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INSIDE THIS ISSUE

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Journal

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contents

table des matières

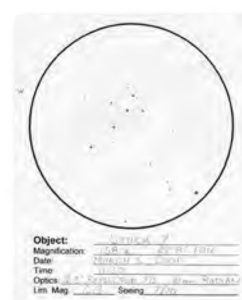
FEATURE ARTICLES/ARTICLES DE FOND

EDUCATION NOTES/ RUBRIQUES PÉDAGOGIQUES

RESEARCH PAPERS/ARTICLES DE RECHERCHE

COLUMNS/RUBRIQUES

Space Science, Space Art, and the Classroom p. 197

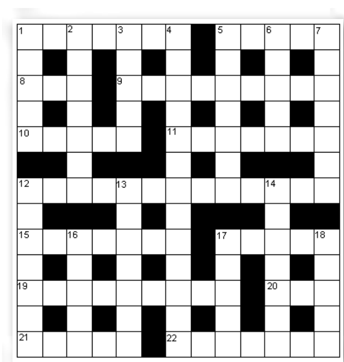


Taking Stock p. 194

Neutrino Detectives p. 185

Membership Awards
p.221

Reviews
p.232



AstroCryptic p. 240

Cover:
RASC GA 2001
p. 218

Photo by Joe O'Neil

President's Corner

by Robert F. Garrison (garrison@astro.utoronto.ca)

This column is an invitation for professional astronomers to consider publishing some of their work here in the research section of the revitalized *Journal of the Royal Astronomical Society of Canada*. Our editor-in-chief, with more than a year in office, is ready and waiting for an increase in the number of papers submitted.

The *JRASC* is a remarkable publication. Reflecting the amateur/professional nature of the organization, the *Journal* now has two distinct sections, the second of which is for technical research papers. It is the only Canadian journal dedicated to astronomical research. Articles are refereed and edited as rigorously as in any of the larger, more well-known journals, and more so than some.

There are several electronic newsletters, such as the University of Toronto's *David Dunlap Doings* and the Canadian Astronomical Society's *Cassiopeia*, which have been very successful and which serve a definite purpose in the Canadian community. Electronic newsletters, while informative, however, do not have the same impact professionally as a refereed journal does, so it is important to have both.

During the past half dozen years, a concerted effort has been undertaken by editors Dave Turner and Wayne Barkhouse, as well as the Executive Committee and National Council, to make the *JRASC* more effective in serving both the amateur and professional constituents, and to stimulate cross-fertilization by bundling the publications together. The efforts are beginning to pay off and more improvements, mainly in content, are being considered. If you are still frustrated with the *Journal*, be patient: it takes time to turn around international perception.

One such effort has now been completed. Past issues of the *JRASC* have been scanned and are now available on the Internet through the Astronomical Data System (ADS), an international organization funded mostly by the US government. For the first twelve months after publication, articles will be available only to RASC members and *Journal* subscribers, however older articles are now available to the astronomical community at large. A non-subscriber does, however, have access to titles and abstracts during the first year. The huge ADS database has been thoroughly indexed and can be searched very quickly. This move is a necessary step in the revitalization process, because it is the way that astronomical research information is accessed now by modern workers in the field and is certainly the way of the future. As the astronomical literature grows in volume and complexity, it is effectively overwhelming the old way of finding references by using printed indices. All major astronomy journals are now part of the ADS database, including the *JRASC*.

The point is that, with the ADS agreement, the RASC has gone a long way to satisfy critics of the *Journal*, who argue that

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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Website: www.rasc.ca
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an article published in the *JRASC* does not have enough international exposure because of its small international subscriber base. By joining the ADS, our international exposure has just grown by a huge factor. Potential authors should certainly reconsider their options.

The *JRASC* research section is the ideal place to publish articles of special interest to the Canadian community of astronomical scholars, such as prize lectureships (Hogg, Northcott, and Plaskett, to name just a few), hot new discoveries by Canadians, new instrumentation for Canadian telescopes, review articles of general interest, and meeting abstracts. That is not to say that we should restrict articles to Canadian content. We should remain open to all high-quality scientific research, though it may be awhile before the latest non-Canadian significant advance in cosmology is submitted first to the *JRASC*. During my visits to centres this year, I have been impressed by the interest of the amateurs in what Canadian astronomers are doing. What kind of research is being carried out by Canadian astronomers? What instrumentation are Canadians building and using? Is there any overlap of interests?

With the new editorial structure, the *JRASC* has all the features one could ask for in a journal: good editors, good referees, timely publication, quick turnaround, relatively inexpensive page charges, much improved international exposure, good design, and more. Editor-in-Chief Wayne Barkhouse has done a great job of reestablishing on-time publication. Any delays are now due to distribution problems. The only thing lacking is a healthy flow of interesting technical papers. It is not as though Canadians are not doing enough great research! The editors, the Publications Committee, and the President need to twist a few more arms to get the ball rolling, and hence, this appeal.

The problem is that it takes time to recover from a reputation as a backwater publication. That may seem like a harsh word to use, but it accurately reflects the situation. There are too many well-known international professional astronomers who are not familiar with the publication, however, a new publication format and structure have been built and a new reputation will come in time.

We are again publishing the CASCA meeting abstracts (last issue). Note the faster-than usual turn around time. [Thanks, Wayne.] The abstracts are a good way to establish a bird's-eye, cross-sectional view of current Canadian research in astronomy. In addition, Wayne has lined up an impressive array of review papers and prize lectures for future issues.

I believe that cooperation between amateurs and professionals is an underutilized resource and that the *Journal* is one of the best ways for each to learn what the other has to offer. Other efforts at creative solutions are underway. So, stay tuned and be patient.

Editorial

by Michael Allen, Assistant Editor (allen@astro.utoronto.ca)

When I was four years old my parents gave me a little book on astronomy. The motivation for this specific purchase was never established, but in hindsight it was not entirely unexpected. My Mom took me, my brother and sister to the local library every second week, and we were all voracious readers; it was natural to give and receive a book as a gift. I loved my new book and asked for another book the following year, and got a sticker book. There followed a nice picture book a few years later. By the time I received any astronomy education in school, which was in grade 5, I found that I knew the whole curriculum already!

At the time I thought this result was an exciting one. Looking back, I now re-interpret it as being somewhat disappointing. Where was the challenge? The readers of this esteemed publication are already "converted," and you have my congratulations! You already know how important astronomy is. You already know how important it is to spread your knowledge and enthusiasm for astronomy to your friends, neighbours, and the school system. You already know that a society only becomes great when it has the confidence to engage in pursuits for the sake of the pursuit itself.

Where is the challenge? We can all challenge ourselves to become active members of the community, and to help friends, colleagues, and schoolteachers learn about astronomy. We can help support our local science centres, planetariums, and observatories (if we're lucky enough to have them nearby) with the gift of our presence. I read with pleasure such articles in the *Journal* as "Improving the Teaching of Astronomy 101 Through Tutorials" (Volume 94, Dec 2000), or about automated telescopes in education in "Astronomy on the Web" (Volume 95, June 2001). Here we have two very different programs with an important commonality: they require the presence of an educated person, with the emphasis on "person." Do not underestimate the importance of interpersonal interaction for making a positive impression on the public. Where is the challenge? To find someone to meet and greet the public.

I refer to astronomy as being the last of the romantic sciences. Astronomy is still largely driven by image-taking (interpreted in an exact way by mathematics and computer simulations, of course, but image-driven nevertheless), and the public can see an image as well as anyone can. This picture-oriented method of research lends to astronomy a real sense of appeal to the layperson. It is our greatest asset, and it is why amateurs in astronomy can have a more profound impact than can amateurs in any other discipline. Where is the challenge? To get out into the community and see what can be done. Can we wait for the appearance of paid teams of public educators who specialize in astronomy? No, for these types of positions, including mine, are of uncertain duration and subject to whim. We must enjoy them while we have them.

In summary, I believe it is important for us to pass our experience and knowledge to other educators and the public at large. In our image-driven science, we have a natural advantage for creating enthusiasm, especially in children. Astronomy has been a part of my life for as long as I can remember. I know many RASC members, amateur and professional, who do just what is described here, and I see many of them on a weekly basis. To those people and people like them, I thank you from the bottom of my heart. We all need a pat on the back sometimes, and RASC members are richly deserving of it. The task of bringing the stars to the public is never finished, of course, and we can all still ask ourselves, "Where is the challenge?" It has been a pleasure and an honour to be able to address you, and I thank Wayne Barkhouse for his trust and generosity. Any and all comments are welcome.

Correspondence
Correspondance

APERTURE WAR

Dear Sir,

I read with considerable sympathy the President's eloquent plea (*JRASC*, 94, December 2000, p.206) that Canada should find space and funds to resist the "zero-sum" option, that sad fate for so many productive and innovative researchers. His closing remark, that "not all interesting objects are faint and not all faint objects are interesting", is a timely reminder that it is primarily the programmes, rather than the tools, that shape our science. Monitoring a bright star with powerful equipment is scientifically worthy and crucially important if that is the only means to adequately observe some unusual phenomenon. Solar observers are all too familiar with the frustrations of pushing equipment to its limits even when the object under observation has a visual magnitude of −27.

