost.

Our approach was to provide participating schools with a low-tech radio observatory, capable of making

Figure 2 — Guy Almberg prepares to install another of his creations at Victoria School of the Performing Arts.

observations of real phenomena in the physical Universe, namely meteors. The concept is relatively simple (luckily for me, an admitted technoklutz), and is described in Phil Gebhardt's article in the RASC *Observer's Handbook* (Gupta 2004).

Although my keen interest in meteors over the years has been primarily visual, I had used this forward-scatter technique to observe the Perseids on a cloudcast night years previously through a "detuned radio" set to an FM frequency with no local stations, monitoring for bursts of signal from a distant transmitter. A car radio and antenna work great for this. In recent years I have taken to conducting both visual and radio observations simultaneously, a combination I heartily recommend to all meteor enthusiasts. In my experience radio bursts are about three times as frequent as visual; the overdense ones produce an extended signal that lasts an order of magnitude longer than visual ionization trains; it is possible to experience either without the other; but maybe a third of all visual meteors are accompanied by an exactly simultaneous radio burst, which leaves zero doubt about their cause. One quickly learns to associate the sound of static as the aural equivalent of a clear dark sky, crackling with potential.

Each remote sensing detector requires a simple antenna on the school roof, wired to a digital radio receiver in a classroom or computer lab below, which in turn is connected to the sound card of a computer (see Figure 3 and 4). The last piece of the puzzle was a software program to record radio bursts, and we chose Jim Sky's *Radio SkyPipe*. (See Figure 5; this program is available in freeware or inexpensive "pro" versions at `www.radiosky.com`.)

The hardware challenge was ably tackled by Sky Scan volunteers Guy Almberg and Robert Rolf. A member of both RASC Edmonton Centre and the Northern Alberta Radio Club (NARC!), Guy the Antenna Guy has background in both radio *and* astronomy. He's just a naturally handy kind of guy of the type I hold in awe, with a heart of gold. Guy worked on an inexpensive antenna design, eventually settling on a three-element Yagi antenna. (See `www.skyscan.ca/3ElementYagi.htm` for plans.) The antenna is simple enough that in theory it could be built in a Grade 9 Industrial Arts lab; in practice Guy has built the antennas and together Guy, Duane Cutrell, my son, Kevin, and I have had a number of adventures installing them on (to date) ten school rooftops in the Edmonton area.

As for radios, digital tuning was a must, since the technique involves monitoring an FM band that does *not* have a local station. With commercial digital radios going for \$200 and \$300 at best, well beyond our price range, the solution was to obtain car radios in bulk from an auto wrecker, and modify them to run on AC, a task ably handled by Robert.

The most expensive component of each detector is the computer, which is the one thing we ask schools to provide. Fortunately, there never seems to be a shortage of "old beater" computers capable of handling this relatively simple task. The rest — wood, ladder line (for the Yagi's driven element), sandbags, coaxial cable, various connectors and cables, modified car radio, pro version of the software — we supply at a cost of under \$200 all in. RASC Edmonton Centre again backed the project, committing a further \$7500 of casino-raised money to cover the cost of the detectors in the growing Sky Scan Array.

Sky Scan was buoyed by a key early success. That first fall of 2002 the new curriculum was still optional, so we did a pilot project involving three schools. By mid-November, the first two were up and running, as well as prototype detectors in the homes of Dave and myself. The morning of November 19 featured the last of the predicted Leonid meteor storms, with western North America extremely well placed to observe the second of two peaks of activity.

What had been a fabulous visual

Figure 3 — Bruce McCurdy and the newly installed Sky Scan 9 antenna at S. Bruce Smith School.

Figure 4 — The business end of the detector at Bannerman School includes a modified car radio (centre) wired to an antenna on the roof above, and to the computer at right. The monitor shows meteor shower data collected during the Leonid Storm of 2002.

show the previous year was disappointing in that respect; the nearly Full Moon reflected off fresh snow, and heavy clouds put an end to even that just before the maximum. However, the night was saved by a terrific radio shower. Listening by car radio we heard burst after burst of signal from distant stations, and by 3:45 a.m. it was nearly continuous reception as it was hard to tell where one meteor ended and the next took its place. (The ability to count only to one at a given moment is a limitation of radio detection.)

Better yet was the fact that all four radio telescopes in the fledgling Sky Scan Array performed brilliantly. At Spruce Avenue School, the science teacher, Dean Jaster, stayed up all night to monitor the detector by camcorder, a "live" recording to augment the captured files. A highlight occurred just before 2:30 when an overdense meteor captured a minute-plus segment of newscast from Classic Country 92, which we later established was in Fort Worth Texas, some 2700 km away. Ironically, the newscast included a report of the Leonids being clouded out in Europe — this information brought to us live via Leonid!

