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Journal

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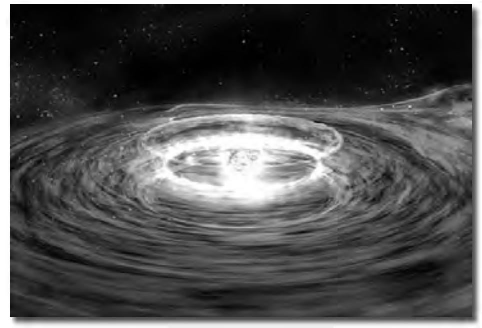

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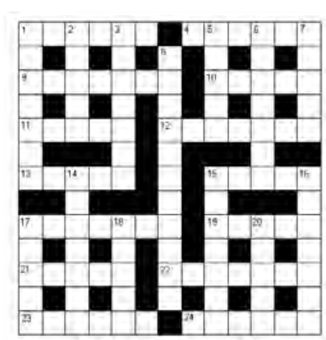

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President's Corner

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

Astrophotography is my passion. Shortly after I acquired my 5-inch f/6 refractor back in 1986, I caught the bug. Every clear, Moonless night, back then in my single days, I packed up the scope and drove to a dark site accompanied by my camera and hypersensitized film. Sometimes, I even did "all-nighters" that involved a six-hour round-trip drive to one of the pristine observing sites we are fortunate enough to enjoy in British Columbia for a night of high-elevation winter imaging. My rule is: observing time must be at least equal to travel time and these frigid soirees qualified.

As advancing age — the circulation in the toes just wasn't as good in my late thirties as it was in my late twenties — and other demands on my time set in, my imaging became less frequent. Sad to say, I would spend many a clear night soaking up the artificial photons generated by my computer monitor instead of the natural ones of the night sky. My observing records reveal that in the late '90s I once went almost a year without acquiring any new exposures!

Four years ago, I made a decision that I *had* to get back to astrophotography in earnest. Technology, in the form of an autoguider I had recently acquired, meant I would no longer have to sit stationary for up to three hours manually guiding an exposure, so frozen toes were less of an issue. I decided that other demands, including RASC responsibilities, would just have to wait while I got in my observing "fixes." These fixes started taking the form of airplane trips to southern locations such as Arizona, California, and even Australia. I had three rigid cases specially built for my equipment, and, the occasional intrusive (should I say "inquisitive?") customs officer and potentially-film-destroying X-ray machine notwithstanding, have been fortunate enough to get myself, my equipment, and my hypered film to some fine remote observing locations in the past few years.

But, I have to say, some of my recent long-distance observing trips have been quite frustrating. It's one thing to make a one-hour drive to a dark site only to discover a glitch in your equipment, and another to lug 250 pounds of equipment cases through two airports only to be met with a broken drive belt, and the realization that there is no spare, at a prime observing location in Arizona. And, favourable long-term weather statistics notwithstanding, I've encountered so many cloudy nights recently in Arizona that it seems as if I haven't left my beloved but infamously overcast Vancouver. To add insult to injury, it seems whenever it's been cloudy in Arizona, it's been clear back home!

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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All seasoned amateur astronomers have such stories: tales of an entire span of several months without a single usable night; tales of clear nights "ruined" by auroral displays; the list goes on. It's just part of the hobby. Anyone who survives the first year or two as a stargazer quickly realizes that the marvels of the night sky are only revealed through considerable patience and persistence. We may need to take a bit of a break once in a while, but the beauties of the heavens will still be there for us when we return. We know that when everything finally goes right, we will be well rewarded. There is a special thrill that comes from seeing for the first time tens of distant galaxies in an eyepiece on a perfectly transparent night or, in my case, marvelling at the intricate structure of an extended complex of nebulosity on a perfectly exposed negative under a magnifying loupe.

This is what binds members of the RASC together: the shared challenge of engaging in what is surely one of the most demanding — but rewarding — hobbies around, as we jointly explore the Universe's unlimited wonders. As the end of my term as president nears, my observing batteries are fully charged, and I am looking forward to devoting even more time to my life-long passion.

Editorial

by Wayne A. Barkhouse

Did you know that there is a 10th planet and that it swings by the Sun every few tens of thousands of years, wreaking havoc on the inner Solar System? Are you aware that an ancient civilization once flourished on Mars and that their ruins are still to be found on the planet? Of course we "all" know that humans have not walked on the Moon and that NASA is involved in a great conspiracy to hide the fact that an ancient culture once lived on our nearest neighbour!

These and a lot more "far out" ideas are being promoted at an increasing pace in our society thanks in part to the Internet, talk radio, *etc*. Why the harm? A large part of the problem is the inability of the general populous to think critically. Given all of the facts, people should be able to dismiss a significant number of these "fringe" theories without being experts in the field. Critical thinking is especially important in recent times when substantial changes in government policy can potentially be enacted without the majority of the citizenry being engaged enough to make informed decisions.

In the June 2000 issue of the *Journal* (*JRASC*, 94,112) Michael De Robertis and Paul Delaney published the results of a survey of first-year university students based on their ability to distinguish between astrology (pseudoscience) and astronomy. Their results are based in part on a comparison with a similar survey conducted six years earlier. The authors report an increase, by several percent, of students' inability to recognize the difference between science (astronomy) and pseudoscience (astrology). It would be worthwhile if a survey like this could be repeated every few years to expose any trend.

If a lack of critical thinking is at fault, what can the average RASC member do? The RASC motto is "the advancement of astronomy and allied sciences." Each member should be aware of the importance in providing the public with the necessary facts and correct scientific explanation to counter the fringe ideas. Encouraging schools to help teach critical thinking would benefit society greatly in all walks of life. Maybe we can prevent pseudoscience-based books from becoming best-sellers in the near future?

Correspondence
Correspondance

Erratum: The caption for the photograph of the Nebra disk on page 245 of the October 2003 issue should read:

The Nebra Disk (courtesy of Landesamt für Archäologie Sachsen-Anhalt. Foto: Juraj Lipták)

News Notes
En Manchettes

ROSSI SPACECRAFT VIEWS NEUTRON STAR SUPERBURST

Scientists at the Canadian Institute for Theoretical Astrophysics (CITA) and NASA, using the *Rossi X-ray Timing Explorer (RXTE)* satellite, have captured unprecedented data relating to the swirling flow of gas that rotates just a few kilometres above the surface of a neutron star, itself a sphere only about 20 kilometres across.

The massive and rare explosion on the surface of this neutron star — which poured out more energy in three hours than the Sun does in 100 years — illuminated the surrounding area and allowed the team of scientists to obtain unprecedented details of a neutron star region never before revealed. The team was able to study the ring of gas swirling around and flowing onto the neutron star. In addition, over a time interval of some 1000 seconds, they were able to see the ring buckle from the explosion and thereafter recover its original form. The observations provide new insights into the flow of a neutron star's accretion disk, usually far too minute to resolve with even the most powerful of telescopes. Dr. David Ballantyne of CITA at the University of Toronto and Dr. Tod Strohmayer of NASA's Goddard Space Flight Center in Greenbelt Maryland, will present the results of the study in an upcoming issue of *Astrophysical Journal Letters*.

"This is the first time we have been able to watch the inner regions of an accretion disk, in this case literally a few miles from the neutron star's surface, change its structure in real-time," said Ballantyne. "Accretion disks are known to flow around many objects in the Universe, from newly forming stars to the giant black holes in distant quasars. Details of how such a disk flows could only be inferred up to now."

As matter, usually supplied by a neighbouring binary companion, crashes down on to the surface of a neutron star it builds up a 10- to 100-metre layer of material comprised mostly of helium. The eventual fusion of this accreted helium into carbon and other heavier elements releases enormous amounts of energy and powers a strong burst of X-ray emission.

What Ballantyne and Strohmayer observed on the neutron star known as 4U 1820-30 was a "superburst." These are much more rare than ordinary, helium-powered bursts and release a thousand times more energy. Superbursts are caused by the buildup of nuclear ash in the form of carbon. Current theories suggest that it takes several years for the carbon ash to accumulate to such an extent that it begins to undergo fusion reactions.

The superburst on 4U 1820-30 was so bright and lasted so long that it acted like a spotlight beamed from the neutron star's surface onto the innermost region of its surrounding accretion disk. Specifically, the X-rays from the superburst interacted with the iron atoms in the accretion disk, which then began to fluoresce. The *Rossi Explorer* captured the characteristic signature of the iron fluorescence. This, in turn, provided information about the iron's temperature, velocity, and location around the neutron star.

"The *Rossi Explorer* can get a good measurement of the fluorescence spectrum of the iron atoms every few seconds," said Strohmayer. "Adding up all this information, we get a picture of how this accretion disk is being deformed by the thermonuclear blast. This is the best look we can hope to get, because the resolution needed to actually see this action as an image, instead of spectra, would be a billion times greater than what the *Hubble Space Telescope* offers."

The *Rossi X-ray Timing Explorer* was launched in December of 1995 to observe fast-changing, energetic, and rapidly spinning objects, such as supermassive black holes, active galactic nuclei, neutron stars, and millisecond pulsars. A "movie" of the superburst on 4U 1820-30 can be found at the following URL: `www.gsfc.nasa.gov/topstory/2004/0220stardisk.html`. For further details on the *Rossi X-ray Timing Explorer* Spacecraft set your URL to `heasarc.gsfc.nasa.gov/docs/xte/learning_center`.

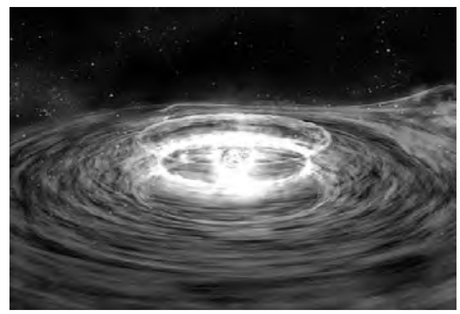

Figure 1 – An artistic rendering of the superburst illuminating and distorting the accretion disk about 4U 1820-30. Image courtesy of NASA.

SPECTACULAR FIREBALL SEEN OVER SASKATCHEWAN

During the early evening hours on March 21 the skies over mid-western Saskatchewan were briefly lit up like daylight. Streaking across the sky from north to south, a brilliant fireball, estimated to have reached a maximum brightness of magnitude −16, startled observers throughout the Kindersley area and provided eyewitnesses from across Saskatchewan and Alberta with a sight only rarely seen. Two distinct flashes were reported, and sonic booms rocked houses and rattled windows in Kindersley and surrounding towns. The fireball is being investigated by the Meteorites and Impacts Advisory Committee (MIAC) to the

Canadian Space Agency, and there is every hope that new meteorites will be recovered as a result of this event.

COVINGTON HONOURED AT DRAO

A new building at the Dominion Radio Astrophysical Observatory (DRAO) has recently been officially named after Dr. Arthur Covington, a renowned National Research Council (NRC) researcher considered by many to be the father of Canadian radio astronomy. Part of the NRC Herzberg Institute of Astrophysics (NRC-HIA), DRAO is located near Penticton, British Columbia.

"The naming of this new building is a most appropriate way to honour Dr. Covington's memory as it is dedicated to the advancement of the field he helped to pioneer," said Dr. Arthur Carty, NRC President. "Dr. Covington's discoveries have contributed in no small measure to Canada's recognition as one of the world's leaders in the fields of astronomy and astrophysics."

The Covington building will be home to a world-class engineering team at NRC-DRAO and will provide all Canadian astronomers with access to state-of-the-art facilities. It will also provide space for industrial partners and is the site of the development of a major engineering project, the signal-processing computer for the Expanded Very Large Array (EVLA).

Dr. Arthur Covington joined NRC in 1942 to work on the development of radar. After the war he adapted his radar technology to observation of the natural sky. He succeeded in detecting radio emissions from the Sun in 1946, taking Canada's first step into radio astronomy.

Covington was the first astronomer in Canada to develop the use of radio interferometry, with widely separated small antennas, to precisely locate the source of solar radio emissions. The people he attracted to his program quickly placed Canada in a leadership position in the new field of radio astronomy. His legacy is found throughout NRC-HIA and in Canadian universities.

NRC-DRAO's 56-year record of carefully calibrated, uniform solar flux measurements constitutes a valuable, uniquely Canadian dataset that is used everyday by industries and researchers worldwide. Among its multitude of users are the satellite communications industry and scientists studying global climate change. With its Solar Monitoring program, NRC-DRAO will continue to distribute reliable and accurate measurements that trace an unbroken line from Arthur Covington's pioneering work.

A few brief details on Dr. Covington's life and scientific works can be found in an article by Ken Tapping at the following URL: `www.ottawa.rasc.ca/observers/2001/an0105p3.html`.

THE HISTORICAL GROWTH OF TELESCOPES

During the past 395 years the diameters of astronomical telescopes have increased from 0.016 metres, corresponding to Galileo's first telescope, to 9.8-metres, corresponding to the Keck I and II telescopes. This improvement in aperture diameter has provided a subsequent 3.75×10^5 increase in light-grasp power. From the first telescopes constructed by Hans Lippershey and Galileo to the present day "giants," the increase in telescope aperture has been remarkably steady. Indeed, in a recent study by Rene Racine, of the Department of Physics at the University of Montreal, the aperture doubling time has remained essentially constant at about 50 years since the early 1700s.

Writing in the *Publications of the Astronomical Society of the Pacific* for January 2004, Racine notes that, from 1730 to the construction of the Yerkes telescope in 1897, the growth in refracting telescope aperture size was strictly exponential with an aperture-doubling time of 45 years. During the past 300 years, however, the apertures of the very largest "frontier" reflecting telescopes have doubled on a time scale of 48 years. Racine also notes that the commissioning of large telescopes has tended to occur in bursts separated by intervals of approximately 35 years.

Racine suggests that the exponential growth in aperture size relates to the rate at which telescope technology has progressed. This being said, however, "the stubbornness of t_{2X} [the doubling time] appears to have yielded to acceleration in the second half of the 20th century," Racine writes, "as increasingly broad collaborations, national then international, teamed up to build larger facilities. ...Progress in technology and engineering is necessary to make larger telescopes possible, but people and money are essential to make them happen."