There is no excuse for thinking that bright stars are uninteresting scientifically simply because they can be observed with telescopes of only 1 metre diameter. Moderate-sized telescopes, those "foot soldiers of the observational army", as Dr. Garrison appropriately calls them, are a vital unit of a necessarily diverse force in which the large-aperture tools are a special brigade. The objective of that army is to understand the cosmos. Because every object bears distinct but interrelated clues, the strategy must be to tackle every problem that is encountered, and the tactics must be to pursue connected assaults on all sides. Many of the problems at present are hydra beasts that will not succumb to a single or limited attack. Troops often need to make provision for a long siege, and must never be tricked into announcing victory prematurely.

Dr. Garrison may be a little heartened by the successes of recent campaigns in Canada to observe optical spectra of binaries of the Zeta Aurigae type which undergo "atmospheric" eclipse, when the hot secondary acts as a light probe behind the chromosphere of the cool-giant primary. During those rare phases the resulting composite spectra of the binary reveal fragile information that bears on many of the unsolved problems concerning the outer layers of cool giants. To examine adequately the primary's chromosphere — and the origin of its wind — requires series of careful high-resolution spectra extending over two weeks, three weeks, or longer. One such set of spectra of Zeta Aurigae was obtained in 1990 at Calar Alto with the 2.2-m telescope, an even longer set was obtained in 1998, and a third was obtained earlier this year. The two latter sets were observed in the near UV at a reciprocal dispersion of 2.4 Å/mm with Canada's 1.2-m telescope at the DAO. The three sets are in fine contrast to one another. The high resolution (R = 80,000–90,000) of the line profiles reveals movements in the line of sight, or inhomogeneities, that change in detail each night, and overall patterns that change significantly from eclipse to eclipse. The observations are unique, virgin, and challenge every assumption of constancy and uniformity in a star's outer atmosphere, yet were extremely modest in terms of the resources they needed.

Equipping several more modest-sized telescopes with high-resolution (R > 70,000) spectrographs would enable a diversity of synoptic or complementary attacks that could include expertise and experience from the whole gamut of astrophysics. The scientific results would render the investment highly cost-effective in terms of their volume, well balanced by virtue of their scope, and exemplary in generating high-quality fundamental information. Stars are the building blocks of galaxies, and spectroscopy is the backbone of astrophysics. Canada has an enviable history of stability in stellar spectroscopy, as its well-stocked archives testify, and can look back with pride on rich victories achieved through the sage diversification of its scientific resources. We should carry that element of our history into our future.

Elizabeth Griffin,
remg@astro.ox.ac.uk
Oxford, UK

News Notes

En Manchettes

LIGHT POLLUTION IS BAD FOR YOU

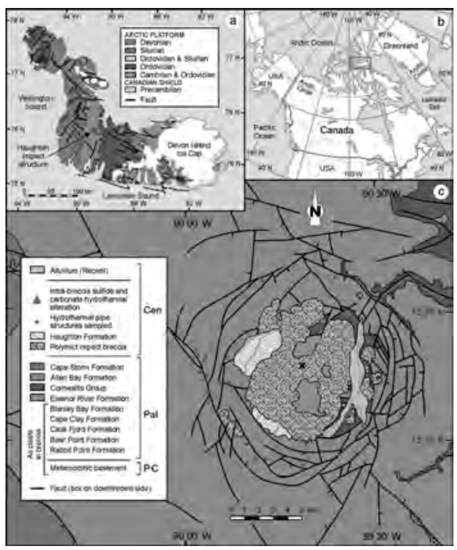
Turning off unnecessary street lights is not only a good way of saving the tax payer some money and making astronomers happy, it is also good for your health. At least, so noted Bill Blackmore in a recent ABC television broadcast. Blackmore's report contained special mention of a recent discovery by biologists that the human body can only produce the hormone melatonin under completely dark conditions. Melatonin, Blackmore reminds us, is an important anticancer agent. Even low dosages of light at nighttime are apparently capable of suppressing melatonin usage, and recent experiments have shown that animals become weak if they are forced to live in artificially bright environments.

In the same report Blackmore also noted that by going dark at night many companies and school boards are not only saving large sums of money, they are also experiencing less vandalism. Police have found that if a building is purposely left with no lights on then the public tends to notice and report more rapidly any unusual activity that they actually see. It also turns out that would-be graffiti artists prefer well lit walls to work upon, and consequently dark site walls are left alone.

THE HAUGHTON IMPACT STRUCTURE

There is little doubt that when a large asteroid impacts upon the Earth the devastation at 'ground-zero' is near complete. However, the short-term destruction of crater formation can lead to longer-term benefits, especially so if the impact results in hydrothermal activity in an otherwise barren and cold landscape. Writing in the journal *Meteoritics and Space Science* (2001, 36, p.731), Dr. Gordon Osinski and John Spray of the Planetary and Space Science Centre, New Brunswick, and Pascal Lee of NASA Ames Research Center, have found good evidence that following its formation the Haughton impact structure was a warmer and wetter place than its immediate surroundings.

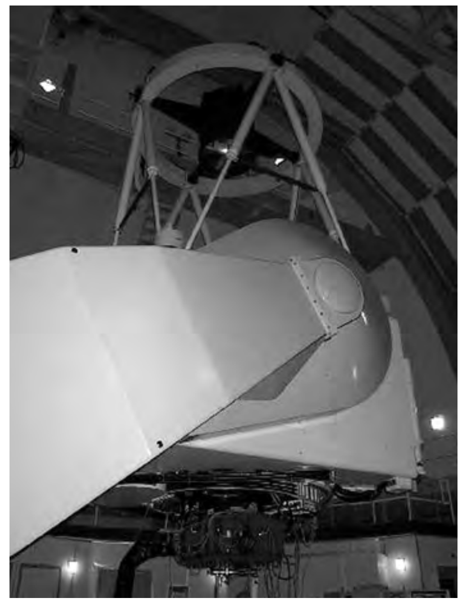
The Haughton impact structure is situated on Devon Island in the Canadian arctic archipelago. It is one of the highest latitude craters known on Earth, and is 24 km across. With an estimated age of 23 million years, the crater lies in a polar desert environment and is considered to be a terrestrial model of the conditions that may have existed on a young Mars.



The Haughton impact structure. Inset (a) shows the geology of Devon Island, while inset (b) locates Devon Island within the Canadian high arctic. Inset (c) reveals the geology of the Haughton impact structure (Image courtesy of Dr. Gordon Osinski)

By careful analysis of mineralization and hydrothermal alteration deposits, Osinski and co-workers have pieced together a thermal history of the Haughton impact crater. The initial stages were clearly hot and inhospitable, but the final cooling stage, lasting several tens of thousands of years, saw the crater support a bedrock-warmed lake.

U OF T ASTRONOMERS GET TIME



The 2.5-metre (100-inch) Irénée Du Pont Telescope at Las Campanas Observatory. Image from, and more information at, `www.lco.cl/lco/telescopes/duPont`

The Department of Astronomy and Astrophysics at the University of Toronto has a long tradition of collaboration and activity at the Las Campanas Observatory (LCO) in Chile. This tradition continues with their recent agreement to join with the Carnegie Institution of Washington to build a widefield infrared camera for the Du Pont telescope at LCO. In addition, U of T astronomers will have the opportunity to collaborate on instrumentation for the two Magellan Telescopes, also at LCO. The first partnership will see U of T astronomers help in the construction of a camera for a multi-object spectrograph and they will also help commission a new echelle spectrograph. The new agreement will also see U of T astronomers receive 33 nights per year of guaranteed observing time on the Magellan Telescopes until 2006. Further images and Web links are available at www.astro.utoronto.ca.

PERSEID BOOSTER SURPRISE

Re-entry of a Soviet rocket booster on August 12, 03:02 UT. The photograph was obtained by Michael Boschat, Halifax Centre, while observing Perseid meteors from the roof of a building at Dalhousie University. More images can be seen at www.atm.dal.ca/~andromed/rocket.html

Many Internet sites are reporting a less than spectacular Perseid meteor shower for this past August. Observers on the Atlantic coast of Canada, however, were treated to a rare and spectacular sight on the night of Perseid maximum: a re-entering rocket booster. The booster was part of a Soviet rocket that launched a Molniya communications satellite on July 20th. While it was being tracked by the US Space Command, its appearance over Halifax skies had not been anticipated. The event was observed and recorded by Michael Boschat, of the Halifax Centre, while attempting to photograph Perseid meteors. "I thought it was a fireball at first" explained Boschat, but then he realized that the slow speed and the many small and trailing fragments were not typical Perseid fireball characteristics. Having earlier given up on observations because of cloud, Boschat commented that he only returned to observations once the night had cleared because of a "gut feeling" that something interesting could happen.

WHERE'S THE CENTRE OF THE UNIVERSE? IT'S IN VICTORIA

The National Research Council of Canada (NRC) has opened a new astronomy interpretive centre at the Herzberg Institute of Astrophysics in Victoria, B.C. The new centre, daringly called the Centre of the Universe, will showcase the work of NRC scientists, engineers, and technicians. "Canada's position as a world leader in astronomy — ranking third after Britain and the United States — is a track record we can all be proud of," said Dr. Carty, President of the National Research Council, at the centre's opening. The centre houses many interactive exhibits, a StarLab planetarium, a sixty-seat theatre, an in-house telescope, and is located adjacent to the historic 1.8-metre Plaskett Telescope built on top of Little Saanich Mountain. The opening of the Centre of the Universe facility is part of the Canadian astronomical community's commitment to public outreach and education as described in the Canadian Long Range Plan for Astronomy and Astrophysics by CASCA (see www.casca.ca/lrp for further details).