The best was yet to come. All four detectors spread over a 25-km arc on Edmonton's north side showed very similar data of an asymmetric storm peaking at 3:47 MST, proof positive that it was caused by real meteor activity and not local interference (see Figure 6). We tabulated the data from each and posted it to our Web site (`www.skyscan.ca`). I subsequently posted a note to "meteorobs," the Global Meteor Observing Forum. A few days later I was delighted to receive the following message:

> Thanks to Rosta, Petr and Bruce for the results of the Ondrejov radar and the Edmonton Sky Skan [sic] radio results for the two Leonid peaks.
>
> After applying the topocentric correction (the peak time varies by a few minutes depending on your location on the Earth), the following geocentric peak times are derived for the two peaks. These geocentric peak times can then be compared with predictions.

	Long.	Lat.	Observed peak UT	Correction m		Topocentric Geocentric peak UT
Ondrejov	14d 47´ E	49d 55´N	04:06	−3.1	=>	04:03
Edmonton	113d 31´ W	53d 34´ N	10:47	−3.6	=>	10:43

> Of course, these are just results from two stations and are not meant to imply a final result.
>
> Cheers,
> Rob
>
> Robert H. McNaught

Dr. McNaught of the Anglo-Australian Observatory is recognized as one of the world's leading experts in the field of meteor science. He and his partner, David Asher of Armagh Observatory in Northern Ireland, had modelled the various filaments laid down by consecutive passes of Comet Tempel-Tuttle and predicted when the peaks of these interplanetary sandstorms would occur. Of course they needed reliable results to confirm their predictions (which proved extremely accurate). For one peak they used data from a multi-million dollar radar observatory in Ondrejov, Czech Republic; for the other, four homemade rooftop radio telescopes in Edmonton, Canada. Our results were reliable because all four detectors agreed when the peak occurred, an unambiguous if low-tech result.

Our original precept that we could somehow make a modest contribution to Science had been spectacularly validated on the first attempt. It also demonstrated the global nature of the international science community, and the emergence of the Internet as the most powerful communication technology developed since, well, radio. All of which address in a meaningful way the curriculum's central theme(s) of Science, Technology, and Society.

Unfortunately, the 2002 Leonids were the last significant meteor storm for the foreseeable future. However, the

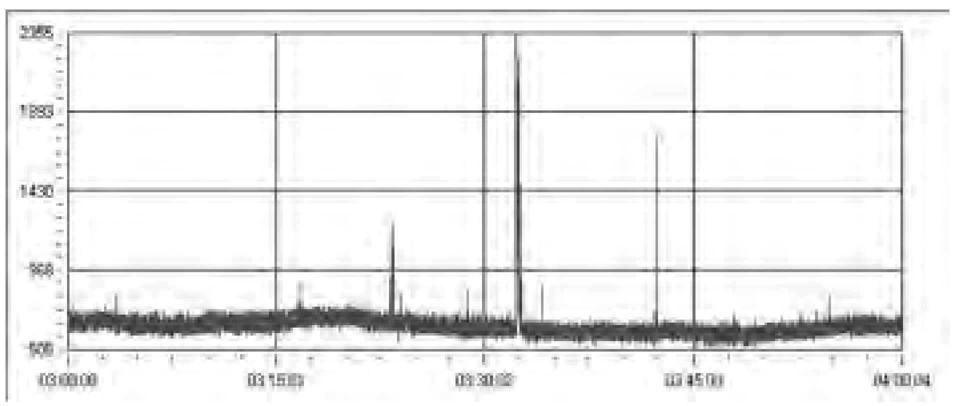


Figure 5 — Radio Sky Pipe is a key element of the method. Shown here is a typical overnight hour at the Northern Claw Radio Observatory in the author's home. The baseline represents static, while each spike is a burst of radio signal from a distant FM transmitter reflected by a meteor. Height of spikes represents volume; width equals duration. During the longer bursts an active listener can occasionally hear a call sign identifying the station (for us, most often CJAY 92 in Calgary, but sometimes much further afield). The genre of music is sometimes a clue as to the signal's source; it's fun to play "name that tune," from Rachmaninoff to Radiohead.