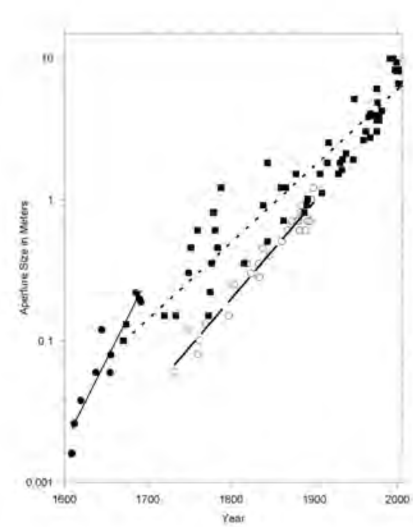

Figure 2 – Telescope aperture diameters as a function of time. The solid line (filled circles) shows the exponential increase in the size of refractor apertures between 1609 and 1700. The line reveals an aperture doubling time of 25 years. The long-dashed line (open circles) for refractors constructed between 1733 and 1900 is another exponential fit with an aperture doubling time equivalent to 45 years. The short-dotted line (filled squares) for reflectors constructed between 1672 and 2003 reveals an aperture doubling time of 50 years. (Diagram based upon data given in Tables 1 and 3 of Racine, 2004, PASP, 116, 77).

My Voyage through the Solar System

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

On the eve of my 16th birthday, while I was watching the television in my Ottawa home, a man stepped on the Moon for the first time. I am a child of the space age, and that moment was a milestone in my life. I remember stepping outside and looking at the Moon, hardly believing that people could be up there. The event was the realization of a dream, and we thought it would open the door to the Universe. That has not come to pass. I find it remarkable that there are grownups today for whom the *Apollo* missions and Moonwalks are simply history: something that happened before their time.[1] This year is a "space" year, with some significant anniversaries, some exciting spacecraft missions, and renewed discussions on the future of manned and robotic space flight. I would like to bundle these thoughts all together in a very personal reflection on the exploration of space, under a title borrowed from Randy Attwood's article on page 32 of the 2004 *Observer's Handbook*. By the way, don't expect a comprehensive history from me in these few pages: if you are interested in a more detailed account, try starting with the chronology in the back of *The Astronomical Companion*, by Guy Ottewell. One of several online resources is `mirkwood.ucs.indiana.edu/space/space.htm`.

Figure 1 – A planetary suit is tested in the Canadian north: will humans eventually walk on Mars? Photo courtesy of the Canadian Space Agency: `www.space.gc.ca`.

Early Days

The exploration of the solar system officially began in October 1957, when the USSR launched the first artificial satellite, *Sputnik 1*. Being only 4 years old, I was too young to remember this event. I think I even missed Yuri Gagarin, the first man in space in 1961, on *Vostok 1*. A friend who is only a few years older than I am remembers going outside to look for *Sputnik*. The first space voyage I definitely remember was John Glenn's three orbits in the *Mercury* capsule *Friendship 7,* in 1962. For me, the space age was underway, and I think this had a lot to do with my interest in astronomy, which came alive that year, according to my observing log. Later in 1962, Canada became the third nation to join the space club when NASA launched *Alouette 1* to study the ionosphere. *Alouette* was a great success, and was eventually deactivated, but I believe it is turned on from time to time. More information on this satellite and Canada's space program can be found at `www.space.gc.ca/asc/index.html`, the Web page of the Canadian Space Agency. I just found out that this year marks the 15th anniversary of the Canadian Space Agency — how did we miss that?

[1] This introduction is the same as the one I used for a book review published in this issue of the JRASC. I liked it so much, I am using it again. It's not plagiarism, it's recycling!

Lunar and Planetary Probes

The years 1962-68 are filled with space "firsts," too numerous to mention. Highlights include the *Mariner* flybys of Venus and Mars (US) and *Luna 9's* first soft landing on the Moon (USSR). The cold war rivals were engaged in the space race, trying to be the first to put a man on the Moon. I was more interested in astronomy than in "space," and I paid more attention to the scientific missions. My memory of that time is a blur, but I have distinct memories of lying in bed listening to a live radio broadcast from NASA during one of the *Surveyor* soft landings on the Moon (perhaps *Surveyor 1*).

Men on the Moon

Everyone's attention returned to manned space flight with *Apollo 8's* flight to the Moon and back in December 1968, followed by Neil Armstrong's famous *Apollo 11* Moon walk in July 1969. How many of us watched those flickering grey images that night, and listened to those crackling words? This is my wife's first space memory and is a milestone in human history. In July, we mark the 35th anniversary of this event. Most people lost interest in the *Apollo* missions after that, and who remembers the last mission: *Apollo 17* in December 1972? (Judging by the cover of the 2000 *Observer's Handbook,* Roy Bishop for one.) NASA cancelled the science-focused *Apollo 18* and *Apollo 19* missions. In all, a dozen men left footprints on the Moon. The space age is nearly 50 years old, but two-thirds of that time has passed *since* a man last stood on an extraterrestrial surface. It makes me feel old to simply remember when it happened!

The Outer Planets

Around this time, I wandered away from astronomy and space. I did not *decide* to give them up; it just happened, coinciding with my university years in Waterloo, Ottawa, and Vancouver. My observing log peters out in January 1970, when I was plotting the path of minor planet Vesta. Fast forward to 1977, when I finished grad school and moved from Vancouver to Halifax to work. That year, in August and September, the probes *Voyager 2* and *Voyager 1* were launched, destined for Jupiter and Saturn. They arrived at Jupiter in 1979 and showed us the best views ever of the giant planet and its moons. They also discovered rings around Jupiter. That was 25 years ago! The following year, they flew by Saturn and repeated the performance. The *Voyagers* delivered spectacular multi-colour images of cloud belts, satellites, and rings. Perhaps I am only imagining this, but did amateur astronomers actually lose interest in the planets after these flybys? After all, how could a backyard telescope compete with the *Voyager* close-ups?

The Space Shuttle

The first space shuttle, *Columbia,* was launched in 1981 and completed its first satellite insertion in 1982. The launches quickly became routine, which is to be expected of a re-usable spacecraft, I suppose. Many space "firsts" followed. In October 1984, the first Canadian astronaut, Mark Garneau, took part in mission STS-41G on *Challenger*. The 20th anniversary of this event takes place later this year. Mark Garneau made two more trips, eventually logging 677 hours in space, and is now the President of the Canadian Space Agency. In 1992, Roberta Bondar became the first Canadian woman in space, flying on *Discovery*. In between those dates was the explosion of *Challenger* just after launch on January 28, 1986. This was a weekday, and for some reason I was home (to watch the launch?). I remember turning on the TV and seeing the very strange plumes of exhaust smoke — I had missed the event by only seconds. For my 30-year-old colleague at work, this is her first space memory.

Nobel laureate Richard Feynman became involved in the investigation of the disaster, and he makes an interesting comment in his memoirs: "In the newspaper I used to read about shuttles going up and down all the time, but it bothered me a little bit that I never saw in any scientific journal any results of anything that had ever come out of the experiments on the shuttle that were supposed to be so important. So I wasn't paying very much attention to it." (From "What Do You Care What Other People Think?" Norton, New York, 1988.) Feynman went on to play a key role in the detective story about the O-rings on the solid rocket boosters that became brittle in the cold and leaked.

Halley's Comet, More Space Shuttles, and Mars

In 1985 and 1986, many of us were excited by the return of Halley's Comet, despite the fact that it was one of its least spectacular apparitions ever. On the space side, the European Space Agency sent *Giotto* for a better look and for the first time we saw a comet nucleus up close, that is, from 605 km. To me, it looked like a potato.

The space shuttle started flying again in 1988, and the *Hubble Space Telescope* was launched from *Discovery* in 1990. On January 22, 1998, my daughter and I were very excited to watch the space shuttle *Endeavour* ascend into space as it passed by Nova Scotia just minutes after launch from Cape Canaveral. *Endeavour* was to dock with *Mir* in its high-inclination 51.6-degree orbit, which explains the unusual flight path. We were able to see the rocket plume using binoculars as it flew by! It turns out that Nova Scotia is uniquely situated to make this observation possible.

Most recently, after a spectacular opposition that attracted huge public attention, and following a string of failed missions to Mars, the twin rovers *Opportunity* and *Spirit* landed on Mars and brought us the best pictures ever of our fascinating neighbour, in colour and in stereo. It is amazing to me that we can sit in our homes and download pictures from robot explorers on Mars!

The Future

As I mentioned last issue, the NASA/ESA space probe *Cassini-Huygens* will soon arrive at Saturn for a 4-year stay. The orbiter is *Cassini*, and the lander is *Huygens*, designed to enter Titan's atmosphere and descend to the ocean of the satellite by parachute (see sci.esa.int).

Following the success of the Mars rovers, there were a couple of controversial announcements: U.S. President George Bush announced a long-range plan to send astronauts to Mars, and NASA announced that it was no longer safe to send the shuttle on an operational mission to service the *Hubble Space Telescope*. These topics have generated a debate in the media and on our RASCals listserver. For NASA's view, go to www.nasa.gov/home/index.html; for an alternative view, read Nobel laureate Steven Weinberg's article in the New York Review of Books at www.nybooks.com/articles/17011. (I hope this link remains active; if not contact me for a copy.)

This voyage through the solar system has been like skipping a rock on the lake: I have only touched some personal high points, and there is a great body of knowledge that lies beneath. Every one of us has his or her own journey. The journey is not over; for some it has only begun.

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.

Second Light

Resolving the Gamma-ray Background into Discrete Sources

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

The history of astronomy shows over and over the importance of increasing the resolution of observations — such increases usually produce major advances in our physical understanding of how the Universe around us works. An instrument that has dramatically increased resolution over the past decade — and is now in the news — is the *Hubble Space Telescope (HST)*, whose existence beyond 2007 has recently been gravely threatened. In a very different wavelength range — that of soft gamma rays — great strides have been made by another spacecraft: the *INTEGRAL* gamma-ray observatory. Francois Lebrun of the Service d'Astrophysique section of the Commissariat a l'Energie Atomique in France, and his collaborators across Europe, have now resolved the soft gamma-ray emission of our Galaxy into individual sources, most of which involve some kind of compact object like a black hole or a neutron star.

Galileo made the first leap in resolution by pointing his telescope at the night sky and finding that the diffuse bands of light known to us as the Milky Way actually were dense collections of individual stars. He also found that Jupiter was circled by four companion moons, and that Venus goes through a cycle of phases that is systematically correlated with changes in the planet's apparent size in the sky. These discoveries (along with a few other observations) changed the world — they firmly established that the Earth orbits the Sun, contrary to the doctrine of the Catholic Church at that time.

As telescopes grew in size over the next few hundred years, our understanding of our Solar System and the nearer reaches of our Galaxy evolved. Increases in the size of the telescopes, though, did not always lead to major advances because the resolution was limited by the "seeing" — the smearing out of the light by the Earth's atmosphere. Seeing is defined as the separation of two stars that can just barely be distinguished from each other, and is expressed in units of arcseconds. Theoretically, increasing the size of the telescope increases its resolving power, but in practice we very soon run into the atmospheric seeing effects. Almost all observational astronomy from the time of Galileo through the early part of the 20th century was done from locations with fairly abysmal seeing. Even at a good site like Kitt Peak (in southern Arizona), where the average seeing is ~1 arcsec, that theoretical resolution is achieved at visual wavelengths by a telescope only 14 cm (5.4 inches) in diameter! Of course, more advances came with bigger telescopes that collected more light, and with the introduction of CCD cameras in the 1980s and the development of very high sites like Mauna Kea (on the big island of Hawaii). Optical astronomy's big leap, however, occurred with the launch of the

HST and just a little later with the use of "adaptive optics" on ground-based telescopes.

In the meantime, other areas of astronomy had been forging ahead, but at all wavelengths the first telescopes were primitive and had low resolution. For example, Karl Jansky's radio telescope (in 1934) found emission from all directions, and it was only with time that he realized the emission was peaking when the centre of the Milky Way was above the horizon. For over 30 years — and to this day — radio observations have achieved higher resolution than optical telescopes (even the *HST*).

At some wavelengths, however, deciding whether emission comes from individual sources is much more tricky than in the optical and radio spectrum. For example, the cosmic microwave background is — to about one part in a hundred thousand — smooth across the entire sky. At higher energies, in the x-ray and gamma-ray range, it is only in the last few years that orbiting observatories such as *Chandra, Newton-XMM,* and *INTEGRAL* have had both the resolution and the sensitivity to pinpoint from where the emissions were coming.

From first principles it was difficult to establish if there should be diffuse soft gamma-ray background from our Galaxy. We know that there must be some diffuse emission resulting from the interactions of cosmic-ray electrons with the interstellar medium. But at what level? Making a theoretical calculation was not easy, and it was therefore far better simply to look.

Lebrun and his collaborators have done just that. Before *INTEGRAL* was launched, the best that could be said was that about half of the soft gamma rays seen by earlier telescopes could be attributed to individual sources. The balance of the soft gamma-ray flux, however, was uncomfortably large to be explained as arising from interstellar gas in the Milky Way — the energy input required to achieve a balance of ionization to explain the soft gamma rays would be in conflict with other constraints, such as the observed molecules and the degree of ionization in the interstellar medium. The molecules would be dissociated to atoms, and many of the atoms ionized, if all of the soft gamma rays came from the general interstellar medium.

The *INTEGRAL* observatory was launched by the European Space Agency in October 2002, and since then has devoted about 5 million seconds (almost two months) to making observations of the central region of the Milky Way. The previously unidentified point sources include binary systems where a star is orbiting a neutron star or black hole. The gamma rays come from the gas that is flowing from the companion star into the accretion disk around the compact object. As the gas spirals into the compact object, gravitational potential energy is converted to kinetic energy, heating the gas to temperatures of millions of degrees — hot enough to emit gamma rays. There are 26 unidentified point sources. In total, the point sources account for about 90 percent of the emission, leaving space for some diffuse emission from the interstellar medium, but the energy needed to maintain that level is in agreement with the other constraints.