Terrestrial explorers will be pleased to know that the Centre of the Universe is open daily from 10 a.m. to 6 p.m. (11 p.m. on Saturdays) from April through to the end of October. There is an entrance fee of $5 for adults, $3 for youths (13–17), and $2 for children (6–12). Further details can be found in the Centre's brochure available at www.dao.nrc.ca/cu/cu.pdf

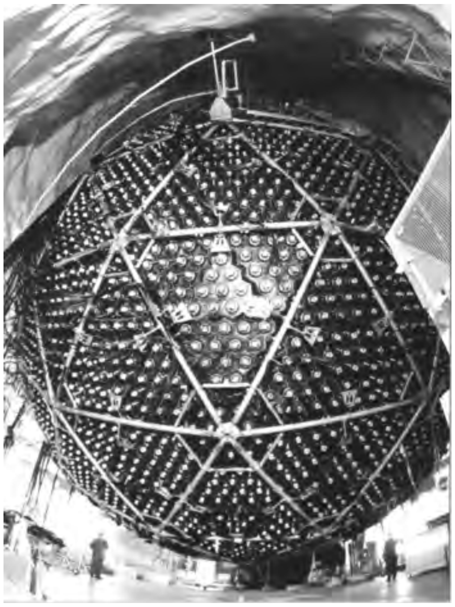
LUNAR CRESCENT VISIBILITY: A SOCIOLOGICAL STUDY

Writing in the *Journal of Astronomical History and Heritage* (2001, **4**(1), p.1), Nidhal Guessoum of the American University of Sharjah, United Arab Emirates, and Kiram Meziane of the University of New Brunswick in Fredericton, have studied the accuracy of naked-eye crescent Moon sightings. The problem is not just of academic interest. The motivation for their study relates to the Islamic calendar in which a new month starts the day after the first naked-eye sighting of the thin crescent Moon. Three times a year, for the purpose of marking religious events, officials from various Islamic countries decree the beginning of the month on the basis of lunar crescent observations. By comparing the deduced results for religious occasions in Algeria between 1963 and 2000, Guessoum and Meziane find that compared to actual astronomical calculations the official dates were in error 80% of the time. In some 17% of the cases the deduced dates were totally erroneous. Guessoum and Meziane conclude by suggesting that Islamic officials should reconsider their methods for the determination of the beginning of the Islamic months.

30-YEAR SOLAR MYSTERY SOLVED

The long-running solar neutrino problem has finally been solved. So claim an international team of scientists working at the Sudbury Neutrino Observatory (SNO). The solution lies not with our understanding of the Sun and the nuclear reactions that take place within its core, but with our understanding of the neutrinos. It is known that there are three types (or flavours) of neutrino, the electron, muon and tau neutrinos, and the thirty-year old solar neutrino problem has revolved around the fact that fewer neutrinos are detected than the solar models predict.

Situated 2000 metres underground in INCO's Creighton Nickel Mine near Sudbury, the SNO detector uses some



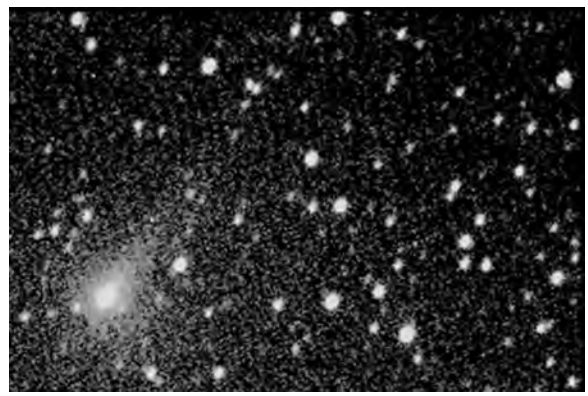
The SNO detector consists of a geodesic sphere supporting 9600 photo detectors. The light detectors 'watch' for the telltale flashes that indicate a neutrino interaction has taken place within the heavy water chamber. Image from the SNO Web site at `www.sno.phy.queensu.ca`

1000 tonnes of heavy water to intercept about 10 neutrinos per day. What the new observations indicate is that the neutrinos emitted from the Sun's core change type as they travel from the Sun to the Earth. The SNO detector 'looks' for neutrino interactions that trigger the conversion of a neutron into a proton. The neutron target resides in the heavy water's deuterium component. By comparing the SNO neutrino detection rate against the rate observed at the Super Kamiokande, an ordinary water detector in Japan, scientists have been able to show that the neutrino flux is actually consistent with that predicted by the solar models. These new results indicate that nuclear physicists will have to revise their models of atomic theory to incorporate neutrino flavor oscillations. A full account of the SNO results will be presented in an upcoming issue of the *Journal*.

STAR PARTY COMET SURPRISE

The odds are certainly staked against the typical observer, but Vance Petriew came up trumps this August with a new comet discovery. Vance, who is a member of the Regina Centre, discovered comet C/2001 Q2 in the early morning hours of August 17th. Testing out his new 0.51-m telescope at the Saskatchewan Summer Star Party in the Cyprus Hills Provincial Park of Southern Saskatchewan, Vance came across the new 11th magnitude comet while star-hopping to M1.

At first thinking he had stumbled upon a faint galaxy Vance turned to his star charts. Richard Huziak of the Saskatoon Centre, who was passing by at the time, realized that no galaxy should be found in the Taurus – Auriga region of the sky (it being in the galactic plane). So the thought occurred that it might be a comet. A search through the available cometary ephemerides failed to reveal any possible candidate, so at 6 A.M. a call was put through to the IAU Central Bureau at the Harvard-Smithsonian Center for Astrophysics. Later that day Daniel Green announced the news to Vance, "Congratulations! It looks like you have a confirmation". The discovery was later published in *IAU Circular No. 7686*. There is a pleasant irony to the fact that Vance discovered C/2001 Q2 while searching out M1, the first object in Charles Messier's famous catalog on non-cometary objects. Vance joins a select company of astronomers, being only the third Canadian amateur to have visually discovered a comet from Canada and the very first person to discover a comet from Saskatchewan.



A two-minute CCD image of Comet Petriew taken on August 23, 2001 using a 20-cm Schmidt-Cassegrain telescope (Image taken by and courtesy of Alan Hale, Cloudcroft, NM).

Feature Articles
Articles de Fond

Neutrino Detectives:
Digging Deep at the Sudbury Neutrino Observatory

by Christine Kulyk (clkulyk@kos.net)

The Sudbury Neutrino Observatory (SNO) is currently the largest particle physics experiment in Canada. Taking 10 years to construct, the giant neutrino detector became fully operational in November 1999. On June 18, 2001, members of the SNO collaboration announced their first results, which they believe have finally solved the "solar neutrino problem" and demonstrated that neutrinos do have mass and are able to change from one type to another while en route from the Sun to Earth. This article, presenting a glimpse at the people working at SNO, is the result of visits to the SNO site and personal interviews conducted with SNO team members by the author over the past three years.

It's 7:30 a.m. at the Creighton Mine near Sudbury, Ontario, and Chris Waltham and Jaret Heise are gearing up for a day of work. Donning coveralls, work boots, utility belt, and hard hat with headlamp, they prepare to join 40 miners crowded into one compartment of the "cage," a double-decker elevator that will take them to the bottom of a mine shaft, two kilometres down.

Unlike the miners, the quarries Waltham and Heise are after are not precious metals but mysterious subatomic particles called neutrinos. Their destination is the underground lab of the Sudbury Neutrino Observatory (SNO).

For astronomers, neutrinos are of interest on several fronts. They hold a key to understanding what happens during a supernova explosion, and they give us a direct glimpse into the inner workings of stars like our Sun, whose nuclear fires spew out trillions upon trillions of neutrinos every second. Tiny, fast-moving neutrinos are able to zip through solid matter with ease. Every second, theorists say, 100 billion neutrinos pass through an area the size of your thumbnail, making them the most abundant particles in the cosmos. Knowing just how much of the universe's total mass is actually made up of neutrinos could help cosmologists predict the ultimate evolution of our universe. SNO's neutrino detector is an immense, transparent acrylic tank — a spherical vessel, 12 metres in diameter, that contains 1,000 tonnes of heavy water. Surrounding the tank is an 18-metre geodesic sphere bearing 9,600 photomultiplier tubes — ultrasensitive light sensors able to pick up the tiny flash that appears when a neutrino collides with a neutron in the heavy water.

Jaret Heise is suspended inside the Sudbury Neutrino Observatory sphere as it undergoes construction (Photo courtesy of Jaret Heise, UBC).

Using heavy water gives SNO an advantage in the neutrino hunt because it contains deuterium, a "heavy" isotope of hydrogen. Each deuterium nucleus has a neutron — in addition to the single proton of a normal hydrogen atom — and those neutrons happen to be the best targets devised so far for colliding with neutrinos.

SNO gains a further edge over the


Art McDonald, the Sudbury Neutrino Observatory Project Director (Photo courtesy of the author).

competition by being located deep underground. The two kilometres of overlying rock act as a natural radiation shield, blocking out unwanted cosmic rays and other ambient radiation, while the prized neutrinos penetrate freely to the detector.

For Waltham, a physics and astronomy professor from the University of British Columbia, Heise, his graduate student, and the other scientists at SNO, their experiment's deep-underground location has meant repeated trips riding in a mine elevator to get to their work site. At the brisk pace of 2,300 vertical feet per minute (about 10 metres per second), the descent takes just three minutes, fast enough to make ears pop as atmospheric pressure abruptly rises. Then there's a walk through a 1.5-kilometre tunnel. The ground is uneven and muddy underfoot, and narrow rail tracks run through the centre. It's a netherworld of rock and steel, where the atmosphere is dim, dusty, and oppressive, and it's tough not to feel conscious of the tonnes of rock held back by pins and braces.