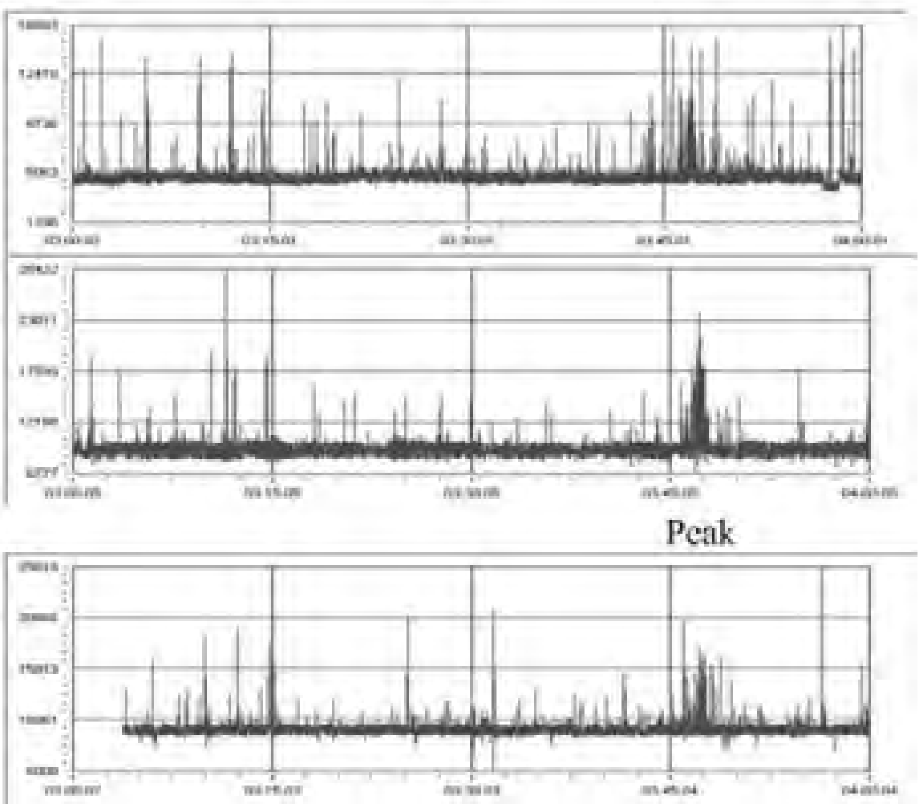


Figure 6 — The Leonid storm of 2002. The same one-hour segment (November 19, 2002 0300 to 0400 MST) as recorded by three detectors of the Sky Scan Array: Northern Claw (top), Bannerman (centre), and Spruce Avenue (bottom). All three show a similar pattern of activity with a broad peak around 1047 UT. Many but by no means all of the spikes are common to more than one detector.

basic method was spectacularly proven, and we have continued to install and operate radio telescopes across the city. Results from the 2003 Geminids (Figure 7 and 8) prove that this method can demonstrate the character of any significant meteor shower. Each shower is unique; each meteoroid stream an orbital oddity.

More to the point, the methodology can be shown to work in the classroom. Construction-minded students are shown how the detector is built; in future, we hope I.A. students will build their own. Class "keeners" learn to operate the software to run their detector; once it has done its work, all students get the opportunity, typically networked in the computer lab, to collect and analyze the data and ultimately publish their results. All hands, including the teacher, get a real sense of the scientific method in action.

Sky Scan is augmented by lesson plans on our Web site, and in-class instruction provided by myself. In the current school year, this will reach over 10 schools and 1000 Science 9 students. While meteor science is central to my 60-90 minute class, it is presented as the thin edge of the wedge in the ongoing process of bombardment in the solar system. Of course kids are particularly interested in the bigger bangs, and this concept is reinforced in a number of ways: the latest images of Phobos and the moons of Saturn, various asteroids, even Comet Wild, all show convincing evidence of impact cratering. The photographic record of the "real-time" collision of Comet Shoemaker-Levy 9 with Jupiter is undeniable, underscored by my personal recollection of that cosmic spectacular. Closer to home, images and animations of Meteor Crater, Tunguska, Peekskill, and Tagish Lake are also presented, and small meteorites circulated. The K-T extinction event is highlighted; this was old news to many kids who had a keen interest in dinosaurs in elementary school. The certainty that Earth will suffer further major impacts in the future is discussed, as is the fact we have developed the capability to detect potentially hazardous asteroids through such automated means