Where do we go from here? There are several wavelength ranges that have not yet been explored with such precision and sensitivity. One is at far infrared wavelengths, where the *Spitzer Space Telescope* is just starting to produce phenomenal results. Another is at millimetre wavelengths, where the long-awaited Atacama Large Millimetre-wave Array will most probably provide startling new insights when it comes online in northern Chile around 2010. Finally, there are numerous facilities being built to sort out the origin of energetic cosmic rays (protons, electrons, and nuclei of heavier atoms). But those are stories for other columns!

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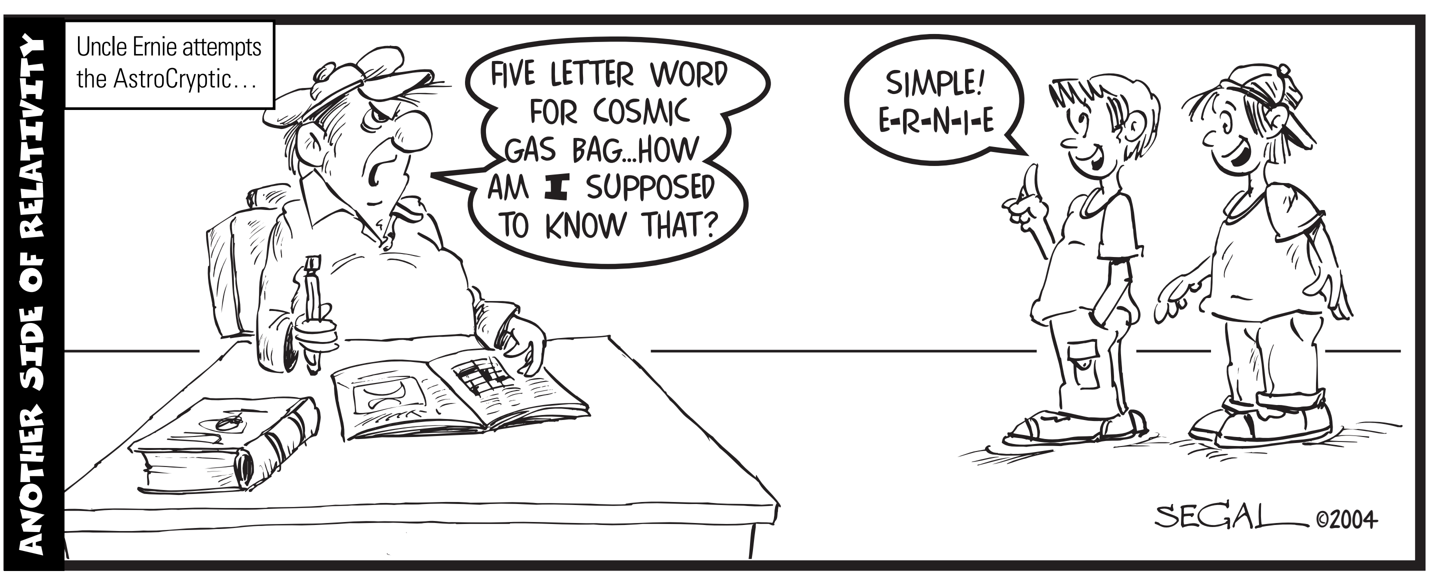

THE UNIDENTIFIED BRIGHT OBJECT SEEN NEAR THE SUN

The object seen near the setting sun on the evening of August 7, by observers in both hemispheres has been the subject of much discussion and the following brief account of it may be of interest to the readers of the *Journal.*

On Sunday evening August 7, a party, which included Professor Henry Norris Russell, of Princeton, Major Chambers, Capt. Rickenbacher and Director Campbell, were observing the setting sun from the porch of the latter's residence upon Mt. Hamilton, Cal. Just at sunset (14h. 50m. G.M.T.) Major Chambers said: "What star is that to the left of the sun?" Capt. Rickenbacher said that he had been watching that star for several minutes but had not mentioned it because he supposed it was well known. All agreed that the body was star-like. Its appearance still seemed stellar when a minute later Director Campbell observed it through binoculars, not more than two seconds before it disappeared behind the cloud stratum at the horizon.

Upon consulting the *Nautical Almanac* it was evident that the object seen could not have been the planet Mercury, as was at first supposed. Professor Russell and Director Campbell concluded that it was brighter than Venus would have been under similar circumstances. After a comparison of notes the following telegram was sent to the Harvard College Observatory:—"Star-like object, certainly brighter than Venus, three degrees east, one degree south, of sun seen several minutes before and at sunset by naked eye. Five observers. Set behind low clouds. Unquestionably celestial object. Chances favour nucleus bright comet, less probably nova." This information was distributed by telegraph the following day and is contained in H. C. O. *Bulletin* 757 of August 9.

by J.A. Pearce,
from *Journal,* Vol. 15, p. 364, December, 1921.

SHORT EXPOSURE ASTRONOMICAL TECHNIQUES FOR OCCULTATION DETECTION

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ABSTRACT. Image intensifiers coupled to video frame rate CCDs have the capability of observing much shorter duration events than conventional multi-channel optical astronomy detection techniques. This equipment is particularly suited to observations of unpredicted stellar occultations. An image intensified CCD system can offer a moderately sensitive multi-channel photometric search tool for occultation events on 500 or more simultaneous channels with effective exposure times of the order of 0.03 s. The increased noise of such short-duration image-intensified techniques demand coincidence approaches with two or more systems. Stellar occultations can result from many types of objects passing along the line of sight between the Earth and a star. These objects can include: asteroids, Kuiper Belt Objects (KBOs), or interstellar planets and planetesimals. Calculations suggest that in most cases occultations by these objects will be of very short-duration. The research described here uses a semi-automated coincidence method to search for short-duration stellar occultations. The image-intensified CCD detectors used can detect about 500 stars per 0.033 s exposure time in a 1200 square degree field of view. During 12 hours of observation from each of two cameras over 2.2 million images, consisting of nearly 1.1 billion stellar images, were analyzed for this study. Semi-automated software performed the initial stage of the detection in real-time. After coincidence processing between the two intensified CCD detectors there was one promising event (a 0.5 magnitude dimming of a +7.6 magnitude K-type star at 7:16:35 UT July 31, 2000). However, additional analysis of this event indicated that the occultation was probably caused by terrestrial phenomena so no confirmed occultation events were identified in this search. This technique is likely best suited to the search for small KBOs, where direct observation from reflected light is difficult or impossible. This paper provides guidance for those wishing to set up observational programs aimed at detection of transient astronomical systems.

RÉSUMÉ. Les intensificateurs d'images accouplés à des CCDs à encadrement visuel rapide ont la capacité d'observer des phénomènes de beaucoup plus courte durée que les systèmes astronomiques de détection optiques multi-canaux conventionnels. Ces équipements conviennent particulièrement aux observations d'occultations stellaires imprévues. Un système CCD intensificateur d'images peut fournir un outil de recherche en photométrie multi-canaux modérément sensible durant des circonstances d'occultations, sur au moins 500 canaux simultanément avec des temps effectifs d'exposition d'environ 0,03 seconde. La croissance de faux signaux survenant de telles images intensifiées de courte durée requiert des méthodes de mesurage par coïncidence à l'aide de deux systèmes ou plus. Les occultations stellaires sont le résultat de plusieurs types d'objets passant devant le champ de vision entre la Terre et une étoile. Ces objets peuvent comprendre : des astéroïdes, des objets de la ceinture Kuiper, ou des planètes ou petites planètes interstellaires. Des calculs indiquent que les occultations causées par ces objets seraient de très courte durée. Les recherches décrites dans ce rapport ont utilisé une méthode de mesurage par coïncidence semi-automatisée pour déceler les occultations stellaires de courte durée. Les détecteurs CCD à images intensifiées utilisés peuvent déceler environ 500 étoiles à chaque exposition d'une durée de 0,033 seconde dans un champ visuel de 1 200 degrés carrés. Durant 12 heures d'observation avec chacune des deux caméras, plus de 2,2 millions d'images, comprenant presque 1,1 milliard d'images d'étoiles, ont été analysées pour cette étude. Un logiciel semi-automatisé a entrepris en temps réel la première phase de la détection. Après mesurage par coïncidence des résultats des deux détecteurs CCD à images intensifiées, il restait un événement

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promettant (une baisse de 0,5 magnitude d'une étoile de type K, magnitude +7,6, enregistrée à 7:16:35 TU le 31 juillet 2000). Toutefois, une analyse supplémentaire de cet événement a indiqué que l'occultation était vraisemblablement causée par un phénomène terrestre. Donc aucune occultation confirmée n'a pu être identifiée durant cette recherche. Cette technique de recherche convient surtout pour les recherches de petits objets de la ceinture Kuiper, lorsque les observations directes de la lumière reflétante est difficile ou impossible à percevoir. Ce rapport offre des conseils à ceux qui désirent établir un programme d'observations cherchant à détecter des phénomènes astronomiques transitoires.

1. Introduction

Conventional CCD and photographic astronomy typically employs exposure times on the order of many seconds to minutes. Some astronomical events occur on time scales that are not appropriate for these lengths of exposures and innovative new techniques must be implemented. One type of event that requires rapid imaging techniques is the detection of unpredicted stellar occultations. The rapid variability in magnitude of a star can be the result of the transit of a variety of objects such as: asteroids, Kuiper Belt Objects (KBOs), and interstellar planets or planetesimals.

In this work a technique was developed to observe stellar fields at a rate of 30 images per second. The goal was to look for rapid stellar occultations that would escape other observing techniques. In order to understand why such short exposures were necessary it is of interest to get a rough idea of the duration of occultation events that can be calculated using the following assumptions. For a star to be considered essentially a point source we require that the angle subtended by the occulting object (an asteroid or KBO) be significantly larger than the angle subtended by the star. This condition can be expressed by the inequality

$$r > \frac{Rd}{D} ,$$

where r is the radius of the occulting object, d is the distance from Earth to the occulting object, R is the radius of the star occulted, and D is the distance to the star. For example, if we consider a star at a distance of 500 ly with a radius of 10^6 km, and an asteroid at an opposition distance of 1.8 AU from the Earth, the asteroid would need to be significantly larger than 0.06 km for the star to be considered a point source. For a KBO at 40 AU we can consider the star to be a point source if the KBO radius is significantly bigger than 1.3 km. It is important to note that for asteroids and KBOs, where we can assume stars as point sources, the occultation duration depends only on the size and relative velocity of the asteroid or KBO and not that of the star.

We can ignore diffraction effects when the radius of the occulting object, r, is much larger than the Fresnel zone. This can be expressed in the form of the following inequality (see Brown & Webster 1997):

$$r >> \sqrt{\frac{\lambda R}{2}} ,$$

where λ is the wavelength of the light. For KBOs at 40 AU, which are significantly larger than 1.2 km, we can ignore diffraction effects.

Now we will estimate typical occultation durations under the assumptions that the angular size of the star is much less than the occulting object and that diffraction effects can be ignored. A main belt asteroid at opposition in a circular orbit at a distance of 2.8 AU from the Sun would be moving at a heliocentric velocity of 17.8 km s^{-1}. At opposition this represents a relative velocity to the Earth of 12 km s^{-1}, and an occultation duration of 0.083 s for a spherical asteroid of diameter 1.0 km. Similarly for a 10 km diameter KBO at 40 AU the duration of occultation would be 0.4 s. Larger KBOs would scale in a linear fashion to longer occultation times. If the objects are not at opposition then these occultation durations become even smaller.

While many KBOs much larger than those assumed here exist (e.g. Trujillo *et al.* 2001), size distributions for the KBO indicate that the majority of objects should be relatively small (see Trilling 2002; Gladman *et al.* 2001). KBOs of the size modeled here are not readily detectable with traditional detection techniques, but are expected to dominate the size distribution. Most studies suggest that the distribution of the number of KBOs with radius r is given by a power law distribution of the form:

$$N \approx Cr^{-q} ,$$

where r is the radius of the asteroid and q is of the order of 3.6 (*c.f.* Chiang & Brown 1999; Sheppard *et al.* 2000 find a value of ~ 4 for q). This means that for every 100 km radius KBO we might expect about 4000 KBOs with radius 10 km. The smallest KBO size is not observationally determined, and we used data from cometary nucleus distributions in suggesting that 10 km might be a typical KBO size.

The original motivation for this work was to examine the possibility that planetary debris was an important contribution to MACHO dark matter. MACHO objects would generally not occult an entire star, but it is possible, however, to get an idea of maximum duration by assuming the star is a point source and determine the time it takes the object to traverse its own diameter.

The planetesimal relative size distribution is generally assumed to follow the same power law as given earlier for KBOs with q values of about 3.5 usually assumed (Kenyon 2002). If we assume a 10 km planetesimal moving at a velocity of 20 km s^{-1} relative to us (this is the typical random component of stellar velocities in the solar neighbourhood; *e.g.* Barnes 1992) then the occultation duration would be 0.5 s. Since most occultations would not be across a diameter, the expected duration would likely be less than this. Interstellar planets are a recent discovery (Lucas & Roche 2000) and could represent longer stellar occultations since they are much larger than 10 km planetesimals, though most likely the number of such events would be significantly less.

Simple models were constructed (see Parker 2001 for details) to model the experimental set-up, which will be discussed below, in order to calculate the expected duration of such events. The asteroid model simulated the entire main-belt of asteroids and looked for the occultation of any stars in a field of view matching that of the experimental set-up. The other model was that of interstellar planetesimals. A distribution of 1 to 20 km radius planetesimals was assumed based on our knowledge of the size distribution of cometary nuclei (Stern 1992). It was found that, with these assumptions and the stellar field of our detector, occultations due to main-belt asteroids were on average 0.39 seconds in duration, while those due to interstellar planetesimals were on average only 0.033 seconds (Parker 2001).

Much more sophisticated models have been developed (Roques & Moncuquet 2000) to predict the appearance and characteristics of stellar occultations caused by KBOs. They consider also the diffraction pattern that would result with occultations. Their models suggest that it should be possible to detect objects smaller than 100 m in diameter at a distance of 40 AU provided the equipment is sufficiently sensitive and the frequency is high enough. Their results show that KBO occultations could last anywhere from 0.1 s to a few seconds.