The environment, Waltham admits, is rather different from his university office: "You go through the day without being able to see the Sun or the outside world, and that exacerbates the tiredness. The first few weeks were disorienting, until I got used to it." "Physically, it's hard," says Teresa Spreitzer, a physics student from the University of Guelph who worked as a research assistant at SNO last summer. "I'm usually carrying 30 pounds of equipment, walking through the tunnel. My first day, I was very scared and nervous. They didn't tell me how close you are crowded in the cage with 50 big men; and I didn't know it would be pitch dark." (Miners usually switch on headlamps during the descent, but if it's crowded, many keep them off so they don't shine in each other's faces.)

Reaching the SNO laboratory/control room at the tunnel's end, the scientists must doff dust-encrusted coveralls in the Clean Change Area, shower, and don sterile outfits. It's a striking transformation: miner's gear exchanged for baby-blue lab coveralls and clean shoes or lint-free white booties. A hard hat is still worn, but this time, it's a spotlessly clean, lightweight model, and a hair net now goes underneath.

At SNO, cleanliness is a prime directive. As project director and chief scientist Art McDonald explains, any dust from outside could contain traces of radioactive elements, and SNO's neutrino detector is so sensitive, it picks up the slightest background radiation, adding unwanted "noise" to the data.

Keeping things clean underground is a major challenge. Small items are bagged in plastic before being carried through the tunnel. Larger equipment is cleaned on arrival. People go through an air shower that works like a vacuum cleaner to suck away dust.

The lab/control room itself is a cramped rabbit warren of computer workstations surrounded by cables, pipes, and girders. The neutrino detector — a gigantic device designed to catch and record the passage of neutrinos — is monitored throughout the day by at least one scientist. Others are in charge of cleaning and cooling the water in the huge detector tank. At night, monitoring continues via computers in the SNO Institute building located on the surface.

Construction of the detector was completed in 1997, and it became fully operational in November 1999. SNO is the largest particle-physics experiment in Canada today, with administrative headquarters in Sudbury and Kingston, Ontario, and a team of 100 participating scientists from 10 Canadian and U.S. institutions, plus Oxford University in England.

Many of the SNO crew have spent several years on the project. Some are based in the Sudbury area, while others bounce back and forth, spending several weeks there before returning to their home-base universities. The champion commuter is McDonald, who spends half of each week at the SNO Institute on the mine site and the other half in Kingston, where he retains a post as physics professor at Queen's University. "It was a matter of organizing my life and the two responsibilities," he says.

McDonald has been involved with the SNO project since its initial conception in 1983. When he and other members of the SNO collaboration approached Inco Limited (the world's leading nickel producer) in 1988 with the scheme of building a neutrino detector in the Creighton Mine, most of the Inco people had never heard of neutrinos. Nevertheless, they listened and agreed to help, excavating an enormous barrel-shaped cavern 30 metres high and 22 metres wide, in the deepest part of the mine, to house the giant detector tank and its control room.

The job provided some unique challenges for Phil Oliver, the Inco mining engineer who supervised the excavation. Stability of the surrounding rock was a prime concern, says Oliver, so great care was taken in choosing the location.

Even his fellow miners were impressed at the enormity of the cavern they hollowed out for SNO, removing over 70,000 tonnes of rock over a three-year period starting in 1990. Oliver designed a monitoring system to measure any stress changes and displacements in the surrounding rock, and he still keeps an eye on things via computer.

Having a bunch of particle physicists and their lab on-site was a new experience for the miners. For one thing, showers underground are not typical mine accoutrements. "For SNO, we had to put in an air purifier," notes Oliver. "And I never figured I'd have to wear a hair net!"

Mark Boulay, a graduate student from Queen's Physics Department, began by doing intermittent two-week stretches working at the SNO site, then cut back to stints of a few days per month. For more than four years he has commuted back and forth to do the research for his Ph.D. thesis, which involves analyzing SNO data. Boulay says he never experienced any significant ill effects from working in the underground environment, although he admits that "in general, it's always more tiring working underground."

For Boulay and the other SNO scientists, the thrill of chasing their neutrino quarry seems generally to have kept thoughts of their underground surroundings at bay. Still, there are reminders, such as the occasional earth tremor or the sounds of routine blasting from the working mine nearby.

As Spreitzer recalls, "There are small blasts, five or six times a day. You can feel the ground shake. The first time I felt it, I was alone in the lab, and it was a bit unnerving."

Then there are periodic fire drills. "During routine fire alarms," says Waltham, "you have to go into the designated 'Refuge' area. It's sealed off, and you stay there until Inco says it's okay to come out — which might be five hours later."

"One time during a fire alarm," Spreitzer recalls, "we sat in the Refuge Station for three hours. Everyone acted very blasé about it, but still, it brings back to you that something could happen, even though you're very safety conscious."

Spreitzer, who plans a career in experimental physics, is one of only a handful of women working at SNO, and she hopes the experience will place her in good stead in what is still largely a male-dominated field. "Working on a collaboration such as this," Spreitzer says, "gives you a unique opportunity to see how the peer-critiquing process of science really works."

Twenty physics students like Spreitzer had summer jobs at SNO last year, according to Clarence Virtue, a Laurentian University physics professor who's been involved with the project since 1992. That was in addition to 40 students and postdoctoral fellows who worked on SNO-related research projects at the various collaborating universities. "One of our biggest spinoffs may be educating young people in high-tech areas," says Virtue.

Among last year's summer crew was Queen's undergraduate astrophysics student Patrick van Kooten, who has his sights set on a career in space science. "My goal is to get into the Mars mission," says van Kooten, now 19, who appreciated getting an opportunity to work at the SNO site as well as doing data calculations back at Queen's.

"Neutrino physics now is so wide open," notes Spreitzer. "Fifty years ago, they didn't have the hardware we have today. Now, with the new technology available, we can start to answer the questions."

Neutrino research, say many physicists today, is leading us toward the formulation of a "new physics." That's because the diminutive neutrino displays properties and behaviours that defy the "standard model" of subatomic physics.

The neutrino's mass is so small that no one has yet been able to measure it. Indeed, debate has raged for decades as to whether it has any mass at all. What's more, the first neutrino detectors constructed observed far fewer neutrinos reaching Earth from the Sun than were predicted by current models of solar energy production. This "solar neutrino problem" has perplexed physicists for the past 30 years.

The race was on to solve the riddle of the neutrino, and detectors of many varieties began springing up or gracing drawing boards in places like Japan, Italy, the U.S., and Russia. A few are underground, others underwater or on the surface, but none currently matches SNO's depth, power, and versatility. Says Virtue: "Our very deep location is the envy of all the other neutrino experiments in the world."

On June 16 of last year, SNO project director Art McDonald announced to nearly 500 eager listeners in Sudbury at the largest-ever international gathering of neutrino scientists that SNO had completed its first six months of operation with flying colours, catching and recording solar neutrinos as it was designed to do.

"We've got it tuned now so it can take a very good 'picture' of the Sun," said McDonald. "We'll continue fine-tuning until the end of the year."

"People know that with results from SNO, in one year from now," said Laurentian University physicist Clarence Virtue at that time, "things will be much better defined. Then we can begin to establish a game plan for new directions of research."

With the first data in hand at last, the task of analyzing it began. That chore fell to people like the University of British Columbia's Chris Waltham, who has been involved with SNO for 13 years, since its early design phases, and now works mainly from his Vancouver office. "It's been a long, hard grind," said Waltham. "But the first whiff of data — and knowing it was good data — dispelled all the previous headaches."

On June 18, 2001, Waltham and his fellow SNO team members were able to celebrate the fruits of their labours at last, as the SNO collaboration announced to the world that their first experimental results appear to solve the solar neutrino problem once and for all. The neutrino does have a mass, said their announcement, and it is able to change from one type to another while en route from the Sun to Earth.

"We now have high confidence that the discrepancy (the so-called "missing solar neutrinos") is not caused by problems with the models of the Sun but by changes in the neutrinos themselves as they travel from the core of the Sun to the Earth," said McDonald. "The new results from SNO, combined with previous work, now reveal this transformation clearly."

"It's a great success. We're very happy," said SNO team member George Ewan, an emeritus physics professor at Queen's. "We spent a long time building this detector. And there is a lot more to come."

Work at the SNO detector over the coming months will involve refining the accuracy and sensitivity of the experiment. The initial results, if confirmed, still leave open the question of *how* neutrinos can change from one type to another — the answer to which could mean formulation of a new model of subatomic physics.

"Neutrino research," says Queen's physics professor Aksel Hallin, "is a new way of looking at the cosmos that we live in. For a physicist, it's exciting because it's the only thing that doesn't fit in with the standard models of physics today."

For the members of the SNO collaboration, the research results announced on June 18 mark the successful culmination of two decades of work and the beginning of the next phase of their ambitious undertaking.