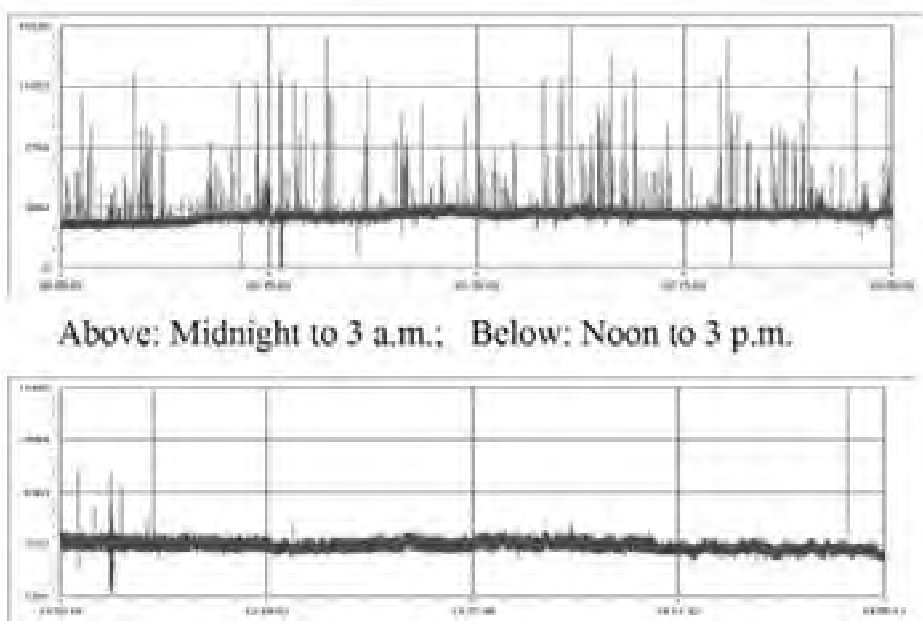


Figure 7 — The Geminids of 2003 show the effect of Earth's rotation. From midnight to 3 a.m. (top) the detector recorded some 313 meteors; twelve hours later, from noon to 3 p.m., only 12. (When conducting counts these compressed data are greatly enlarged.) The radiant set around 12:30 p.m., leaving only a few sporadic meteors.

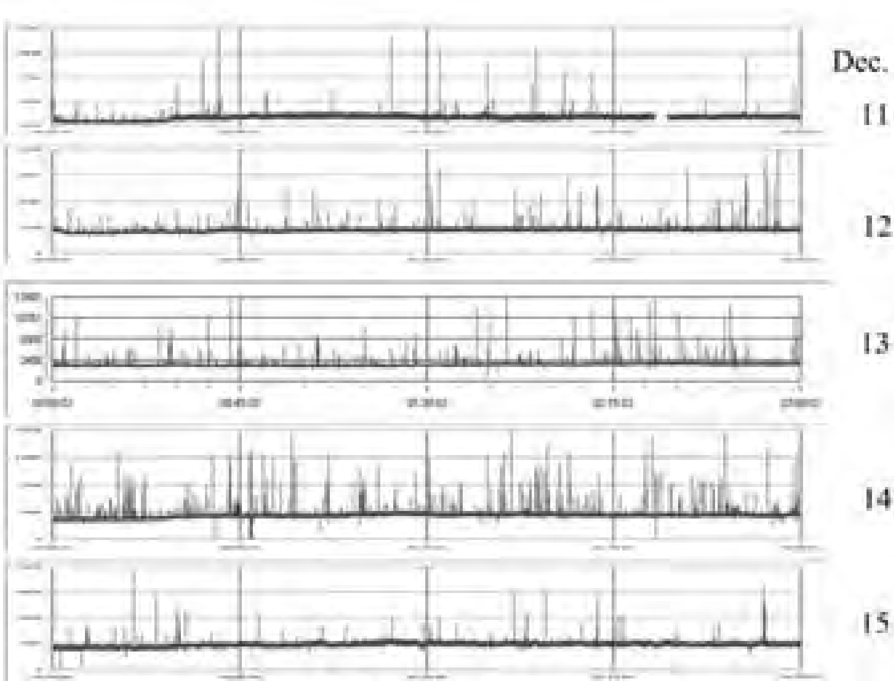


Figure 8 —The same three-hour window from five consecutive nights shows the Geminids slowly building to a peak the morning of December 14 before rapidly dropping off. The hourly rates show this asymmetrical progression: Dec. 11, **27**; Dec. 12, **39**; Dec. 13, **77**; Dec. 14, **104**; Dec. 15, **22**. The radiant set around 12:30 p.m., leaving only a few sporadic meteors.

as Project LINEAR, itself a remote-sensing technology with superficial similarities to our own Sky Scan detectors. The open question, "if an asteroid were found that was certain to hit Earth a few decades from now, what would/could/should we do?" always sparks a lively conversation. Kids love to brainstorm and never have a shortage of interesting ideas. Who's to say one of them might not be the "correct" solution? The karma police?

I have long maintained that astronomy deserves a much larger presence in grade school because it is an umbrella science that puts all the others in context. As a student (many) years ago, I always found physics, biology, chemistry, and mathematics pulled in separate directions, and it was only through my discovery of astronomy as an adult that I came to collectively embrace them. Sky Scan delivers brilliantly on this premise through its cross-curricular connections with *all* of the disparate units in Science 9. The detector itself pertains to the Electricity unit; meteor science to Matter and Chemical Change; extinction events to Biological Diversity; bombardment in general to Environmental Chemistry. All this while addressing all seven key concepts in the Space Exploration unit itself.