Clearly, conventional long-exposure astronomical imaging techniques are not optimized to capture these rapid occultations; it is apparent that much more rapid imaging is required. An interesting point to make is that the detection of stellar occultations would allow the detection of objects that escape all other methods of direct detection. The largest asteroids and KBOs can certainly be detected directly but the smaller ones, which represent the vast majority, reflect too little light to be detected using established methods. The more distant an object is from the sun the more favorable occultation techniques are compared to direct-imaging techniques.

While rapid imaging over wide fields of view is not frequently used in astronomical applications, others have suggested it as a possibility in the detection of KBOs. The Robotic Optical Transient Search Experiment (ROTSE) looks for optical variability in stars and has the capability of detecting KBO occultations of stars through rapid imaging. ROTSE I can image to magnitude 15 with 5-second exposures in a 16-degree field of view (Kehoe *et al.* 1998), while ROTSE II has a 1.9-degree field of view with a 10-second exposure.

Finally, there is an observational project in the process of being built that will search for occultations caused by KBOs. The Taiwan-America Occultation Survey (TAOS) consists of three telescopes operating in coincidence that observe 3000 stars per night and automatically consult with each other in order to eliminate false events. They claim that only 10 to 4000 events should probabilistically be expected to be discovered each year with the capturing of 100 billion images. The enormity of data therefore requires efficient analysis and maximum automation (Wen 2001). The TAOS system provides images at a rate of 5 Hz (Chen 2000).

We set out to develop a semi-automated system that would be able to monitor the brightness of a large number of stars over an extended field of view at a very high (30 frames per second, with some information at double that rate) scan rate. The equipment, detection software, and initial results are described in the remainder of the paper.

2. Short-Exposure Astronomical Equipment

In order to detect rapid occultations it is necessary to capture images many times each second. The most cost effective way to achieve this is to use commercially available video rate CCDs, which in North America operate at 29.97 video frames per second. Most video rate CCDs are interlaced (although progressive scan systems are becoming more common), with each video frame divided into even-line and odd-line video fields. As well as leading to cost effective CCD detectors because of economies of mass production, adopting video scan rates means that data can be recorded on standard analog or digital video recorders. The time exposures of video rate sensors are appropriate to the typical occultation durations calculated in the previous section, although in many cases we would expect the occultations to last for one video frame or less. This would be recorded as an incomplete dimming during the integration period.

Unintensified video rate CCDs are probably not sensitive enough for most occultation work. With modest-aperture objective optics the quantum limitation will mean that only a small number of photons are received from a faint star in each video frame integration period, and the signal to noise ratio of the signal is limited due to the readout noise of the detector. Therefore, the quantum efficiency of the detector is related to noise since one of the limiting "noise" characteristics is due to the fluctuation in the number of photons received during an integration cycle. Astronomers are most familiar with thermally generated noise in CCDs. This noise, which predominates in long exposure times, can be limited by cooling of the CCD. However at video rate operation the thermal noise can, for most work, be neglected due to the short integration period. Readout noise is a pseudo-random noise component, which is added to each pixel readout and which is essentially independent of exposure duration (Buil 1992). If this readout noise becomes comparable to the number of photons received during a single frame integration time, then it will become impossible to effectively measure the intensity of a star to search for occultations. It is this readout noise that limits the effectiveness of unintensified video rate CCDs for astronomical photometry and occultation studies of bright stars.

While there have been significant improvements in reducing CCD readout noise in recent years, nevertheless for most rapid-exposure astronomical work one will need an image intensifier. The image intensifier is placed between the objective optics and the CCD (the coupling can be done with either fibre-optic image conduits or by macro-lens coupling). Essentially an image intensifier makes a much brighter image so that the readout noise of the CCD that views the image intensifier output window is no longer important compared to the amplified signal from the astronomical source. Image-intensifiers were first developed for military applications, specifically night vision, and are extensively used in surveillance work, but are less common in most branches of astronomy. Some commercial manufacturers do sell image-intensifier-based eyepiece viewers, and some astronomical spectral detectors are image intensified. It is in fields dealing with transient events, such as meteor astronomy, that image-intensifiers are most widely used. Image-intensified CCD detectors form the backbone of electro-optical meteor astronomy (Hawkes & Jones 1986; Molau *et al.* 1997; Hawkes 2002).

Image intensifiers come in three main generations, with two main principles of operation. In all cases the image intensifier has an input photocathode that emits photoelectrons in response to incident light, and an output phosphor that generates an intensified image. The earliest image intensifiers (termed Gen I devices) operated like electronic pinhole cameras. The photoelectrons were attracted toward a point with a high positive voltage in a vacuum tube. The highly accelerated electrons overshot this point, and struck a phosphor. The increase in kinetic energy of the electrons resulted in a brighter image, although most Gen I devices are limited to gains of about 70, and therefore several stages usually need to be cascaded. Imaging was achieved by electrons being attracted to the high positive potential point in a manner analogous to photons passing through a pinhole in a pinhole camera. The limited gain of Gen I devices, the moderate resolution resulting from the multi-stage implementation and simplistic image formation design, and blooming, the spread of bright sources over extended spatial regions, make these devices of only limited suitability. Gen II and Gen III devices use microchannel plate (MCP) technology to produce much higher gains, somewhat higher resolutions, and significantly reduced persistence. The photoelectrons created at the photocathode are accelerated down hundreds of thousands to millions of tiny microchannel plates. The high applied voltage (typically 10 to 20 kV) results in secondary electron emission along these microchannel plates and a multiplication effect similar to that in photomultiplier tubes (except the microchannel plates retain an image as opposed to simply a measure of total light signal in the PMT), so that a much brighter image is produced at the output phosphor (luminous gains of 30,000 or more can be achieved in a single stage with Gen III devices). Gen II and Gen III image intensifiers are essentially the same in physical design, with Gen III devices having enhanced photocathodes that result in extended infrared response, enhanced quantum efficiency, significantly extended device lifetimes, and flattened noise across the field of view.

The limitation on sensitivity of high-frame-rate image-intensified CCD systems is usually determined by either lack of discrimination between unresolved background illumination or the discrete quantum nature of the incident photons (*e.g.* Hawkes 2002; Hawkes & Jones 1986). At some level the quantum nature of the incident-light photons will appear as noise in the image intensified CCD, and will add to the readout noise of the CCD. If for example 100 photons are received from a stellar source during a video field integration time, we would expect a SNR of about 10:1 (assuming variability proportional to the square root of the number of received photons). Therefore if one wants a SNR of 10:1 one would need to detect at least 100/η photons per integration period where η is the quantum efficiency. Image intensifiers have much more limited resolution than photographic plates or many astronomical CCDs (a typical Gen III image intensifier has a resolution of 35 line pairs per mm across an 18- or 25-mm active area).

Hawkes & Jones (1986) and Hawkes (2002) have considered in detail the various limitations on detection sensitivity of video rate image-intensified CCD detectors. For the type of detector and optical system employed here the limiting element is the background arising from unresolved stellar and nonstellar objects and atmosphere skyglow. Hawkes & Jones (1986) derive that the limiting sensitivity (in astronomical magnitudes) is given by the following where α is the angle in degrees subtended by one effective resolution cell and M_s is the limiting sensitivity in astronomical magnitudes

$$M_s=3.8 - 5.0 \log_{10}(\alpha).$$

With our field of view (14 degrees horizontal) and assuming an effective resolution of 300 pixels, we get a limiting magnitude of +10.5. Objects would need to be somewhat brighter than this to be clearly resolved (the above equation represents a value in which the object and unresolved background have equal brightness), consistent with the measured limiting magnitude of +8.7 quoted later in this paper.

A very important effect that causes optical variability in observations through the Earth's atmosphere is stellar scintillation. This twinkling of stars is a result of the different indices of refraction of small packets of air in the Earth's atmosphere. In order to isolate stellar scintillations from occultations, two experimental set-ups were established to operate in coincidence. It turns out that if two apertures are separated by 30 centimetres or more then the stellar scintillation effects they detect will be largely independent (Jakeman *et al.* 1978).

3. Transient Event Detection Software — MachoScan

Rapid detection techniques require not only specific hardware but also very efficient and sophisticated software for analysis. In order to search the over 100,000 images per hour of video data for stellar occultations, real-time software is required to operate at video frame rates (29.97 Hz). To this end a program was developed to search pixel by pixel for statistically significant dimming of stars. The software developed by one of the authors (PG) for this study (MachoScan version 0.1 — named in recognition of the initial aim of the project, which was to detect dark-matter planetesimal and planet candidates from interstellar space) was actually an evolution of software developed to automatically search for meteors (Meteorscan). Some of the principles of MeteorScan for real-time transient-line detection are outlined by Gural (1995, 1997, 1999). Up until about 1996, meteor occurrences recorded on video needed to be located by human observers. After a few versions of the software both the computer processing speed increase and algorithmic detection efficiency improvement converged making it possible to process 30 frames per second. This processing involved examination of 640 × 480 pixels per video frame using Hough transform techniques to search for linear meteor segments in the intensified video imagery. It is estimated that with optimum settings this software can detect about 80 percent of the meteors detectable by a careful human observer (Hawkes 2002), and the software was used with great success for real-time meteor detection in the international Leonid campaign in 1999 (*e.g.* Brown *et al.* 2000).

For the MachoScan implementation, modifications were made to remove the Hough transformations and line detection processing and concentrate on pixel variability. The processing basically reduced to looking for pixels with large intensity deviations from a mean level in the direction of a dimming light source. This is in the opposite sense of meteor detection, which looks for a brightening rather than a dimming. Because of the specular noise behaviour in image-intensified video systems some spatial and temporal averaging was included at the user's discretion to beat down the noise in the image mean.

The software grabs or digitizes 640 × 480 spatial resolution imagery at the full NTSC video rate (30 video frames composed of 60 odd/even video fields in each second) into the onboard frame grabber memory (Scion Corp. LG-3). The frame grabber is a bus-mastered PCI board that the computer (G4 *Macintosh*) has direct memory access to at all times. Before beginning the real-time detection portion of the algorithm, MachoScan uses previously digitized frames to update a mean value and a standard deviation for each pixel in the image. These are tracked and updated at a 4-Hz rate using a first order response filter. For each new digitized video frame the software searches for statistically significant dimming of pixels (or spatial-temporal pixel averages) relative to the mean, and flags these as potential occultation events.

In the implementation of MachoScan used in this research we require a significant dimming in a 2-by-2 pixel spatial block (since all stars are bloomed, in the sense that photons from each star will spillover onto adjacent pixels, to at least this degree) and temporally in two consecutive frames (this will obviously result in some brief occultation events being missed, but it was felt that the tradeoff of a very significant reduction in false alarms warranted this loss). Although anti-blooming gates are employed in the CCD, and blooming is minimized through the microchannel plate structure of generation-III image intensifiers, bright sources still spill over to neighbouring pixels to some degree. The software operates in real time thus taking only a single hour to analyze a one-hour data tape. MachoScan writes, in a compressed format, the x and y locations of all potential occultation events, including the time and the significance of the dimming.

For each sensor there is a very large number of potential events recorded. For example, for the two intensified CCD cameras used in this study the raw number of potential detections ranged from 53,000 to 84,000 events per hour of observation. However, the next stage of the analysis routines compares the files of potential events from two coincident detectors. A slight spatial transformation was necessary to precisely match x and y locations on one detector to those of the other. This stage of the analysis only kept those events that occurred at the same spatial location on the two cameras (within two pixels), and at the same time within the time coincidence uncertainty (1 second). The power of this experimental set-up and analysis is the ability to look for coincident detections and reduce the number of hourly detections from many thousands down to approximately 10 per hour. These coincident events were then compared from the two data tapes and the stellar light curves of events that occurred on both cameras were plotted. At this stage it was easy to eliminate a number of events (such as bats flying in front of the detectors) since these would result in dimming of a number of stars in the same area simultaneously.

4. Experiment and Preliminary Results

As a preliminary test of this approach to occultation detection, a set of wide-field observations were made. In order to search for occultation events two systems of 50-mm f/0.95 objective lenses, ITT 18-mm diameter Gen III image intensifiers, COHU 768 × 494 video rate CCDs, and *Sony* Digital 8 video recorders were used. The field of view of each system was 14.0 degrees by 10.5 degrees. Observations were conducted over 35 hours under Moon-free conditions on July 2 to 6, 2000 and July 30 to August 2, 2000. Observations were made from a dark-sky location near Alma, N.B. at latitude 45° 36′ N and longitude 64° 56′ W. The average number of stars in the field at any one time was approximately 500 with a limiting magnitude of +8.7 for exposures of 0.0167 s (see below for detail on the COHU exposure system). We show in Figure 1 a typical short-duration image recorded with the observing system. Stellar crowding was not an issue since there were only 500 stars in this large field of view, and it is also an unimportant effect because crowding effectively just reduces the number of parallel photometers, since only resolved stars were analyzed for occultations. The CCD cameras used incorporate microlens technology so that the effective fill-factor is essentially 100% (there are no insensitive areas of the pixel).