Christine Kulyk is a freelance writer and editor based in Kingston, Ontario. Specializing in science reporting, she has written for Equinox *magazine and* Canadian Geographic *and is Assistant Editor of* SkyNews. *She is currently a member of the Kingston Centre and was previously a member of the Montreal and Edmonton Centres.*

Royal Astronomical Society of Canada National Awards — Call for Nominations

The RASC sponsors several national awards. Their purpose is to recognize Society members for outstanding service to the RASC as well as excellence in all aspects of amateur astronomy. Members are encouraged to nominate candidates for these awards. The Awards Committee reviews all nominations and puts forward outstanding candidates to National Council for approval. Successful nominees are invited to attend the General Assembly the following summer to receive their awards.

Nominations for all four awards must be received at the National Office by December 31st, 2001 to be considered.

Service Award

The Service Award is presented to members who have performed outstanding service to a Centre or to the National Society over an extended period of time. The nominee must have been a member in good standing for at least 10 consecutive years prior to nomination. The service performed should have had a major, constructive impact on the Centre or Society, requiring a very substantial and continued commitment on the part of the nominee over a period of at least 10 years.

When submitting a nominee to the Awards committee, the nominating Centre (or individual if the nominee is an unattached member) must provide a statement establishing the suitability of the candidate.

Chant Medal

The Chant Medal was created in 1940 and is named for Prof. C. A. Chant. It is awarded to an amateur astronomer who has carried out a significant and original project that has contributed to the science of astronomy. The nomination of a Centre member should be submitted by the Centre itself.

Ken Chilton Prize

The Ken Chilton Prize was established in 1977 and is named after Hamilton Centre member Ken Chilton. It is awarded to a member resident in Canada in recognition of a significant piece of astronomical work carried out or published during the year. Any member can submit a nomination for consideration.

Simon Newcomb Award

The Simon Newcomb Award is intended to encourage members of the Royal Astronomical Society of Canada to write on the topic of astronomy, either for the Society or the general public, and to recognize the best published works through an annual award. Any member is eligible for the award. Nominations can be submitted by a member, a group of members, or by a Centre.

More information about these awards can be found in the RASC manual at the RASC web site. If you have any questions about the Society's awards, please contact the undersigned via email (attwood@istar.ca) or through the National Office.

Please submit nominations to:

Randy Attwood
Chairman - Awards Committee
attwood@istar.ca
or by mail to RASC National Office
136 Dupont Street
Toronto, ON
M5R 1V2

The Titius-Bode Rule, Part 2: Science or Numerology?

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

Last month, I presented the history of the Titius-Bode rule of planetary orbit spacing in the solar system, including the spectacular concordance of the "predictions" of the rule (also called Bode's law) in the case of Uranus and the asteroids, and the abysmal failure of the rule with respect to the last two planets discovered: Neptune and Pluto. This month, I will review the quest for a scientific basis to this rule. At the time I made this rash promise, I was going out on a limb, as I was unsure of what I would be able to find. To my relief, I found an extensive body of literature on the subject, including some recent interesting studies. For those pressed for time, I will now present the thumbnail version: according to the experts, a large part of the thought and writing on this topic is rubbish, although there is evidence there is some sort of self-scaling property for planetary systems that results in bodies ending up in a roughly log-linear dependence of semi-major axis against planet number. In other words, although the precise relationship we know as Bode's law has no physical basis, Titius and Bode were on the right track.

To briefly recap, the German naturalist Johann Daniel Titius (1729–1796) postulated the following rule for the radius of the planetary orbits: from Mercury through Saturn,

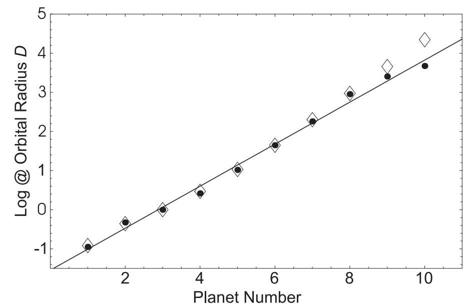
$$D = 0.4 + 0.3\,n, \text{ where } n = \{0, 1, 2, 4, 8, 16, 32\}$$

in which D is the semi-major axis in Astronomical Units (*i.e.* D_{Earth}=1 AU). Fellow German Johann Elert Bode (1747–1826) liked the idea so much that he included it in one of his popular textbooks on astronomy, and everyone started calling it Bode's Law. In fact, there was a gap at n=8, as no planet was known to occupy the zone between Mars and Jupiter. When William Herschel (1738–1822) discovered Uranus, it fit the n=64 extrapolation of the rule very nicely, fuelling the search for a planet in the Mars-Jupiter gap. Eventually, the Italian astronomer Giuseppe Piazzi (1746–1826) discovered the minor planet Ceres. Subsequent discoveries of Neptune and Pluto did not fit the law so well, and the whole business turned a bit sour. A summary of the success and failures of the Titius-Bode rule is shown in the Table. The entries in parentheses denote bodies unknown to Titius and Bode.

Another way to examine the data is to plot a graph. In this case, it is instructive to plot the *logarithm* of the semi-major axis against planet number k, starting with Mercury as k=1, and outward and upward from there. This is shown in the figure, along with a "best fit" line, which is summarized by the expression

$$D = 0.21 \times 1.71^k$$

(The uncertainty on 0.21 is 0.02 and the uncertainty on 1.71 is 0.03.) In other words, as we move from the inner to the outer planets, the distance of each planet is 1.71 times the distance of the previous planet, on average.



The approximate logarithmic spacing of the planetary orbits. Filled circles are the exact semi-major axis values; open diamonds are the Titius-Bode law results. Note the excellent "predictions" of Ceres (k=5) and Uranus (k=8) and the poor "predictions" of Neptune (k=9) and Pluto (k=10).

TABLE
SUCCESSES AND FAILURES OF THE TITIUS-BODE RULE
(*items in brackets unknown to Titius and Bode*)

Distance from Sun (in AU)	Mercury	Venus	Earth	Mars	(Ceres)	Jupiter	Saturn	(Uranus)	(Neptune)	(Pluto)
True (mean)	0.39	0.72	1.0	1.5	(2.8)	5.2	9.6	(19.6)	(30.1)	(39.5)
Titius-Bode rule	0.40	0.70	1.0	1.6	(2.8)	5.2	10.0	(19.6)	(38.8)	(77.2)
N	0	1	2	4	(8)	16	32	(64)	(128)	(256)
K	1	2	3	4	(5)	6	7	(8)	(9)	(10)

To the practiced scientific eye, despite the variations in the data, there is a strong suggestion in this figure that there is some regularity to the planetary spacing. The fit appears to be simply too good to be random. (More on this later.) It would help if there were more multi-planet systems to study, and in fact the satellite systems of Jupiter, Saturn, and Uranus show similar patterns. This observation does not "prove" Bode's law, but it does provide some justification for studying the possible physical causes of the apparent regularity.

To my surprise and delight, there is an entire book devoted to this problem, *The Titius-Bode Law of Planetary Distances: Its History and Theory*, written in 1972 by Michael M. Nieto of the University of Copenhagen, and published by Pergamon Press (Oxford). This is not a readily available book, but I was able to get it through Inter-Library Loan from NRC's Canadian Institute for Scientific and Technical Information, in Ottawa. Nieto's book is a fairly methodical summary of all the thinking on the subject up to the date of publication, and describes many hypotheses, including theories based on electromagnetic, gravitational, and nebular (condensation of gas clouds) effects. Nieto does not reach a definitive conclusion but, rather, he narrows the range of options and suggests avenues for further research.

I asked around a bit to see what has been done more recently and in the last 29 years. Bruce McCurdy, author of the *Orbital Oddities* columns in this journal, says that John Gribbin, in his *Companion to the Cosmos* (Little, Brown, 1996), showed that the three "planets" orbiting the star PSR B1257+12 also conform very nicely to Bode's Law. Bruce wonders if there are any other multi-planet systems out there to add to the data set.

Another correspondent (who prefers to remain nameless, but you might guess who it is) opined that the geometric scaling of planetary orbits is tied to the fact that the orbital speed of the planets decreases as the inverse square root of distance from the Sun. To create planets by mergers, one needs objects to collide at relatively low speeds in nearly similar-sized orbits; otherwise, the collision becomes destructive rather than constructive. If one assumes a spread of 2–3 km s^{-1} (say) as a potential range of speeds for constructive collisions to occur, one finds that a growing protoplanet is capable of attracting and melding with other objects over a specific interval of distance from the Sun, but no larger. That interval increases rather dramatically with increasing distance from the Sun, so planetary spacings must increase markedly with increasing distance from the Sun. In other words, the Titius-Bode relation simply expresses Newtonian mechanics in empirical form: each planet in the solar system is about 1.5 to 2 times further from the Sun than the next innermost planet.

This sage continues with an "editorial" comment (hint) to the effect that it is unfortunate everyone and his uncle seem to think the "law" is a way to explain just about everything in the solar system, forgetting of course that it is based on mechanics, not complex numerical mumbo-jumbo, and that reputable journals would not publish such clap-trap.

An amusing side note: in 1823, James Utting published a paper in the *Philosophical Magazine* regarding his observation of the inverse-square-root law of planetary speeds alluded to above. Apparently, neither the author nor the journal was aware that this proposed new "law" is simply a derivable consequence of Kepler's Third Law, which had been around for over 200 years! (This is an exercise left to the reader, as they say.)

Wayne Hayes (University of Toronto) and Scott Tremaine (then U of T, now Princeton) analyzed the statistical aspects of Titius-Bode laws in their paper "Fitting random stable solar systems to Titius-Bode laws," *Icarus* 135, 549 (1997). This rather skeptical paper did not consider the underlying dynamics to a large degree, but ended up concluding that it would be necessary to perform numerical "experiments" to look at the evolution and stability of randomly generated solar systems, to properly investigate the universality of the suggested relations.