As I write this, Sky Scan's initial NSERC grant is winding down, potentially the end of wages that are, as I once ruefully told the Steering Committee, "sufficient to keep a starving astronomer starving." But the project has been personally rewarding in other ways, producing the sort of warm feelings that public education in astronomy has provided me for two decades. I am hopeful that by the time you read it, our application for a further three-year grant will have been approved and the project renewed for an extended, broader outreach. I feel Sky Scan has proven its worth, and its potential.

References

Dodd, W. 2002, JRASC 96, 114

Gebhardt, P. 2004, Observer's Handbook 2005, ed. R. Gupta (University of Toronto Press: Toronto), 219

Bruce McCurdy has been active in astronomy education as a volunteer at Odyssium Observatory since 1987. He has represented RASC on uncounted occasions over the years giving astronomy talks to schools, youth groups, workshops, and the general public. He currently serves RASC's National Council as Astronomy Day National Coordinator. Bruce often forgets which hat he might be wearing at a given moment.

A Moment With…

Dr. Douglas Gies

by Philip Mozel, Toronto Centre (philip.mozel@osc.on.ca)

Amateur observers are constantly trying to improve their views of the night sky. They may carefully clean their optics, find a new observing site, or buy a bigger scope. Amateur-turned-professional Dr. Doug Gies has done all these things and more in his quest to provide us with some of the clearest views of the Universe.

Dr. Gies is a member of the Center for High Angular Resolution Astronomy (CHARA), which uses interferometry to study the sky at optical and infrared wavelengths. Simple interferometric effects can be seen by looking at a light through the slit formed by two fingers held very close together. The dark bands are interference fringes and indicate where light waves have destructively interfered with one another. The same thing can be done by fitting a full aperture mask with two moderately sized holes in it over the front of a backyard telescope. Looking at a bright star will reveal interference fringes. It is this effect that Dr. Gies studies.

Dr. Douglas Gies

CHARA will eventually use an array of six one-metre-aperture telescopes situated 350 metres apart atop Mount Wilson, not far from the famous Hooker Telescope. Light pipes bring starlight into a beam-combining room where fringes from a pair of telescopes are observed, analyzed by computer, and the data extracted. No images are produced this way, but with the addition of at least one more telescope, actual pictures of the target can be obtained. At the telescope separation used by CHARA, and observing in the infrared, angular resolutions of 0.001 arcseconds are realized. Greater resolutions will be possible at shorter wavelengths. Imagine looking at a solar-diameter star and resolving its disk at a range of one hundred light years!

Regulus provides an example of what can be accomplished. This star spins at a speed of more than three-hundred kilometres per second at the equator, close to the speed at which mass would be flung off into space. The equator should be dimmer than the rest of the star due to an effect known as gravity darkening, and CHARA observations have confirmed that this is in fact the case.

Being the largest facility of its kind in the world, the CHARA array will do much more. It should be able to watch the changing chromospheres of distant stars, detect star spots, resolve the components of close binary stars and determine their separations. It might also be used for detecting extra-solar planets, including those that may be lurking in binary systems.

"It is remarkable that we can do this," Dr. Gies says. "As an amateur, one arcsecond was good!"

Such pioneering work on interferometry will eventually lead to space-based systems using satellites and perhaps even situated on the Moon. Here, telescopes working in an airless environment, and separated by three-hundred and fifty kilometres, will allow a tenth of a solar diameter to be resolved at a distance of ten-thousand light years!

A particular object of longstanding interest for Dr. Gies is SS433, a microquasar. For many years, this object has been known to be a large star and a compact object orbiting one another. Mass from the star flows toward its companion where it forms a fiercely hot, glowing accretion disk. For reasons not fully understood, energetic jets of material then corkscrew away from the companion in opposite directions at a quarter the speed of light.

A team of astronomers led, in part, by Dr. Gies, has looked at the optical and X-ray spectra of this system to more precisely characterize its components. The glare of the incredibly bright accretion disk makes this difficult, so the astronomers had to wait until the system's orbital precession moved the disk behind the star (which happens every 162 days). The observations suggest that the latter weighs in between eight and eleven solar masses while its companion, a supernova remnant, is around two or three solar masses. This suggests it is a black hole. Work such as this may help determine the nature of SS433's larger cousins, the multi-million solar-mass quasars lurking in the hearts of many galaxies.

Dr. Gies' interest in SS433 arose during his time at the University of Toronto where he obtained his undergraduate and Ph.D. degrees. There, astronomers inspired him with their work on SS433 and black holes. However, his interest in astronomy dates back much further. RASC member Richard McWatters introduced Dr. Gies to the subject while they were in junior high school. Dr. Gies soon persuaded his mother to buy him a life membership in the Society. He became an active member, attending telescope-making workshops at the McLaughlin Planetarium, becoming involved in Toronto Centre meetings and General Assemblies, going on eclipse trips to the Gaspé and Gimli, and participating in astronomical events at the Ontario Science Centre.