The observational field selected was based largely on practical considerations for our observing station and equipment. We had originally hoped to view in the region of Sagittarius where the ecliptic intersects the Milky Way, but this was too low in our local sky for good sensitivity. The cameras were fixed and the average altitude of the field of view throughout the observations was about 50 degrees and

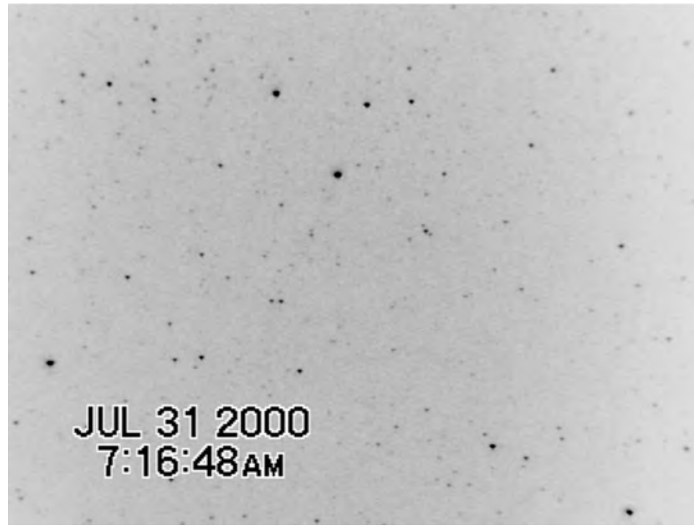

Figure 1 — A typical 0.033 s stellar field from one of the image-intensified CCD detection systems. On the original image, stars to about +8.6 magnitude are visible, with about 500 stars identifiable. The field of view is 14.0 degrees by 10.5 degrees. The brightest star in the upper central part of the image is the +3.6 magnitude star 41 Ari (SAO 75596).

the average azimuth was about 105 degrees so that a variety of stellar fields drifted slowly by as the Earth turned. This meant that portions of the constellations Pegasus, Andromeda, Pisces, Triangulum, and Aries drifted through our field over the course of the night.

The spacing between the two detectors was about 0.9 m, which ensured independence of the two detectors from stellar scintillations according to the results obtained by Jakeman *et al.* (1978), which found that, at distances of more than 0.3 m, stellar scintillations are essentially uncorrelated. The MachoScan software had flexibility in a number of the settings, including the number of frames to average temporally and the level of significance of dimming required to register an event. The temporal average was left at two frames for all of the analysis so that the shortest duration events could still be detected and the level of significance was set so that a potential event must be at least three standard deviations away from the average. This statistical criteria meant that we would expect several false events to be detected each hour that appeared coincident. However, we can greatly reduce the number of these false detections if we require a dimming for several consecutive time intervals.

When the data tapes were compared it was required that events on the two cameras be coincident to within a second of time of each other and within two pixels in both the x and y directions in order to be considered for further analysis. For events passing this criteria the light curves of the star (an integrated pixel intensity over the stellar image) were plotted so that the events from the two stations could be visually compared and the statistical significance of each event computed. This stage of the analysis produced what was to be expected — few events beyond the level of stellar scintillation. On average there were 10 events found for each hour of data but almost none of these produced convincing correlated dimming.

After analyzing 24 hours (12 hours for each of two cameras) of observational data one event was located that was significant on both cameras and was similar enough to potentially represent an occultation dimming (but see below). This event took place at 7:16:35 UT on July 31, 2000. The stellar location of the event was right ascension of $2^h 43.6^m$

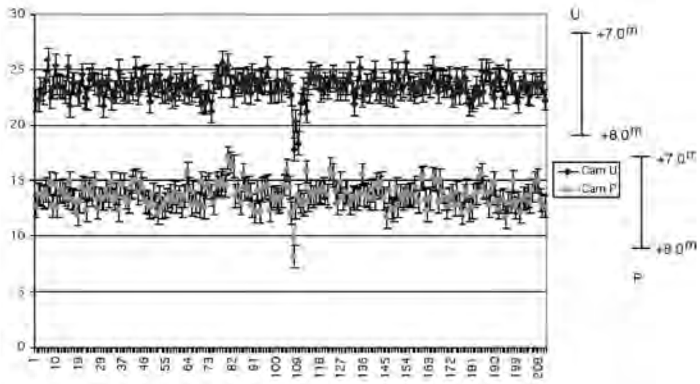

Figure 2 — A plot of mean pixel intensity averaged over a single star (on a scale with 0 = black level of the CCD camera and 255 = an arbitrary maximum luminosity level for the digitized CCD signal, hence the two cameras have different absolute scales) versus sample number (each data point is 0.033 s following the preceding one or a total time of about 7 s illustrated here). This represents a potential occultation event of a +7.6 magnitude star (SAO 75535) observed at 7:16:35 UT July 31, 2000. The vertical error bars on each data point represent one standard deviation value (for that time period) for each camera. Horizontal error bars are not given, but would be about the width of the spacing between data points. While the vertical scales are nonlinear, for reference purposes we have indicated the approximate values of +8 and +7 magnitude in absolute terms with the bars given to the right of the diagram for each camera.

and a declination of 24° 4′. This event was approximately six standard deviations away from the mean intensity for both of the cameras and represented a drop in stellar magnitude of about 0.5. Figure 2 displays this event in a plot of light intensity (an integrated intensity over the stellar image) versus time. The dimmed star was a +7.6 magnitude K0 spectral type star (SAO 75535). Each data point plotted is 0.033 s following the preceding point (so the entire interval represents about 7 s of data). In Figure 3 a detailed plot of the points near the dimming is shown.

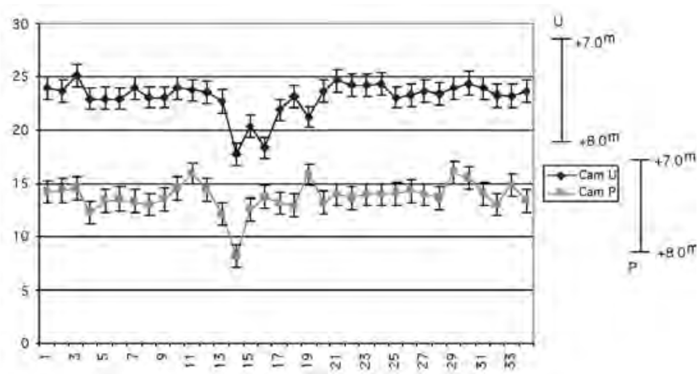

Figure 3 — A detailed plot of intensity versus sample number for the potential occultation event of Figure 2. The time uncertainty (determined from using meteor occurrence on an earlier video frame) is about the spacing between time samples (0.033 s). Approximate absolute magnitudes for each camera are indicated to the right of the diagram

While the time signal (crystal controlled) on the digital video recorders could not be synchronized more precisely than one second, the appearance of transient events such as meteors (the cameras typically detect 15 sporadic meteors per hour) could be used to determine precise time coincidence between the two cameras to within 0.033 s (by measuring the number of video frames from the meteor to the time-signal change on each camera).

Clearly the events did not appear to last precisely the same length of time on both cameras. It was (subsequent to the observations) discovered that the two COHU CCDs had been set in different scan modes, and this was partially responsible for the difference in appearance of the dimming event. The COHU camera can be set in a mode in which each of the scan lines represent the direct integration for that scan line, or (through an internal jumper) to a mode in which in an even video field the even lines are an average of the intensity integrated on that line averaged with the preceding odd line. Camera P was set to the simple line-only integration mode while Camera U was set to the averaging mode. As a result an event of the same real duration would appear longer on Camera U.

However, after further study it has been concluded that the event was a false detection. After the apparent detection the video frames immediately before and after were investigated for possible changes in brightness in other resolved stars. A series of these changes that moved with time, but appeared differentially spatially, indicated the clear presence of a bat. From the observing location bats were common at the time of year. We include the event here though as representative of the sort of dimming that would be expected in an astronomical occultation. Occultations caused by local flying objects were usually easy to eliminate from the data because they would cause the dimming of many stars in the image. This event passed the analysis filter, which required that dimming be localised and not over a region of the image.

In our 24 hours of data we detected no events that we consider conclusive occultation events. This is not to say that some minor dimming of stars were definitely not occultation induced events. A total of 55 events were studied that were 3 standard deviations outside the mean photometric intensity for that star (*i.e.* an average of about 4.6 events per hour of observation at one of the detectors).

We adopted 3σ as the criteria for keeping events. If the noise was normally distributed, which it is approximately, using the 99.7% within 3 standard deviation criteria, this would suggest that we would get one event by chance for every 770 samples (note there is a factor of 2 here since we only consider cases in which the star dims by more than 3 standard deviations). Let's assume that there are 500 stars that can be resolved in the image. Any one of these stars has a 1/770 chance of a 3σ dimming in any one integration period, or there is 500/770 chance that one of the sample has a 3σ dimming. The chance that the same star on the other camera is dimmed at the same time is 1/770, so we have an overall probability of $500/770^2$, or about 1 in 1190 chance. If this was our only requirement we would expect a false detection rate of more than one per minute (since there are 30 frame samples per second). However, we also insisted that the dimming persist for more than a single video frame. If we insist that the following (or preceding) frame be dimmed by at least 2σ on both coincident detectors this would reduce the chance detection rate by a further factor of $(1/20)^2$, or a total false detection rate of about 4.4 false events per hour, approximately the number that our process triggered (4.6 potential detections per hour). We would not expect the next frame image to be statistically independent in terms of stellar scintillation, so the analysis above would actually under-estimate the false detection rate somewhat.

5. Discussion

In a 12-hour search over two coincident detectors (representing more than 1.1 billion stellar images) no convincing coincident stellar occultations were detected. As indicated in the preceding section, the rate of false detections was about that expected given our selection criteria. The null result for this experiment is not unexpected based on the simple model for occultation events (Parker 2001), which suggested that a much longer observation period would be necessary to expect positive results. This study served as a pilot to test the hardware and software techniques.

The main goal in presenting this paper is to encourage others, including amateur astronomers, to use image-intensified video rate CCD detectors to search for occultations and other transient astronomical events. In essence, with rather modest equipment, one can construct a system that can simultaneously perform automated photometry on 500 or more stars with a time resolution of the order of 0.03 s. One of the authors (PG) will make the MachoScan software freely available to amateur astronomers for this purpose. The current version of MachoScan operates on PowerPC *Macintosh* computers and requires a *SCION LG3* scientific video-input card. Technically the setting up of a program such as the one outlined here has relatively modest needs. Image intensifiers can be purchased as used units at moderate cost (less than $1000 each), and in addition a good monochrome video frame rate CCD camera (a few hundred dollars), an objective lens, and a stable video recorder are all that is required. In addition to occultation events, such a transient-event astronomical system can be used potentially to detect transients associated with such events as optical counterparts to gamma ray bursts (*e.g.* Kehoe *et al.* 2002), and the need for optical transient detection of a variety of events has been stressed by Paczynski (2000).

One practical difficulty is that image-intensifier units (except Gen I devices) are normally used in military and surveillance applications and are covered by the Canadian Controlled Goods Program (see `mmsd1.mms.nrcan.gc.ca/cgrp/`). Military goods restrictions make it difficult to import these devices. Users must be registered with the Controlled Goods program and safeguards must be in place for security of the devices.

This research project saw the implementation of an innovative rapid-imaging technique to seek to capture events that elude conventional astronomical-detection techniques. It is important to note, however, that was this was only an initial trial to test the feasibility of this experimental method. There are certainly many improvements that can and should be made to the simple experiment outlined above. Since the image intensifier degrades resolution and adds its own sources of noise, something that should be considered is whether low-readout-noise, high-quantum-efficiency unintensified CCDs have sufficient sensitivity.

An interesting question that others may wish to pursue is whether a system could be optimized by using larger-aperture optics. Essentially for success in occultation searches, one wishes to maximize the number of stellar images as potential occultation targets. Obviously this would mean that dimmer stars could be observed, but also a large aperture would result in enhanced SNR for quantum noise and also less severe stellar scintillation. Coupling the image-intensifier CCD to telescopic optics and imaging a globular cluster with resolved stellar images might well be an efficient strategy. Future work that chooses fields in the ecliptic plane would have a higher chance of success in asteroid and KBO occultation detection.

As the analysis has suggested, coincidence is crucial to the success of the experiment. The number of false events could be significantly reduced if the two detectors employed here were expanded to three or more. Another necessary improvement in the area of coincidence is to improve the time correlation between the two systems. One possible way to improve the current set-up is to time-stamp both data tapes simultaneously with the same digital time signal, and to synchronize the frame readout on the CCD detectors (this is possible with some video rate CCD cameras).

From Figure 2 it can be observed that stellar scintillation is a real problem with this technique (the largest part of the apparent noise is from this source). In order to lessen or eliminate this problem, observations should be moved to locations with a less dense and less turbulent atmosphere. This could be achieved by observing from a mountain top or even potentially making space-based observations. The authors welcome communication from those who wish to set up astronomical transient-detection programs.

We consider KBOs as the objects best suited to occultation detection. KBOs represent some of the best indicators of early Solar System processes (Luu & Jewitt 2002; Schulz 2002). Even powerful telescopes such as Mayall, Kitt Peak (Millis *et al.* 2002), Palomar (Gladman & Kavelaars 1997), and Keck (Chiang & Brown 1999) can only probe the larger KBOs by reflection processes. Occultation processes can help fill the void by detecting much smaller KBOs even with modest optical equipment. However, the nature of occultation detections allows very little information to be gathered about the occulting bodies. Perhaps the best application of this technique would be to set statistical limits on the populations of various types of bodies.

The work of the TAOS project has indicated the probability of detecting occultation events is so small than an enormous amount of data must be collected. This requires a more automated system. The process used in this investigation required analyzing the data with software after collection, transforming and comparing data, and then plotting light curves. Ideally a system should operate, like the TAOS project plans to, with cameras in coincidence and with completely automatic analysis. Observers should only be notified when a potential event has been recorded simultaneously by all of the cameras. At that point there should be a follow-up program so that the orbits of these objects, assuming they are bound gravitationally to our solar system, can be determined. Asteroids and the larger KBOs could be sought by direct reflection processes from more powerful telescopes in this follow-up survey.

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Robert Hawkes teaches physics and astronomy at Mount Allison University and carries out a research program in electro-optical meteor detection and analysis. He is active in various organizations concerned with innovations in science teaching, and was the year 2000 winner of the Canadian Association of Physicists Medal of Excellence in Physics Teaching. He is also the year 2001 winner of the Atlantic Council on the Sciences Communication Award as the Atlantic scientist who most effectively communicates scientific research to the public.

Peter Gural has worked as a senior scientist for Science Applications International Corporation in Chantilly, Virginia since 1985. He received his MSc. in Astronomy from the University of Arizona in 1980. He has worked on problems involving real-time video detection of meteor events, development of a mirror tracking system for high-resolution meteor spectra, applying matched-filter algorithms to asteroid detection and recovery, and detecting meteoroid impacts on the Moon.