A recent textbook by Carl D. Murray and Stanley F. Dermott, *Solar System Dynamics* (Cambridge University Press, 1999) also considers the statistical significance of Titius-Bode laws. I have not been able to put my hands on this book, but the sample chapter on the publisher's Web page happened to include the appropriate section! Murray and Dermott are perhaps even more skeptical than Hayes and Tremaine, but they do allow that there are some remarkable numerical relationships among the bodies in the solar system, and these are dynamically significant.

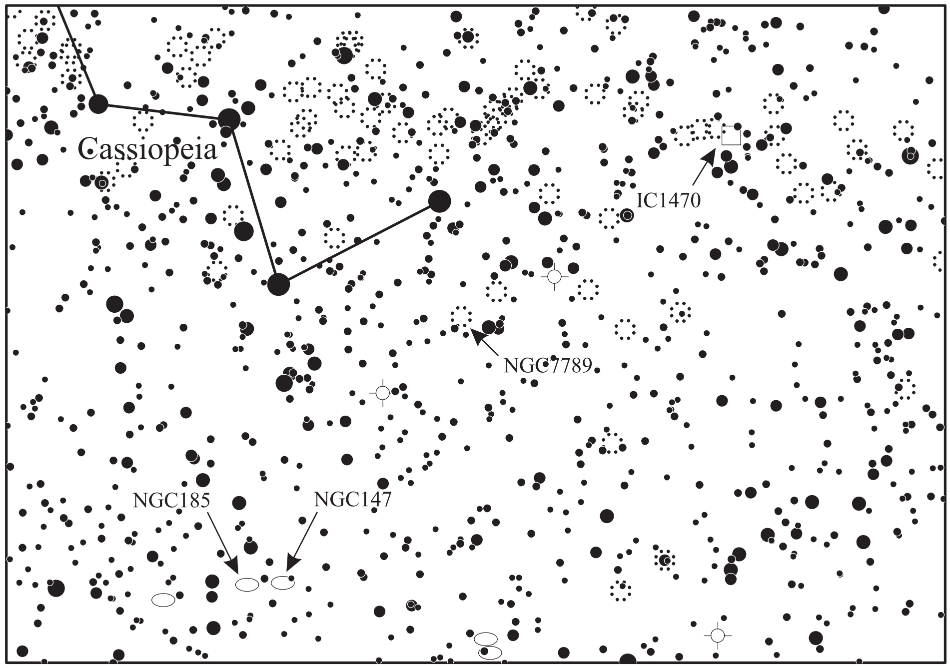
In conclusion, there is no truly definitive treatment of the evident geometrical relation between planetary distances, although much has been written on the topic. My scientific intuition tells me there is something behind the Titius-Bode rule, but also that there is no mysterious force at work. It is most likely that the geometric progression of distances is a consequence of Newton's laws of motion, but not something that can be derived simply by manipulating a few equations. Rather, it is the result of a complex non-linear interaction of many bodies. An infinity of possible solar systems can be conceived, but few of them would remain stable in their original configuration. Perhaps it will be discovered that those systems settling down to stable configurations and lasting long enough to be observed (or to allow intelligent life forms to evolve?) must have a regularity in their spacing of a Titius-Bode type. A starting point for such investigations would be to bone up on the latest techniques of celestial mechanics, and to apply the power of modern computers to perform enough simulations to develop further understanding of the phenomenon. Perhaps Bruce McCurdy is already working on a future *Orbital Oddities* column!

David Chapman is a Life Member of the RASC and a past President of the Halifax Centre. Visit his astronomy page at www3.ns.sympatico.ca/dave.chapman/astronomy_page

Here and There in Autumn Skies

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

Many dedicated deep-sky observers are as familiar with the showpieces of the New General Catalogue as other amateur astronomers are with the famous Messier Catalogue of clusters and nebulae. With over 13,000 objects (including the two Index Catalogues), the overwhelming majority of NGC entries are faint, little-known objects. Some of the catalogue entries, though, represent clusters, nebulae, or galaxies every bit as compelling as their brighter Messier brethren. Mention the numbers "4565" or "891" to the accomplished observer and thoughts of subtle, yet beautiful, needle-thin galaxies come to mind. "2392" is the bright Eskimo Nebula in Gemini while "7000" is summertime's glorious North America Nebula.



A finder chart (showing stars to about 8th magnitude) containing some of the objects mentioned in this column (ECU Chart by Dave Lane).

When I first began reading (and rereading!) *Burnham's Celestial Handbook* in the early 1980s, I slowly but surely became familiar with these significant wayposts in the skies. While they were not all necessarily bright or beautiful objects, often they had a significance beyond their sometimes-modest appearances. In my early days it became as much a goal to one day view these objects as it was to observe the entire Messier list. By and large, most of these objects have been visited and duly noted in my observing log. Happily, some remain to be observed, even after fifteen years of exploring the night sky. Rather than concentrate on one constellation this month, we will sweep across the northern sky, noting some interesting viewing opportunities for chilly November nights.

The constellation Cepheus is quite well placed in the sky throughout the autumn months as darkness falls. In its southwestern corner on the border with Cygnus lies the faint, diffuse spiral galaxy NGC 6946. This galaxy is noteworthy as being one of a handful of "spiral nebulae" first observed by Lord Rosse and his assistants with his 72-inch reflector in the nineteenth century. I first came across this galaxy in July of 1992, observing from dark New Brunswick skies with my old 8-inch SCT. Not surprisingly, not much could be made of the observation. I found it was a faint, diffuse glow, elongated in an east-west direction with rather even surface brightness.

Seven years later, from an observing site just down the road from the one I used in 1992, and armed with my 15-inch reflector, I returned to this galaxy on a pitch black August night. Initially I noted a diffuse glow as I had many years before, but as my eyes adjusted to the view and slowly scanned the field, a subtle arc of light descended from the core to the north and east — one of the galaxy's spiral arms! With averted vision I tried to find its counterpart to the south and west, but only a stubby, formless glow could be detected here, as can be seen in the drawing reproduced on the page opposite. A few more inches of aperture would have assured success, but the diffuse, asymmetrical glow of NGC 6946 would now join the galaxies M83, M33, M51, and M61 as ones in which I had detected spiral structure.

Also in Cepheus, high in the north near Polaris, is the surprisingly difficult open cluster NGC 188. Located high above the plane of the Milky Way, this cluster is reputed to be the oldest of its type in our galaxy, with some estimates placing its age at about 12 billion years. According to *Burnham's Celestial Handbook*, the cluster can be detected with a 6-inch telescope, but this hasn't been my experience! In the 1980s I made repeated attempts to observe this faint open cluster from suburban locations in the Montreal area, always without success. On two occasions in the 1990s, using my 15-inch reflector at my old cottage in Sutton, Quebec, I was stymied again; part of the reason here is that this area of the sky was usually brightened somewhat by the glow from Cowansville, fifteen kilometres to the north.

Success finally came in 1999 from New Brunswick, on the night following my observation of NGC 6946. Initially detected as a hazy glow at low magnification, the cluster resolved at 146× into about 60 individual members, all fainter than magnitude 12, with a prominent starless zone at the centre. This feature can be noted in the wide-field photo of the cluster reproduced on page 612 of *Burnham's Celestial Handbook*. This is a good target for the observer with a small telescope who wants to push his observing skills to the limit.

A fairly bright object in southeastern Cepheus, interesting to observe because it escaped the detection of both William and John Herschel, is IC 1470. Once classified as a planetary nebula, this glowing cloud of gas is easily detectable in an 8-inch telescope as a small, round nebula with a faint star shining through.

The constellation Cassiopeia, imbedded in the glow of the Milky Way, is well known for its abundance of bright and faint star clusters. There are a few challenges here for galaxy hunters and we will look at three.

Due east of Beta Cassiopeiae and buried in rich Milky Way starfields is the faint, nearby galaxy IC 10. This object would be much better known if it was located away from the plane of the Milky Way, as its brightness is considerably reduced by intervening gas and dust in our own galaxy. In 1993, from Sutton, this galaxy appeared as a moderately large, though faint, nebulous glow shining around a magnitude 11 field star that could be mistaken for a nucleus at low magnification. The galaxy was a little brighter to the core and appeared slightly elongated in an east-west direction.

Two dwarf companions of the Andromeda galaxy are located in Cassiopeia and, though they will probably pose a bit of a challenge for smaller telescopes, both were easy to see from Sutton in my 15-inch reflector. The two galaxies in question are NGC 147 and NGC 185. Of the two, NGC 185 is the brighter and easier to detect galaxy, a fairly large diffuse glow in a rich star field. The galaxy appears slightly elongated in a north northeast-south southwest direction and very gradually brighter to the middle. Although fainter, the other galaxy, NGC 147 appears considerably larger. In the 15-inch reflector it was a very diffuse, roundish glow with indefinite boundaries. The brightness increased very suddenly at the centre to what was in all likelihood a faint field star.

One of the richest open clusters in the sky is located in Cassiopeia and is a great target for the small telescope. I first came across NGC 7789 in the 1980s with my old Schmidt-Cassegrain telescope in light-polluted suburban Montreal skies. Even under these conditions, the cluster can be resolved into hundreds of faint stars. One of my best views ever occurred from the observing deck at Mount Sutton in the fall of 1992. The cluster was peppered with faint stars, and dark zones or channels were visible, particularly across the southwestern portion of the cluster. These dark zones are visible in photographs; a good example is the one on page 532 of *Burnham's Celestial Handbook*.