It's a long road from one arcsecond to one milli-arcsecond, and Dr. Gies enjoys forging the way ahead. "It's been a lot of fun," he admits. "The next few years should be exciting!"

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

The Skies over Canada Observing Committee News

by Christopher Fleming (observing@rasc.ca)

A major project that we have been working on for a few years is nearing completion and should be available to everyone in the spring of 2005. It is a comprehensive lunar observing certificate program that will be named in honour of legendary astronomer Isabel Williamson of the Montreal Centre. Isabel was an enthusiastic promoter of observational astronomy, and she devised innovative observing projects that helped RASC members to develop quality observing skills. One of those projects is very well known today as the Messier list and was officially adopted as a national certificate program in 1981.

It has been said that Isabel promoted participation in the Messier list so that observers could learn the night sky well enough to apply those skills to variable star observing. What a great idea that was, since finding deep-sky objects requires many of the same techniques as those needed for finding remote variable stars. In those days, there was no such thing as "Go-To" telescopes, so an observer would have to learn star-hopping skills in order to find objects on the Messier list, and in the process would gain the ability to correctly identify the star-field of any object, including a variable star.

Another project that she challenged observers to try was to identify 300 features as listed on a map of the Moon that was published early in the twentieth century. It was a reasonably good map for its time (still available from Sky Publishing), and some well-known observers, such as David Levy, took up the challenge. Today we have much better charts (such as Antonìn Rükl's *Atlas of the Moon*) and equipment to explore our near neighbor with, and the observing committee would like to encourage RASC members to take advantage of this wealth of information, charts, hardware, and software. The Moon is by far the most detailed celestial object visible from Earth and offers a complete range of observing targets, from unaided eye features, to binocular and small-telescope objects, as well as challenging features requiring high magnification through larger telescopes.

To enhance the Isabel Williamson lunar program we have plans to include a significant amount of lunar geology via an overview of the history of the Moon, and by including key observing notes for most objects. These handy notes will explain the origin, age, chemistry, and so on of the current observation. We also plan to include a preliminary introduction to the major features of the Moon as well as templates for making drawings and a list of several challenge objects that will cover the outer regions of the lunar disc, where the effects of libration can be observed.

When designing the Isabel Williamson lunar program we decided that, in order to provide a complete tour of the Moon, it would be necessary to include a greater number of required objects than other currently available programs of this type. To accomplish this we first chose the most important key features, and then added nearby "must see" objects that are highlighted in the accompanying observing notes. Many of these additional objects, referred to in the notes, will be required observations. This means that the total number of mandatory observations will be significantly greater than the apparent number featured as titled objects. To make this as clear as possible, each titled feature will be referred to as an objective, and not as a single observation. In addition there will be optional or challenge observations (not required) included where appropriate.

The Explore the Universe Certificate program contains an excellent introductory lunar observing list, and we recommend that observers try this first before delving into the more advanced Isabel Williamson program. We are also planning to provide, in the not-too-distant future, a number of intermediate-level programs for binocular and small telescope users that will bridge the gap between the Explore the Universe program and more advanced programs like the Messier list, the Finest NGC list, and the upcoming Isabel Williamson list.

There have been three Explore the Universe Certificates awarded since our last report and they are listed in Table 1.

There have been six Messier Certificates awarded since our last report and, they are listed in Table 2.

Congratulations to all!

The Asteroids Section features charts containing the orbital position of several bright asteroids that will be visible in 2005, and during March and April you will be able to print charts for the asteroids (1) Ceres, (2) Pallas, (6) Hebe, (10) Hygiea, (14) Irene, (15) Eunomia, and (29) Amphitrite. Those asteroids will all be brighter than tenth magnitude at that time, and the charts will display nearby stars to tenth magnitude on a five-degree vertical field layout. Dates for the position of each asteroid will be listed at three-day intervals, and nearby bright "finder stars" will be highlighted. In many cases the finder stars are bright enough to be seen visually and therefore a *Telerad* or similar pointing device can be used to target the field printed on the charts. Otherwise a typical finder-scope or binoculars will be sufficient to find the brightest star in the field.

The Variable Stars Section features direct links to genuine American Association of Variable Stars Observer's (AAVSO) magnitude estimate charts for Mira-type Long-Period Variables that will reach maxima in 2005, and that will be brighter than magnitude 8.0. For March and April 2005, you will be able to print charts for R Leporis, R Canis Minoris, R Triangulum, T Hydrae, R Virginis, V Canes Venaticorum, R Canes Venaticorum, R Bootis, V Coronae Borealis, RS Herculis, X Ophiuchi, R Aquilae, T Sagittarii, and T Aquarii. We also have direct links to charts for several other variable star types, and you will find them on the Sample Charts 2 page. Many of the most interesting variable stars in the night sky are listed there as well as the positions of possible nova outbursts.