CANADIAN THESIS ABSTRACTS

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

The Canada-France Deep Fields-Photometric Redshift Survey: An Investigation of Galaxy Evolution Using Photometric Redshifts, By Mark Brodwin (brodwin@astro.utoronto.ca), University of Toronto, Ph.D.

Progress in the study of galaxy evolution has traditionally followed from improvements in spectroscopic measurement techniques and subsequent groundbreaking surveys. The advent of large-format CCD detectors, coupled with the demonstrated success of the photometric redshift method, has given rise to a new, potentially very powerful alternative. It has, in fact, motivated the present detailed investigation of the potential of photometric redshift surveys to complement, or in some cases, supersede traditional spectroscopic surveys in galaxy evolution studies.

This Thesis describes a new deep, wide-field, multi-colour imaging survey, 10 times deeper and 30 times larger than its spectroscopic predecessor, the Canada-France Redshift Survey (CFRS). Highly accurate photometric redshifts, calibrated using hundreds of spectroscopic CFRS galaxies, were measured for tens of thousands of objects, with typical dispersions of only sigma/$(1+z) < 0.06$ to I(AB) = 24 for $z < 1.3$.

A new Bayesian method to measure the galaxy redshift distribution is developed. The accuracy of the method, which incorporates the full redshift likelihood function of each galaxy in an iterative analysis, is demonstrated in extensive Monte Carlo simulations. I(AB) and R(AB) redshift distributions, along with the run of median redshifts, are measured in various magnitude ranges, with special attention given to quantifying both random and systematic errors.

We measure the evolution of galaxy correlations with redshift, a primary observable of the structure formation process, correcting for the dilutive effect of photometric redshift errors on the clustering signal. The high $z \sim 3$ correlation amplitude seen in this work provides compelling evidence for the biased galaxy formation paradigm. The measured galaxy correlations from $0 < z < 3$ are in excellent agreement with the findings of the largest, state-of-the-art spectroscopic studies.

For the 1- and 2-point statistics of the galaxy distribution studied in this Thesis, the measurement accuracy is limited not by the photometric redshift error, but rather by the effect of cosmic variance, whose contribution to the total error budget is dominant. Therefore, future studies will be well served by adopting the photometric redshift approach, the efficiency of which will enable them to survey the hundreds or thousands of square degrees required to obtain a fair sample of the Universe.

Society News/Nouvelles de la société

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

National Council Meetings & RASC Happenings

Since our last article, the March 6, 2004 National Council meeting has come and gone. Though the meeting had some teleconferencing difficulties (mainly incompatibility with the building's phone network), it was a very well-attended meeting, by phone and in person, with representatives from 20 out of 27 Centres, in the trial location at the JPR Arbitration Centre, Toronto.

On a Sad Note

Many of our RASC members are also members of other organizations, however, Dr. Janet Mattei from the AAVSO, is a special person to many RASC members, and many of us met her at the 1999 Toronto GA. This was an event held in co-operation with the AAVSO and the ASP. It's my sad duty to let others who knew Dr. Janet Mattei that she passed away on March 22, 2004 after a very hard and strong fight with cancer. Janet, her husband Mike, and the AAVSO family kept us all current as to her progress; just when it appeared she was on the winning side, she took a turn for the worst. A private funeral service was held on March 26, 2004 in Lowell, Massachusetts. A memorial service for Dr. Mattei is being planned for later in the year.

Many of us knew Dr. Mattei as a very strong force behind the Variable Star Observing program in place at the AAVSO. The RASC has sent a card of condolences and sympathies to the family. She was a great person, and she touched many of us in a special way. Please visit the AAVSO Web site at `www.aavso.org` to see the work that she has done over the years.

On another science front, Dr. J. Beverly Oke passed away March 3, 2004. Dr. Oke was instrumental in the development of equipment for spectral analysis, plus he developed the technique to accurately estimate the temperature of stars — a technique that is still in use today. Dr. Oke was working on the design of instruments to be used on the proposed 30-metre telescope.

Dr. Oke was born on March 23, 1928 in Sault Ste. Marie, Ontario, receiving his BA in 1948 and MA 1950 at the University of Toronto. He received his Ph.D. at Princeton University in 1953. (Thanks to Craig Breckenridge for suggesting this article)

Congratulations

Many of our members may know Ruth & Terry Hicks, of the Kingston Centre. Terry is a past-Treasurer of the RASC and an avid historian & mathematician, and Ruth is very active in astronomy and gardening. Well on July 30, 2004 they will be celebrating their 50th wedding anniversary, and they are still going strong. Congratulations Ruth & Terry from all of your friends in the RASC — with many more years to come.

May your summer be filled with clear skies and Star Parties! Have a great holiday one and all. Clear Skies Everyone.

The Skies Over Canada
Observing Committee News

by Christopher Fleming, Chair, Observing Committee (observing@rasc.ca)

The RASC Observing Committee was originally called the New Observing Certificates Committee and was formed in the late nineties through the keen insight of Past President Randy Atwood. It was one of several new special committees that were formed by National Council at that time in order to revitalize the Society, which was experiencing a modest drop in membership numbers. The primary mandate for the fledgling committee was to create a new certificate program, designed for new members that would help them develop the skills necessary to enjoy a variety of the most popular observing categories. Early committee efforts lead by Richard Wagner of the Ottawa Centre were very helpful in creating the basic framework for the new program and we would like to salute those initial committee members for starting the wheels in motion. I joined the committee in 1999 while I was the National Representative for the London Centre and I have enjoyed very much the opportunity to further enhance the programs and activities offered by the Observing Committee and to develop additional, innovative new programs.

Development of the proposed new observing program went through several prototypes before the final design of the Explore the Universe Certificate was presented and approved at the 2001 General Assembly held in London, Ontario. The program incorporates features that allow summer stargazers to obtain the required number of observations without having to endure the bitterly cold temperatures of our northern climate, although winter objects are included for hearty or early morning observers. The program has proved to be quite popular and here is a list of the fine people who have received the Explore the Universe Certificate up to March 2004. Congratulations to them all and to the people who offered their support and encouragement!!

Table 1 — EXPLORE THE UNIVERSE CERTIFICATES

Name	Centre	Date
Ian Donaldson	Toronto, Ont.	June 2002
Michael T. Clancy	Saskatoon, Sask.	October 2002
Gail Lorraine Wise	Winnipeg, Man.	October 2002
Brenda Paraschos	Kitchener, Ont.	October 2002
Denis Grey	Toronto, Ont.	October 2002
Christopher Fleming	London, Ont.	October 2002
Brian Battersby	Prince George, B.C.	November 2002
Dennis Roth	Toronto, Ont.	December 2002
Janet Pollock	Winnipeg, Man.	January 2003
Hugues Lacombe	Montreal, Que.	May 2003
Ken Lemke	Hamilton Ont.	June 2003
Janice Low	Winnipeg, Man.	September 2003
Emma MacPhee	Moncton, N.B.	October 2003
Charles Doucet	Moncton, N.B.	October 2003
Michael Stephens	Winnipeg, Man.	October 2003
Marguerite Hamilton	Sarnia, Ont.	October 2003
Ivan Robichaud	Moncton Centre	October 2003
Tenho Tuomi	Saskatoon Centre	January 2004
Terrill Bartlett	Canadian, Texas USA	January 2004

When work on the new Explore the Universe Certificate program was complete the original mandate of the New Observing Certificates Committee was realized and proposals were then put forth by the committee for the development of additional programs including lunar, double-star, and deep-sky observing certificates. Discussions then ensued and it was decided that a new long-term mandate for the committee should be developed and that it must include not only the development of new certificate programs but also a mandate to provide a wide range of observing resources and projects directed at those who have completed the certificate programs. This all culminated in a proposal that was presented and approved by the membership at the 2003 General Assembly held in Vancouver, British Columbia. Since then the new Observing Committee has been designing new certificate programs and resources for observing-skills development. In addition we have launched three new Observing Sections that provide key resources for those who would like to further develop and use the skills they have learned through the certificate programs.

As part of the new mandate the Observing Committee is now responsible for maintaining the Messier and Finest NGC Certificate programs as well as the recently added Explore the Universe Certificate. This involves approving new

TABLE 2 — MESSIER CERTIFICATES

Name	Centre	Date
Dan Williams	London, Ont.	October 2003
Michael Karakas	Winnipeg, Man.	November 2003
John Appleyard	London, Ont.	November 2003
Alden Foraie	Regina, Sask.	January 2004
Daniel LeBlanc	Moncton, N.B.	February 2004
Norman Leier	Regina, Sask.	February 2004
Joseph Shields	Belleville, Ont	March 2004

TABLE 3 — THE FINEST NGC CERTIFICATES

Name	Centre	Date
Bill Weir	Victoria, B.C.	October 2003
Geoff Meek	Ottawa, Ont.	January 2004
Joseph Shields	Belleville, Ont.	March 2004

applications for the certificates and creating resources such as observing forms and sky charts to enhance and encourage members and non-members alike to participate in those programs. We would like to thank Kim Hay the National Secretary who was very supportive and helpful in regards to transferring this responsibility to our Committee. Since the 2003 General Assembly there have been several Messier and Finest NGC Certificates awarded.

The Messier Certificate Recipients are listed in Table 2.

The Finest NGC Recipients are listed in Table 3

Congratulations to all!!

The additional mandate of the Observing Committee, to develop resources and projects beyond the certificate programs, has really enhanced our overall function and it has turned us into a complete unit covering all aspects of astronomical endeavors. This has also led to an opportunity for others beyond the core committee to participate and to help bring observing in Canada up to a level not seen before. By combining the skills of talented people across the country, new projects and resources can be developed to a higher plane not usually possible in a smaller group. Several fine people have already been working with the Observing Committee and more are welcome. If you have a particular interest in a specific observing category that you would like to promote and share with others, you are invited to contact us and we will do our best to help develop your ideas. The level of skill required to participate is of course helpful although a genuine interest and willingness to learn is just as important. Other talents could also be utilized such as web-publishing skills, plus there is a need for regional organizers and promoters.

As of March 2004 we have created three new Observing Sections for Asteroids, Variable Stars, and Special Projects, with a Comets Section in the works. They were designed to provide key information for learning a new skill and to support the ongoing work of organizations like The Minor Planet Center and the American Association of Variable Star Observers. Each section required a significant amount of research and time to develop but now that they are in place they only require updating every few months or so, which means that if an individual or group wanted to develop and maintain one of these it would not be a major commitment of time and effort beyond the initial production stage. All in all it will be up to RASC members to make the most of this new initiative and perhaps individual RASC Centres would like to develop an Observing Section as a Centre Project since some areas of the country may have a greater concentration of specific observing skills and interests.

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. He is also a musician and Webmaster of the London Jazz Society Web site.

Transit Twists

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

I ride tandem
with the random
Things don't run the way I planned them
In the humdrum
...
From the black hole
Come the tadpole
With the dark soul
In coal she burn
as I drove into the Sun
Didn't dare look where I had begun
— Peter Gabriel, "Humdrum"

The long-term patterns of celestial events within our Solar System are a subject of considerable fascination. Such patterns can be divined by studying periodic extreme values in certain orbital relationships. These values can be somewhat arbitrary in nature, and thresholds are chosen by convenience or from nearby round numbers. However, the occasional line-ups of three or even four bodies that result in events known as eclipses or transits have well-defined parameters based on the angular sizes of the bodies involved; either an event is (at least hypothetically) visible, or it is not.

In past issues we have looked at eclipses of the Sun, Moon, and satellites of Jupiter, and transits of Earth as seen from Mars or Jupiter. Of particular interest in 2004 is the rare phenomenon known as the transit of Venus. Last time we examined the short-term patterns of such events, which in the current epoch happen in pairs at eight-year intervals at one node of Venus' orbit, with the next pair at the opposite node more than a century later. Those of you who have attended lectures or read the literature will know the pattern by rote: 8, 105.5, 8, 121.5 years, repeat. Except the pattern does not repeat, at least not indefinitely. And in the peculiar case of Venus transits, there are unusual asymmetries from one node to the other.

Typically with such series of events one sees complementary patterns at the opposing nodes. If a series of events progresses from north to south at one node, a complementary series will progress from south to north at the other. Such is certainly the case with the 8-year pairs: the current event at the descending node occurs in the southern hemisphere of the Sun; the next occurs some 20 arcminutes to the north in 2012. At the ascending node the second event in a pair occurs some 24′ to the south of the first. (The greater separation is primarily due to Earth being near perihelion in December and therefore closer to Venus.)

However, Venus transits offer particularly precise repetitions at intervals of 243 years, where transits occur in lengthy series of 20 or more, with each displaced from its predecessor by only 1 or 2 arcminutes. And they are *not* complementary. To cite Meeus' seminal pamphlet on the subject of *Transits* (1989):

> "It's remarkable that this displacement of chord is southwards at both nodes of Venus' orbit. The mean displacement of the track after 243 years is as follows:
>
> | | *at May-June transits* | *at Nov.-Dec. transits* |
> |---|---|---|
> | near the year −1500 | −81″ | −107″ |
> | 0 | −74″ | −113″ |
> | +1500 | −63″ | −106″ |
> | +3500 | −41″ | −89″ |
>
> These numbers show that after several millennia the southward displacement may change into a northward one. These changes are due to the secular variations of the elements of the orbits of Venus and Earth (inclination, eccentricity, longitudes of nodes and apsides)."

The unusual nature of this displacement can be seen when the dates of the 243-series are tabulated. Table 1 lays out these series from −2000 to +7000. Data was obtained from *Guide 7.0,* with the first 81 transits over 6000 years independently corroborated to identical lists provided by both Meeus (*op. cit.*) and Espenak (`sunearth.gsfc.nasa.gov/eclipse/transit/catalog/VenusCatalog.html`).

Immediately apparent in the table is the opposite slant of the series at the two nodes. Typically such tables will reveal the same slant: two planets return near the same relative positions only after an integer number of orbits, in the current instance 395 for Venus and 243 for Earth, whereas the optimum alignment with the node occurs at a similar, but non-integer interval. This gets naturally corrected by shifts from one series to its replacement, and these shifts are normally in the same direction at either node. For example, lunar eclipses at a given node occur singly or in pairs a month apart, recurring in series at intervals of twelve synodic months, with occasional "corrections" of eleven-month intervals, never thirteen. This is because the eclipse year, 346.62 days, bears a non-integer relationship of some 11.74 synodic months.