Across the border in Perseus, the observer will come across the prominent, but seldom-observed, nebula NGC 1491. In my 15-inch reflector, the nebula was quite easily detected without a nebula filter though the edges were not well defined. Using a UHC filter, the glowing patch of gas stood out well, bordering a magnitude 9 field star to the west and north. The nebula was also more sharply defined with the filter and brightest to the west of the field star.

A little further east are two star clusters suitable for smaller instruments. NGC 1528 is a very attractive cluster of stars, predominantly magnitude 10 and 11 with a few brighter members. It is well separated from the sky background and is about 25 arc minutes in diameter. Nearby and a little fainter is NGC 1545, a cluster that I described as disappointing from a light-polluted observing site. The cluster is dominated by a bright triangle of 8th magnitude stars, with the rest of the visible cluster members being around magnitude 11. At low magnification, a delicate double star is visible to the north.

The cool, though not necessarily uncomfortable, evenings of November and December are ideal times to set up the telescope and observe the wide range of deep-sky objects that populate the north circumpolar sky. Good hunting to you!

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

EDITORIAL

This number of the *Journal* is an unusual one, being largely devoted to a commemoration of the life and work of John Stanley Plaskett, on the occasion of the inauguration of the Plaskett medal. The history of this new RASC — CASCA award is recounted elsewhere in the number by Dr. Higgs. It gives me pleasure to mark the end of my tenure of the editorial chair by this commemoration of the founder of the observatory at which I have spent almost my entire professional career — I am now in the thirtieth year of my association with the Dominion Astrophysical Observatory. Plaskett remains one of the most outstanding astronomers that have ever lived and worked in Canada. He was not as closely identified with the RASC as was his contemporary C.A. Chant, but it is entirely appropriate that the names of these two great figures from the past should each be perpetuated by awards of our Society. I do not know what their personal relationship was in life but, from our perspective, their lives were complementary. Plaskett gave Canadian astronomical research an international reputation, while Chant did the same for Canadian teaching and popularization of astronomy. Plaskett was supremely successful in obtaining government financing for astronomy; Chant was similarly successful in obtaining private support. Both men were, in the words of our masthead, "devoted to the advancement of astronomy and allied sciences."

by A. H. Batten,
from *Journal*, Vol. 82, pp. 308, December, 1988

Taking Stock

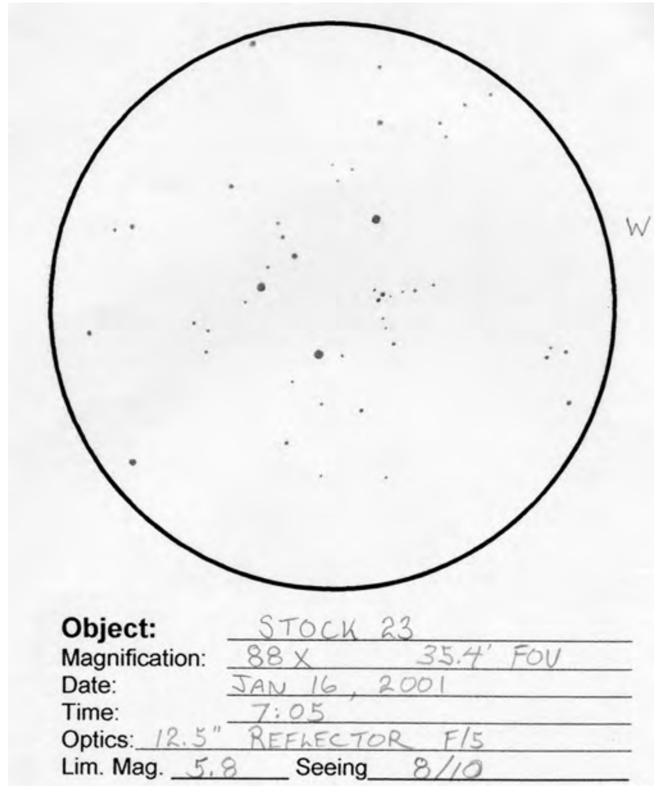
by Guy Mackie, Okanagan Centre (guy.m@home.com)

Astronomy is a journey of discovery, a labyrinth of objects, observing plans, mind-bending concepts and serendipitous adventures, each one leading on to endless hours of enjoyment and wonder. While observing objects on the RASC Finest NGC Objects list I came to many celestial crossroads. When I had finished the list (taking about one year), I chose to retrace my steps and explore some rewarding branches I had been introduced to.

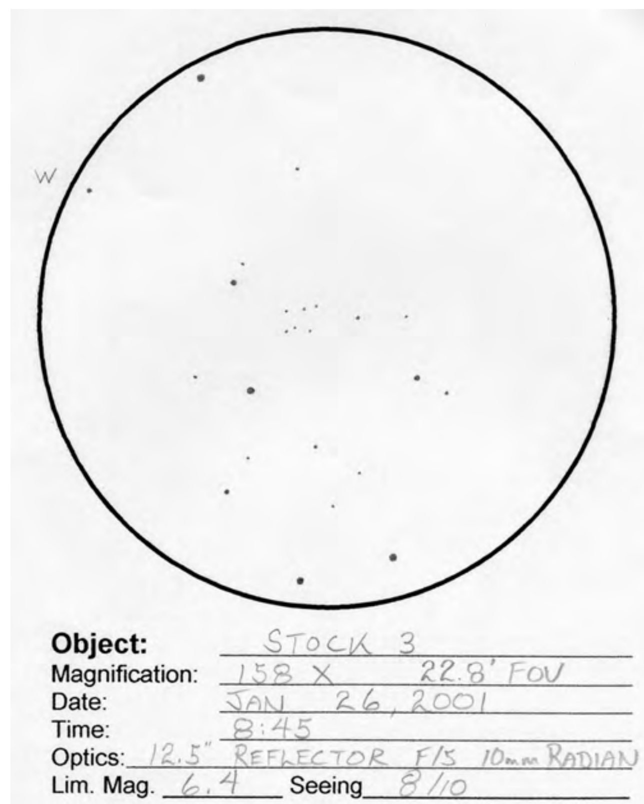
Perhaps the most challenging object on the list for me to find was IC 289, a 13.3-magnitude planetary nebula in Cassiopeia. My starting point for a star hop to the location of IC 289 was a very distinctive open cluster marked St. 23 on my *SkyAtlas* 2000 star map. After each fruitless search for IC 289, I would return to the comfortable familiarity of St. 23 and wonder at both its beauty and the origin of its discovery. My observing partner Ron Scherer was able to explain that the St. stood for Stock, but that was where local knowledge petered out. Thanks to Alan Whitman, a circuitous Internet search, and a generous namesake in the form of Dr. Jürgen Stock, I was able to realize my hopes of learning more about the Stock objects.

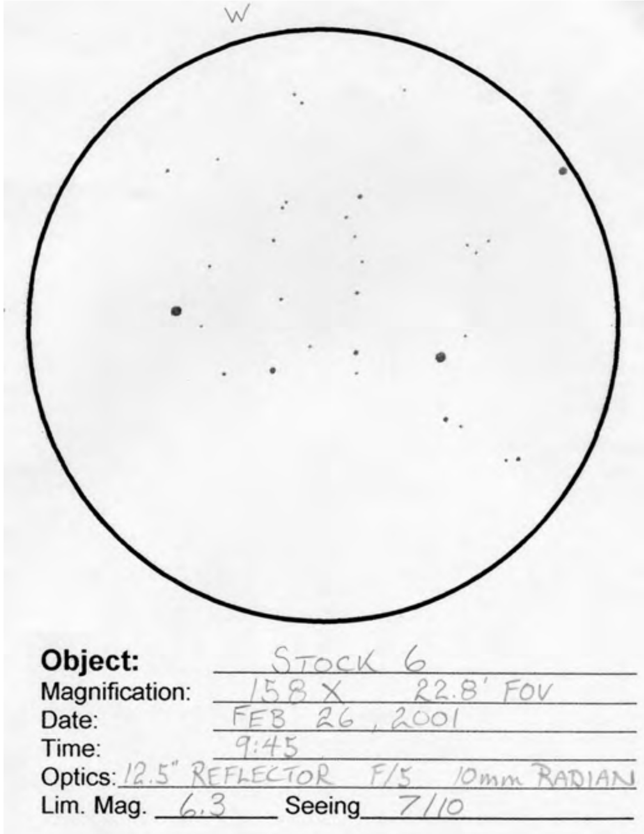
A native of Germany, Dr. Jürgen Stock has followed his astronomical career around the globe. He began his employment at the Hamburg Observatory, then moved to the Warner and Swasey Observatory in Cleveland, spent a one-year term as director of the Boyden Observatory in South Africa, and then moved on to the McDonald Observatory in Texas where he became involved in site survey projects. He contributed to the site survey for the Cerro Tololo Interamerican Observatory, of which he was the first director. His next project took him to Venezuela where he founded their national observatory, and was the director for the first 12 years. Dr. Stock has now been associated with the Venezuela National Observatory for more than 30 years. His main fields of research have been photo-metry, spect-roscopy, astrometry, meteorology, and climatology. He has recently written a book entitled *Weather, How It Works and Why It Matters*, published by Perseus Publishing, Cambridge, Mass. While at the Warner and Swasey Observatory forty years ago, Dr. Stock spent some time examining objective prism survey plates. He was looking for areas with a concentration of stars, which according to their spectra and photographic magnitudes might be related and so form a coherent HR-diagram. More than 20 possible clusters were found that were not on any lists or catalogues at the time. Dr. Stock sent his data to a Dr. Alter in Czechoslovakia, who was preparing a card catalogue of open and globular clusters. Dr. Alter included the objects in his catalogue and designated them as Stock 1 through 24.