The Special Projects Section regularly posts Web pages containing information about upcoming, noteworthy astronomical events, and we plan to enhance that section with additional content and links provided by various members across the RASC. If you have a project you are working on that you would like to share with other RASCals, you are invited to send us information about it or a URL link to your Web site. Our email address is `observing@rasc.ca`.

Our new Comets Section is now fully operational and features information and finder charts for comets that are currently visible. It also contains a comprehensive overview of the history of comets, a frequently asked questions page, observing tips, observation forms, images, recommended books, links to related sites, and suggestions for comet observing or imaging projects. You can find the Comets Section at `www.rasc.ca/observing/comets` or from links in the observing area of the national site.

Table 1. Explore the Universe Certificate Recipients.

Name	Centre	Date Awarded
Robert Lavoie	Ottawa, Ont	Oct. 2004
Arlyne Gillespie	Kingston, Ont.	Oct. 2004
Adam Clayson	Toronto, Ont.	Nov. 2004

Table 2. Messier Certificate Recipients

Name	Centre	Date Awarded
Roy Ramdeen	Edmonton, Alta.	Oct. 2004
Trent Bjorndahl	Edmonton, Alta.	Oct. 2004
Jnani Cewel	Edmonton, Alta.	Oct. 2004
Bob Crossman	Moncton, N.B.	Oct. 2004
Leo Brodeur	Kingston, Ont.	Oct. 2004
Philip Downey	Niagara Falls, Ont.	Nov. 2004

Christopher Fleming is Chair of the RASC Observing Committee and Observers' Chair in the London Centre. He enjoys all types of observing, especially deep-sky, lunar, double stars, and variable stars. Chris is also a musician and Webmaster of the London Jazz Society's Web site.

International Astronomy Day 2005 Is Saturday, April 16

On that day, professional and amateur astronomers all over the world bring the Universe to the public, through observing sessions, displays, and information booths in malls, science centres, and planetaria. The RASC joins groups from nearly 30 countries in celebrating International Astronomy Day. Last year 23 of the 27 RASC Centres celebrated the event in some fashion; this year the objective is 100% participation. It is a fun and educational event for the public and astronomy enthusiasts alike.

The full-length celebration known as International Astronomy Week 2005 is April 11 to 17. Coincidentally, that exactly spans the 35th anniversary of the famous Apollo 13 mission, which launched on April 11 and safely splashed down after a harrowing space adventure on April 17, 1970. Centres may consider using this as a theme for their local events. Another possible theme is the World Year of Physics 2005; see the official Web site at `www.wyp2005.org`.

For those planning public observing sessions, the skies of mid-April feature the "big three" of the Moon, Jupiter, and Saturn. On the 16th a high first-quarter Moon soars over Saturn, while Jupiter will be just two weeks past opposition.

Background info on Astronomy Day can be found on the Astronomical League's site, at `www.astroleague.org/al/astroday/astroday.html`. As we get closer to A-Day 2005, particulars about activities of the various Centres will be available on the RASC Web site, at `www.rasc.ca/activity/astroday`. Please contact me to advise of your Centre's plans and to request further ideas and assistance.

Bruce McCurdy (Edmonton Centre)
Astronomy Day National Coordinator
bmccurdy@telusplanet.net

Call for Photos — 2006 RASC Observer's Calendar

All members of the RASC are encouraged to submit astronomical photos for consideration for publication in the 2006 RASC Observer's Calendar. Images can be of any type – deep-sky or solar system; prime focus, piggy-back, or fixed-tripod; film or CCD-based.