Table 1 — Transits of Venus from −2000 to 7000, laid out in columns at 243-year intervals revealing lengthy cycles with 20+ iterations. Of interest are the opposing slants of consecutive series at the two nodes, as encapsulated in the reversed order of the series numbers at top. The centre column, Transit Sequence, summarizes the intervals between all transits from the first event in one row to that of the following row. A transit may be inferred in −2006 as simply being outside the parameters of the data set; in fact one did not occur, so Series A2 is correctly shown as beginning in −1763, with all 20 members shown. Series D3 is a special case, which certainly contains many more members than the 27 shown here. By 6872 at the end of the data set, transits in this series remain single and therefore must be located near the equator of the Sun. The displacement from one event to the next is very small, and the series is destined to retreat northward from whence it came. Eventually descending nodes transits will again occur in pairs through the resumption of Series D2 rather than the start of a new Series D4.

Descending Node Series				**Ascending Node Series**			
D1	**D2**	**D3**	**Transit Sequence**	**A4**	**A3**	**A2**	**A1**
							−1998
−1892	−1884		8-121.5-8-105.5			−1763	−1755
−1649	−1641		“			−1520	−1512
−1406	−1398		“			−1277	−1269
−1163	−1155		“			−1034	−1026
			8-121.5-8				
−920	−912		*-113.5=251*			−791	−783
	−669		121.5-8-113.5			−548	−540
	−426		121.5-121.5			−305	
	−183 “					−62	
	60		“			181	
	303		“			424	
	546	554	8-113.5-121.5			667	
	789	797	“			910	
	1032	1040	“			1153	
	1275	1283	“			1396	
	1518	1526	8-105.5-8-121.5		1631	1639	
	1761	1769	“		1874	1882	
	2004	2012	“		2117	2125	
	2247	2255	“		2360	2368	
	2490	2498	“		2603	2611	
	2733	2741	“		2846	2854	
	2976	2984	8-105.5-129.5		3089		
	3219	3227	“		3332		
	3462	3470	“		3575		
	3705	3713	*8-105.5-137.5=251*		3818		
		3956	105.5-137.5		4061		
		4199	“		4304		
		4442	“		4547		
		4685	“		4791		
		4928	“		5034		
		5171	97.5-8-137.5	5269	5277		
		5414	“	5512	5520		
		5657	“	5755	5763		
		5900	“	5998	6006		
		6143	“	6241	6249		
		6336	“	6484	6492		
		6629	“	6727	6735		
		6872	“	6970	6978		

If displayed in tabular form, such series would appear to shift one column to the left for approximately every four rows down. Tables at either node would be extremely similar in this respect.

What makes the Venus-Earth relationship unusual is that these shifts occur in opposite directions at the opposing nodes; effectively, at one node the optimum alignment occurs at intervals slightly smaller than 243 years; at the other, slightly greater. The 243-year period is so precise that secondary effects such as the rotation of Earth's perihelion can sway the balance one way or the other. The two curves are out of sorts with each other, if not quite a random tandem.

While Venus transits always occur singly or in 8-year pairs at a given node, the intervals between events at the two nodes fluctuate over extremely long periods. These are summarized in Table 2 and 3. In the first case, the series are anchored to the first transit at the descending node, in the other, to the ascending. At times of significant repetition, as at present, this simply means a re-ordering of the sequence; 8, 105.5, 8, 121.5 as opposed to 8, 121.5, 8, 105.5. But it gets interesting at the transition points where series begin and end. In Table 2, this means a couple of instances of 243+8=251 year cycles, in Table 3, of 243−8=235 years. After a few of these transitions, the intervals between opposing nodes can be as short as 97.5 years or as long as 137.5.

Will these intervals gradually become still more unbalanced? If this were a linear development, eventually transits at the two nodes would overlap, clearly an impossible situation. I would instead conclude that an extreme has been reached by the bottom of the table, where the pattern 97.5, 8, 137.5 repeats at least eight times. I envision this as the top of a sine curve — a solstice, if you will — with the sequence about to slowly "turn the corner" and gradually return to more intermediate values. Indeed, it seems consistent with Meeus' displacement values shown above, that the May-June (descending node) transits would be achieving a positive value somewhere around 6000 or 7000 A.D., and thus beginning to retreat back

Table 2 — The intervals between transits pegged to the first event at the descending node, summarizing the centre column in Table 1. The six-fold repetition of the current sequence of 8-105.5-8-121.5 years represents a period of relative stability, but is hardly permanent. Note the single iterations of the transition sequences, which in each case total 251 years as an old series peters out and the first event at the node therefore occurs eight years "late."

Descending Transit Groupings, (−2000) – 7000

	First D	D to D Sequence	#	Comments
D1	−1892	8-121.5-8-105.5	4	
	−920	*8-121.5-8-113.5=251*	1	Transition D1-D2
D2	−669	121.5-8-113.5	1	
	−426	121.5-121.5	4	
	546	8-113.5-121.5	4	
	1518	8-105.5-8-121.5	6	
	2976	8-105.5-129.5	3	
	3705	*8-105.5-137.5=251*	1	Transition D2-D3
D3	3956	105.5-137.5	5	
	5171	97.5-8-137.5	8+	

Table 3 — The intervals between transits pegged to the first event at the ascending node. Note that in this case the transition sequences total only 235 years, as a new series begins eight years "early."

Ascending Transit Groupings, (−2000) – 7000

	First A	A to A Sequence	#	Comments
A1	−1998	*105.5-8-121.5=235*	1	Transition A1-A2
A2	−1763	8-105.5-8-121.5	4	
	−791	8-113.5-121.5	2	
	−305	121.5-121.5	3	
	424	121.5-8-113.5	4	
	1396	*121.5-8-105.5=235*	1	Transition A2-A3
A3	1631	8-121.5-8-105.5	6	
	3089	129.5-8-105.5	3	
	3818	137.5-105.5	5	
	5034	*137.5-97.5=235*	1	Transition A3-A4
A4	5269	8-137.5-97.5	8+	

northward to the limb from which the series commenced.

I suspect that the largest secular variation causing this wobble around the 243-year cycle would be the eccentricity of Earth's orbit. In an ellipse, two halves are not created equal. By 7000 A.D. the Earth-Venus nodes will be closer to 90° removed from Earth's perihelion point, so that the "half years" are relatively unequal, with one half roughly centred on Earth's perihelion and the other on its aphelion.

It is interesting to note that the two transit series achieved a rough balance of eight consecutive single events at intervals of 121.5 years, from −426 to +424. By strange coincidence this sequence of balanced transits is centred very near the year 0. The events in question happened in late May and late November, respectively, very close to Earth's aphelion and perihelion at that time, and consistent with the logic cited above.

Earth's perihelion completes a full rotation in some 21,000 years. The orbit of Venus, while only some 40% as eccentric, also slowly advances. As a result, even 9000 year's worth of data will reveal only a fraction of one cycle of the relationship between the two planets; we are only seeing part of one curve. I must utter yet again the familiar plaint: I need more data! That said, even 100,000 years of transit data would hardly be enough; the orbits of the two planets are continuously evolving, so that any patterns of repetition are ultimately transitory.

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Bruce McCurdy is active in astronomy education with the RASC Edmonton Centre, Odyssium, and Sky Scan Science Awareness Project. He currently serves National Council as Astronomy Day Coordinator. In the process of considering the minute details of obscure astronomical phenomena many millennia outside of his humdrum natural life, Bruce sometimes forgets what day it is.

Dr. Wendy Freedman

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

While people have long wondered about the origin, fate, and age of the Universe throughout history, only in relatively recent times have scientists made serious progress in solving these mysteries. And now, due in part to the efforts of Canadian astronomer Wendy Freedman, the birth date of the Universe seems to be in hand.

A native of Toronto, Dr. Freedman earned a Ph.D. in astronomy and astrophysics from the University of Toronto in 1984. She then joined the Carnegie Observatories in Pasadena as a postdoctoral fellow and, three years later, became the first women to join Carnegie's permanent scientific staff. She is currently the Observatories' director.

Dr. Freedman's interests range across a wide spectrum of astronomical subjects such as observational cosmology, galactic evolution, and the evolution of stellar populations. She has also been involved in making the most accurate optical observations of the luminous constituents of the Universe. This will aid in determining the amount of ordinary matter that exists. With the launch of the *Hubble Space Telescope (HST),* she saw an opportunity to "unstick," as she puts it, the slow progress being made in determining the age of the Universe. This involved using *HST* to help determine the cosmic expansion rate H_o, the Hubble Constant.

In the mid-1980s, a panel of astronomers identified several key questions that *HST* could help answer. These included a determination of the extragalactic distance scale and the expansion rate of the Universe. The Extragalactic Distance Scale Key Project was therefore set up to find accurate distances to nearby galaxies. This would, in turn, form the foundation for other methods to be used at far greater distances, which would allow several

independent determinations of the Hubble constant. Dr. Freedman was one of three principal investigators on the project, which was allotted the greatest amount of observing time on *HST* for a period of five years. In all, nearly a decade was spent on the project. But how *does* one determine the age of the Universe?

The process begins with the study of Cepheid variable stars. Such stars have long been used as standard candles for distance determination because their intrinsic luminosity is tied to their period of variability. Measure the period and the *intrinsic* brightness is known. A measurement of the *apparent* brightness allows their distance to be calculated. But observing faint, individual stars is impossible beyond relatively nearby galaxies. However, *HST* makes our measuring stick much longer. Dr. Freedman's team measured the distances to nearly 800 Cepheids in 24 galaxies. This technique allows distances out to 3 megaparsecs to be measured accurately (and to 20 megaparsecs with correspondingly less precision).

The next rung up the ladder involved tying the Cepheid distances to luminous Type Ia supernovae. This allows distances to be found out to about 400 megaparsecs.

Since reliance on one or two methods can lead to inaccuracies, the Freedman group used several secondary distance indicators as well: observing Type II supernovae, for example. And simply having new, high-quality CCDs was of enormous help.

And the outcome of all this measuring? The observations indicate an expansion rate, H_o, of 72 ± 7 kilometres per second per megaparsec. Combining all the Freedman team's different kinds of observations gives 74 kilometres per second per megaparsec, with an uncertainty of ten percent. This is close to results obtained independently elsewhere. For example, studies with the *WMAP* satellite give a value for H_o of 71 ± 4. Factoring in the amount of (mostly) dark matter and dark energy (which has a bearing on whether the Universe is accelerating or decelerating), the age of the Universe comes out at about 13.5 billion years with an uncertainty of ten percent.

Knowing H_o provides us with more than just the age of the cosmos. It provides a window into how much hydrogen and helium were formed right after the big bang, how cosmic evolution has unfolded, and how the seeds that grew into galaxies came to be.

Dr. Freedman admits that the decade-long search has been both exciting and satisfying, but she refuses to rest on her laurels. Her next project involves characterizing the expansion of the Universe over time, from the early days when matter dominated, and the Universe was decelerating, to the present accelerating Universe. Using large, ground-based telescopes, distant supernovae will again be scrutinized to provide clues about dark energy and its effect on universal expansion. Dr. Freedman suggests that this could take over five years, perhaps close to a decade, to sort out.

Dr. Freedman's historic research has garnered her numerous awards. And history does, indeed, play a role. She walks the same halls that Edwin Hubble did in the early 20th century when he was determining that the Universe was, indeed, growing larger. Still providing inspiration, his presence is felt to this very day by a worthy successor.

Philip Mozel is a 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.

Reviews of Publications
Critiques d'ouvrages

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

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

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

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

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

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

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

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

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

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

— David Chapman

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

The Search for Life in the Universe, by Donald Goldsmith and Tobias Owen, 3rd Edition, pages 573 + xvii; 19.5 cm × 26 cm, University Science Books, 2002. Price $62.50 US hardcover (ISBN 1-891389-16-5).

In the third edition of *The Search for Life in the Universe,* Goldsmith and Owen cover an enormous breadth of material. The book was written as a non-mathematical text for an "introductory astronomy course with a focus on planetary science and the search for life in the universe." The authors note in the preface that they "delight in showing students that the joy of science lies more in what we don't know than in what we do." That is certainly what they do in the text, and in my opinion they have done an excellent job.

I enjoyed reading the book and, as someone who has spent many years teaching science to non-science students, I think it serves a very useful function and should be well received. Even students with a background in astronomy, or any other area of science, could gain a great deal from the text because of the emphasis throughout on the search for life in the universe.

The twenty-two chapters of *The Search for Life in the Universe* are divided into five parts: Why Do We Search?, The Universe, Life, The Search for Life in the Solar System, and The Search for Extraterrestrial Intelligence. The single chapter comprising Part One is an introduction to the theme, and covers the typical background topics one would normally find in an introductory text: the nature of science, the scientific method, the laws of nature, some history of science, and the search for extraterrestrial life.

The five chapters comprising Part Two constitute an introductory course in stellar astronomy. Most of the topics covered in a traditional astronomy course are there, but with very little mathematical content. Readers with a background in astronomy can read the chapters quickly and still gain a great deal from the many interspersed discussions relating to the search for extraterrestrial life. The non-science student or general reader is exposed to all of the big concepts. That may suffice for some, but for others it would likely spur them to go further in astronomy.

Part Three comprises four chapters and is essentially a miniature biology course. Included are discussions of the nature of life as we know it and the possible makeup of alien life forms: the chemicals (DNA, proteins, *etc.*) important to life, the contribution of living organisms to the development of the atmosphere, and theories for the chemical origin of life, among many. It is not possible to search for life in the universe without a comprehensive knowledge of what life is or could be. Part Three is an easy read for those who have completed a course in biology, and is of value for non-science majors and physics/astronomy students who have not studied biology previously.

Part Four, the Search for Life in the Solar System, is an excellent overview of our knowledge of the Solar System and the models for its formation. All of the basic ideas are there, once again in non-mathematical format. As in all other chapters, the authors present the evidence and how we have collected it. Included are excellent discussions of why we would expect to find life in some parts of the Solar System and not in others.