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

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

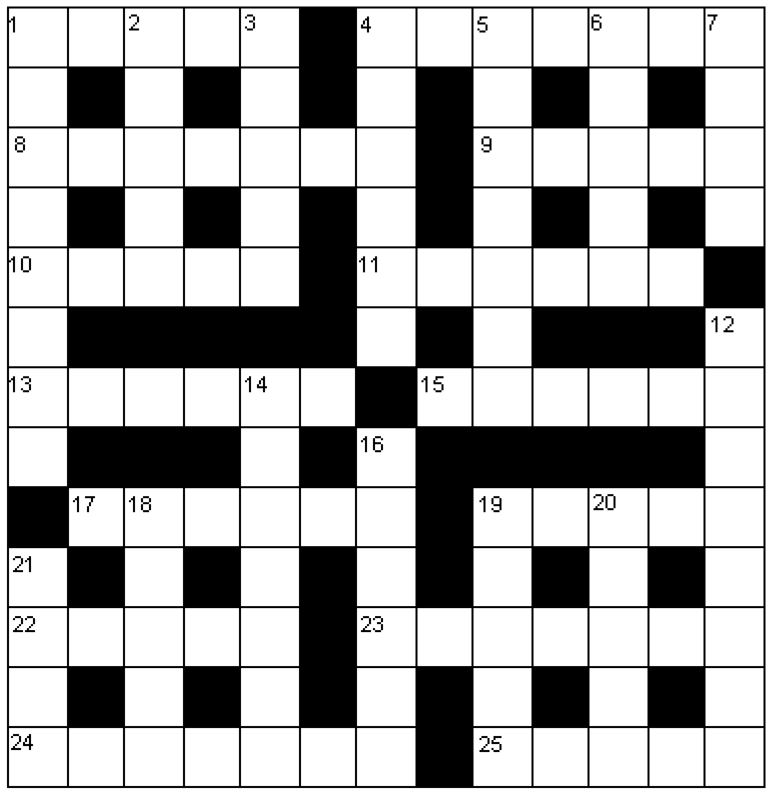
The submission deadline is April 30, 2005.

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

Rajiv Gupta
Editor, RASC Observer's Calendar

Astrocryptic

by Curt Nason, Moncton Centre



ACROSS

1. Uncertain times for an asteroid (5)
4. Oddly, one pile of haze around this sister (7)
8. South Kentucky points all to our magazine (3,4)
9. Shelton returned to the commercial about Neptune (5)
10. Is our Newcomb a drawback? Hardly. (5)
11. Halley was detected in a hundred mundane observations (6)
13. The first failed solar mission is an Apollo (6)
15. An asteroid bust o'er Poe's chamber door (6)
17. Mistakenly dub Leo a binary (6)
19. Unit of energy in a lunar crater (5)
22. A disk breaks up around Saturn (5)
23. …while another turns to steel (7)
24. He plays dirty when he's determining globular distributions (7)
25. He found a comet somehow near the head of Draco (5)

DOWN

1. The twentieth so named, alias Sam (8)
2. Space rock guts Hydra after the end of night (5)
3. The rate of ocean rising (5)
4. Mixed spices resemble fish (6)
5. When given a funny IOU, name an asteroid (7)
6. Constellation reversed in Renoir oil painting (5)
7. Whirlpool initially seen by David Dunlap in East York (4)
12. A growth hormone unwanted by sport and supernovae teams (7)
14. Blue rim seen around Uranus in large telescopes (7)
16. Newton changes final answer to Yes, making that Newtonian for some (3,3)
18. Within the cosmos, a kangaroo hops to the city of Kyoiku Observatory (5)
19. Asteroid appears in the extremities of Jupiter and Himalia (5)
20. The sky bears up under suspicion of a ruse (5)
21. Asteroid is seen twice in Egypt (4)

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Université de Moncton, Moncton NB E1A 3E9

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

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PO Box 4040, St Catharines ON L2R 7S3

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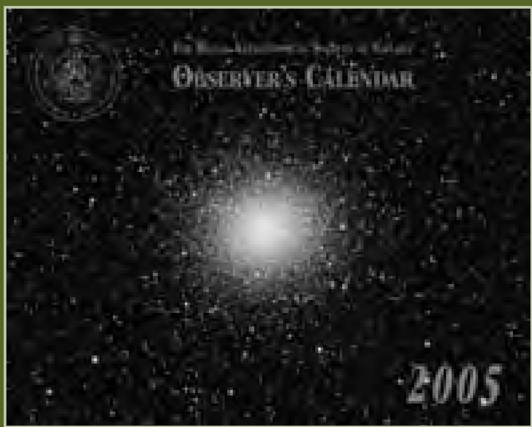

Observer's Calendar — 2005

The award-winning RASC Observer's Calendar is your annual guide

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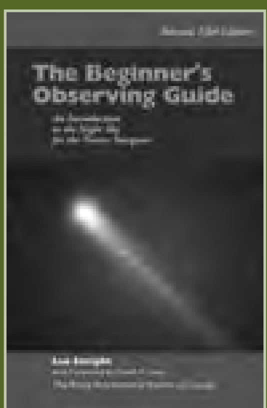

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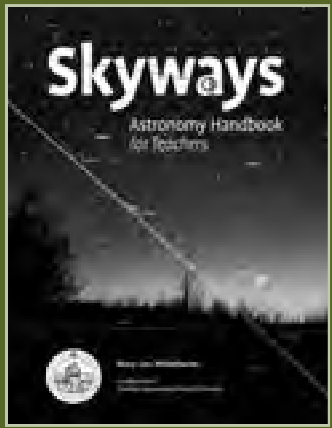

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