The final section of the book considers the possibility of extraterrestrial intelligence and how one might search for it, as well as how other life forms might establish our own existence. It is also the section covering the discovery of planets in orbits about stars other than the Sun, and presents material one would expect to find in a treatise on the search for life in the universe. It is perhaps the most interesting section of the book when one considers the great amount of current interest that exists for the search for extraterrestrial intelligence. The non-science major and general reader can gain a great deal from this section, as will anyone with a background in any of the sciences.

The book is well written, flows well, and has good pagination. Throughout the text there are many black and white images, photographs, and drawings, as well as three clusters of very nice colour plates. Each chapter includes an introduction, well laid out text with an easy-to-read font, a well written summary that includes a list of key terms covered in the chapter, a list of questions to test your understanding of the topics, and a section on further reading.

The appendix has a list of appropriate Internet sites where one can find further information, a table listing the components of the solar system, which includes radius, mass, average density, *etc.,* followed by a glossary and an index.

It is a great book, one that should be included in every high school library. As well, it is an excellent text for non-science majors at university, yet has much to offer the science major as well. For the general reader it beats anything I have seen on the popular market. While the basic ideas are current, Internet sites should do an excellent job of keeping the facts up to date for those worried about the impossibility of retaining such a feature for any textbook. I highly recommend the book to anyone with an interest in the search for life in the universe.

— Fred Smith

Frederick R. Smith teaches at Memorial University of Newfoundland and is an active member of the RASC St. John's Centre.

Latitude: How American Astronomers Solved the Mystery of Variation, by Bill Carter and Merri Sue Carter, pages 255 + xi; 13 cm × 21 cm. Naval Institute Press, 2002. Price $24.95 US hardcover (ISBN 1-55750-016-9).

We live in an age where the satellite-based Global Positioning System (GPS) can provide us with worldwide positioning within an accuracy of a metre or less. But it was not always so! In the decades prior to the late 1800s, navigators, scientists, and astronomers puzzled and argued over the ever-changing variation in terrestrial latitude established by different techniques. The problem played particular havoc with those who worked at sea. The result was the loss of life, ships, and commerce.

In the year 1891, a little known actuary by the name of Seth Carlo Chandler, Jr., who worked for a Boston insurance company, startled the European and American scientific communities with his announcement that he had solved the controversy over variations in terrestrial latitude by means of an $800 instrument that he had designed himself. To make matters worse, Simon Newcomb, a well-known American astronomer, embarrassed the European scientific community further by validating Chandler's findings, thus correcting the accepted notion of a difference between one's observations and theory.

Seth Chandler, Jr., was a graduate of Boston English High School. During his final year of school he was fortunate enough to be hired by, and taken under the wing of, one of America's greatest mathematicians, Benjamin Pierce, who utilized his young assistant to carry out complex calculations reducing astronomical observations. That led the young Seth Chandler into a lifetime of challenges that he enjoyed greatly. In the ensuing years Seth Chandler utilized his mathematical skills to publish many papers in *The Science Observer* (a popular publication for amateur astronomers), one of which involved using his skills to speculate on the size of the two newly discovered moons of Mars!

In the years prior to his revelation, he worked on and received a patent for an instrument he first called "Altitude Instrument" (Patent # 239315 issued on March 29, 1881). Seth Chandler himself later called the instrument "The Chromodeik." It was described as an instrument adaptable for astronomical amateurs, watchmakers, and surveyors to determine more accurate local time by observing the Sun at equal altitudes at a prescribed period before and after noon. In a subsequent issue of *The Science Observer* he designed another instrument that he called "The Almucantar," an instrument for the determination of time and latitude. A model of the new instrument was then constructed. The newly designed instrument involved a unique automatic leveling system that relied on a mercury flotation bearing located at one end of the horizontal axis. In time a full scale Almucantar designed by Chandler was installed at Harvard Observatory, and at long last revealed the true "Variations of Latitude."

Chandler went on to refine his "wobbly variations," as they became known, with calculations based on observations from around the world. Most of the calculations where done by Chandler himself, a task he enjoyed. Occasionally he allowed an assistant to do some of the calculations for him, when pressed for time or dealing with family or business commitments. As usual he would always check the calculations himself before publication. With all of the complex observations at his disposal, he was finally able to determine that the "Latitude Variations" changed systematically with time, having a half period of seven months. Seth Chandler further refined the changes to show internal cycles within the full fourteen-month period.

Over time Chandler received a great many awards for his diligence, inventions, and advancement of science. Possibly the most rewarding for him was the Gold Medal from The Royal Astronomical Society in London, an impressive accomplishment for an amateur and an actuary. The details of the accomplishment I will leave to the reader.

—Barry Matthews

Barry Matthews is a long-time member of the Ottawa Centre of the Royal Astronomical Society of Canada. He is an amateur astronomer in the truest sense, and operates a home-based business (Opticks), repairing and servicing all manner of scientific instruments for hospitals, labs, and schools throughout eastern and northern Ontario. The heavens, astronomy, and his business are also shared with Barry's partner and wife, Cecilia. Cecilia has been Barry's inspiration and the incentive to make Opticks a reality. It could never have succeeded without her.

William Harrison Thurlow (1942 – 2004)

Many people, including the members of the Halifax Centre of The Royal Astronomical Society of Canada, were shocked and saddened by the sudden and unexpected death of Bill Thurlow on February 14.

Dr. William Harrison Thurlow IV possessed many traits: an enthusiastic spirit, a down-to-earth friendliness, a gentle sense of humour, a child-like curiosity, a genuine interest in the opinions and perceptions of others, and a love of the outdoors in all aspects, especially the night sky. As a teenager, he was consulted by news media for information on astronomical events. As a cadet in the U.S. Navy, he sailed on the tall ship "Eagle." As a surgeon, he saved lives, improved the quality of life of many people, and provided sound advice to his patients and friends. As an environmentalist, he single-handedly took on the Newfoundland government and prevented the spraying of toxic chemicals on large areas of the forests of that province. As a pacifist, he was a member of the Society of Friends (Quakers) and inspired others to examine their assumptions about politics and nationalism. As a marathon runner, he encouraged people half his age to look after their health. As an amateur astronomer, he was a keen observing companion and knew the sky intimately. He was a larger-than-life member of the RASC Halifax Centre for the past quarter century, the first member of the Centre to complete the Messier List, and with his telescope "Big Red," the first to introduce Centre members to large-aperture observing.

Bill graduated from the University of Maine and from the University of Vermont Medical School, where he received his M.D. in 1969. He was a Fellow of the Royal College of Surgeons of Canada and served on the Board of Directors of the American College of Surgeons. His career as a general surgeon was spent in St. John's, Nfld., Hamilton, Ont., Gander, Nfld., Digby, N.S., and Summerside, P.E.I. He retired from full-time medical work in 2002, sold his home, and with his wife Dana, moved into residence at Saint Mary's University in order to pursue his lifelong dream of studying astronomy. He began a program of studies leading to an M.Sc. in astronomy.

Bill and Dana raised four children: Nell, Amy, Eva, and Harry. He dearly loved his family and spent as much time with them as he could spare from his busy practices.

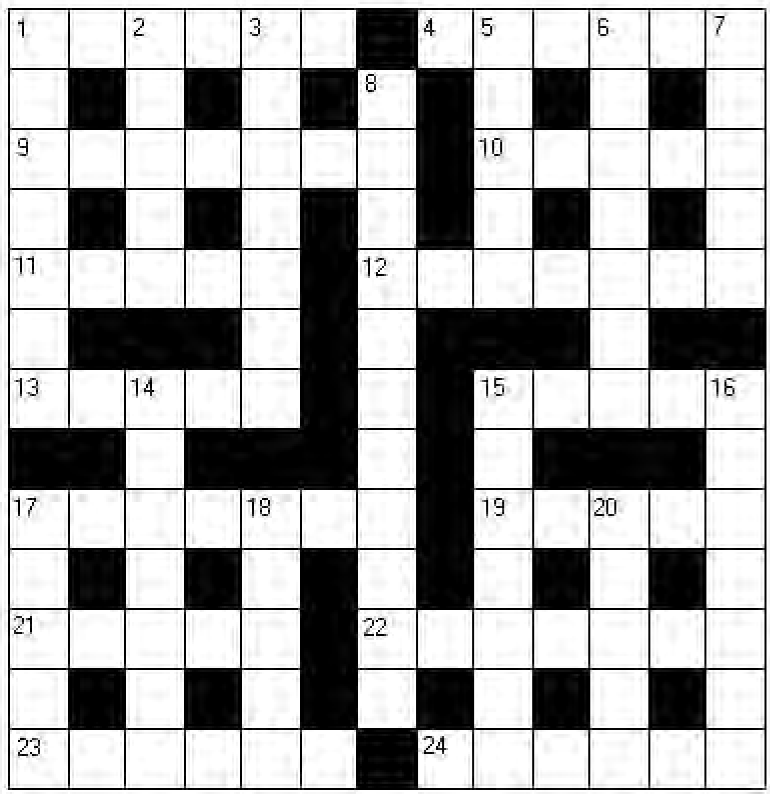
In the spring of 2002, with four of his friends, Bill flew to Hawaii to spend a week observing on the summit of Mauna Kea. On the morning we left, I picked Bill up in Halifax on my way to the airport. He was glowing with enthusiasm and said to me: "Today is my 60th birthday, and here I am undertaking the trip of a lifetime!"

It is not commonly known that, as measured from its base on the floor of the Pacific, Mauna Kea is the highest mountain on Earth. The top of Mauna Kea has several volcanic cinder cones, one of which is slightly higher than the others. There is no road to this summit, only a hiking trail that leads down into a small valley and then up to the top. Because our muscles and lungs complained from lack of oxygen when we attempted even moderate activity on Mauna Kea, all but one of us were content not to attempt the hike to the summit. My favourite memory of Bill is watching him climb to the very top of Mauna Kea. That was Bill, and I will miss him. He left us too soon.

—Roy Bishop

Astrocryptic

by Curt Nason, Moncton Centre



ACROSS

1. Will the chart maker be lost in riot? (6)
4. A great one at the meridian or in winter around Orion (6)
9. Elementary astronomers' muse of core material (7)
10. It stretches between Hydra, Corona Borealis and the bears (5)
11. Dangerous start to bad omen concerning Algol (5)
12. Santa packed six for his trip to a crater in 2001 (7)
13. Scrap super scarp on the Moon (5)
15. Looks oddly cute to the south, but threatened Andromeda (5)
17. Scientists prove mice not confused by the lunar cycle (7)
19. Many spin after beginning Lent due to simple hydrogen series (5)
21. Cousin of Corvus featured in *Brave New World*
22. Ron entered dog star in Kansas and moved to Society's centre (7)
23. Lord's scale starts with nothing? Absolutely naught! (6)
24. Its rising sounds agreeable, and somewhat right to astronomers (6)

DOWN

1. Northcott scrambled around the wrong end after the lightning (7)
2. Virgo's galactic empire is true to Messier (5)
3. Relates to the hunter or is about a charged particle (7)
5. Lead in to return assistance for Chandrasekhar's home (5)
6. Chart about ten stars to carry Auriga (7)
7. Perhaps ogles modern observing records (1-4)
8. Ironic comet, oddly enough, makes a wonderful star (7,4)
14. Ring bell about television with central zenith in the SSW libration zone (7)
15. Dieter's count dropping egghead in the basin on Mercury (7)
16. He made our atlas by mixing tin, tons of it (7)
17. Cosmo Kramer loses his tail, gets confused and points north (5)
18. Sister takes potassium iodide tablet to view a star in Sagittarius (5)
20. He found descriptive geometry below the Sea of Fertility (5)

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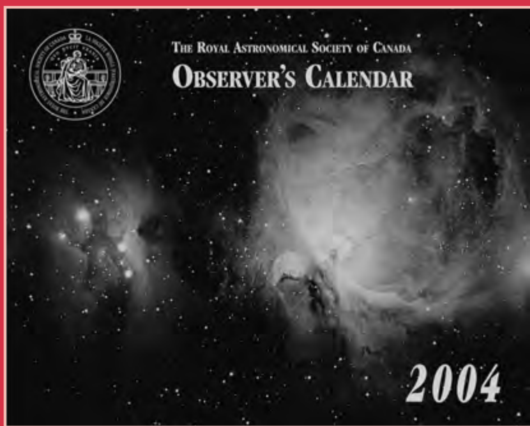

Observer's Calendar — 2004

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

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

Individual Order Prices: $16.95 Cdn (members); $19.95 Cdn (non-members)
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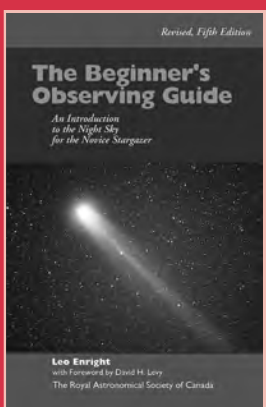

The Beginner's Observing Guide

Extensively revised and now in its fifth edition, The Beginner's Observing Guide is for a variety of observers, from the beginner with no experience to the intermediate who would appreciate the clear, helpful guidance here available on an expanded variety of topics: constellations, bright stars, the motions of the heavens, lunar features, the Aurora, and the Zodiacal Light. New sections include: lunar and planetary data through 2010, variable star observing, telescope information, beginning astrophotography, a non-technical glossary of astronomical terms, and directions for building a properly scaled model of the solar system.

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Skyways: Astronomy Handbook for Teachers

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Price: $16.95 Cdn (members); $19.95 Cdn (non-members)
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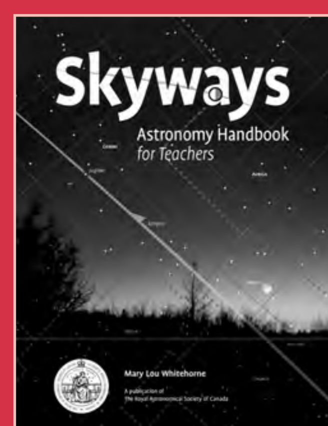

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