When preparing this article, I could not help but smile as I recently returned to St. 23 and thought of all those nights that it was my sheltering home port during my quest for IC 289. At 88×



All sketches are by the author.





with my 12.5-inch reflector this loose open cluster, which is 14´ in diameter, is most notable by the lack of stars in its core area. The distinctive box-shaped empty core is bracketed by four bright stars (mag 7.5 to 8.2) and numerous fainter stars that line up in chains and trails radiating from the core. At 158×, it is revealed that the western most "corner" star is actually a close double.

Stock 2 is a huge, one-degree splash of 50+ stars that defies sketching. At first glance most of the 8th magnitude stars burn a cool white; however, a closer examination reveals a gentle yellow to orange hue showing most frequently in many of the dimmer stars. Standing out for me was SAO 23041 (spectral class K0, mag 7.6, position RA 02^h 12^m 28.7^s Dec +59° 11´ 45.7″). Glowing a subtle yellow, it is the brightest component of a wide double on the southwest side of the cluster. Just outside the cluster is the beautiful rusty orange of SAO 23203 (spectral class K5, mag 8, position RA 02^h 20^m 22.46^s Dec +59° 40´ 16.9″), whose definitive colour caused me to examine the rest of the cluster more closely.

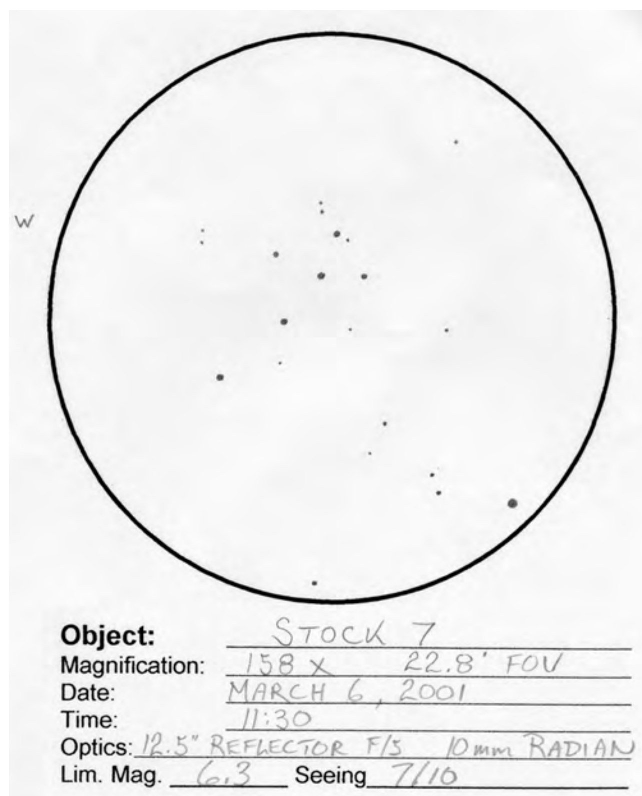
At 63×, Stock 3 is a tiny (2´diameter) dim condensation of about five faint stars set in a glow. At 158× there are six stars in the faint core with another half dozen magnitude 12 outriders widely scattered just outside the fringes of the central core.

Lost in an already rich star field, Stock 4 is easy to overlook. With a diameter of 20´ this loosely scattered cluster of 11th magnitude stars does stand out in a casual sweep, as most of its stars are slightly brighter than the surrounding field. I noticed colour again in SAO 22711 (spectral class K5, mag 9, position RA 01^h 53^m 30.75^s Dec +56° 55.86´), which glows a subtle orange in the southeast edge of the cluster.

Through a 19-mm Panoptic eyepiece yielding 83×, Stock 6 is a small oval fuzzy area, which catches the eye, around about 15 faint stars. According to *Guide 7*, this concentration is only a small part of Stock 6 and is on the southwest edge of the cluster. I liked the look of this small area and made my observation of this section only. At 158× using a 10-mm Radian eye-piece, I see an eyepleasing arrangement of two parallel lines of 11th magnitude stars extending about 8´ in length, bracketed by two bright and colourful stars on the north and south sides. The ruddy orange 8.3 mag SAO 12256 (spectral class KO) is in the north, and the yellow orange 8.9 mag SAO 12260 (spectral class G5) is in the south. The double line of faint stars makes a very nice impression of the constellation Gemini in miniature. My observation may be compromised in that I have not observed the "entire" Stock 6 cluster, and could be more properly titled "a description of the eye pleasing area on the southwest edge of Stock 6."

Stock 7 is almost a full degree south-southwest of IC 1805, and is so distinct that I noticed this 7´ long line of stars when sweeping to find my start point of IC 1805! Star hopping from IC 1805 to confirm the find was surprisingly easy. The four 7th to 8th magnitude stars that dominate this cluster form an almost straight line, and a few fainter stars sprinkle the southern tip.

Perhaps the most intriguing find on this project was Stock 9. Using my computer-generated maps, it would seem that Stock 9 is embedded in the brightest portion of the glowing haze on the northwest corner of the boxlike star arrangement that delineates the emission nebula NGC 1931. With a diameter of only 1´, Stock 9 is one of the smallest of the 24 Stock objects and the glow of NGC 1931 obscures most if not all of it. Close inspection of this knot of haze at 264× and using a light hood reveals suspected



granulation; using averted vision, three or four twinkling faint stars are seen.

Stock 10 is a loosely scattered group of 15 to 20 stars. It is bracketed in the northeast by an arc of three 7th magnitude stars and in the southwest by two slightly dimmer stars. In between, a light dusting of 10th to 11th magnitude stars makes for an eye-pleasing cluster.

Most of the Stock objects (21 of 24) are in the northerly constellations of Cassiopeia, Perseus, Camelopardalis, Auriga and Vulpecula, so they are well suited to Canadian observers. Other than Stock 2 and 23, most of the Stock objects I observed were quite challenging to find, and the use of detailed star charts is a must. Even with good astronomy software such as the *Guide 7* that I use, it seems that some of these smaller open clusters are not 100% accurately plotted and a little detective work is required. In fact, of the twelve Stock targets I had originally sought to observe for this article, I failed completely on four. This may be in equal parts due to the inaccuracy of charts, the ill-defined nature of some of the objects, and of course the ability of the observer.

If you enjoy the challenge of the "hunt" along with the naturally eye-pleasing character of open clusters, then maybe it is also time for you to "take Stock."

Guy Mackie enjoys observing from the dark hillsides near Kelowna, British Columbia. He has completed the Messier and Finest NGC Objects lists and eagerly pushes the limits of his 12.5-inch Dobsonian on the Challenge Objects list and other deep sky targets.

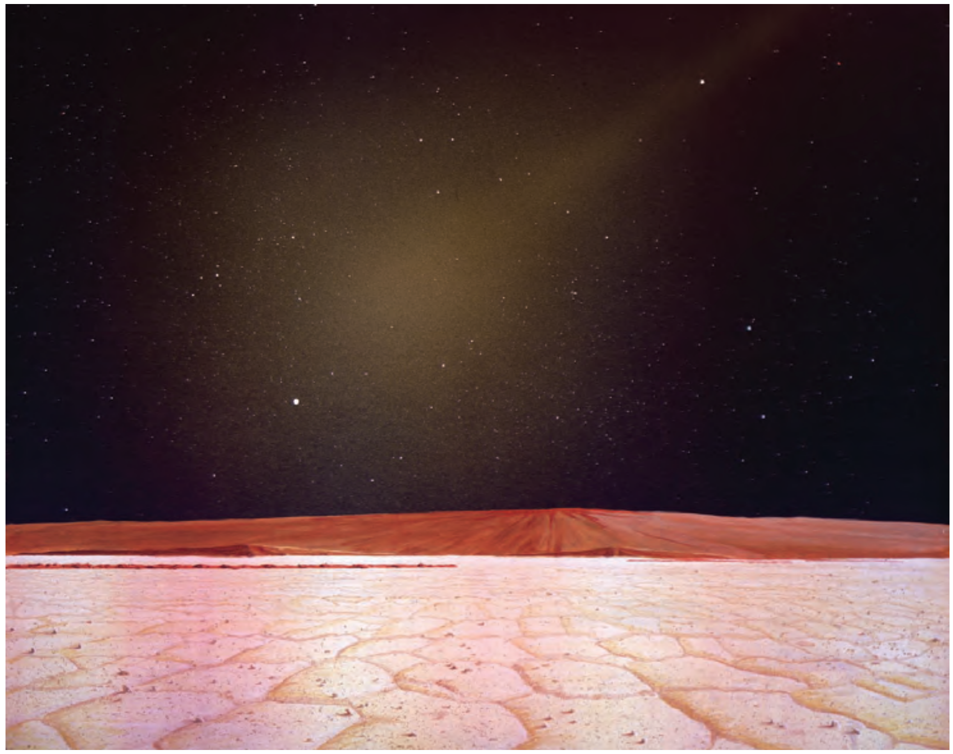
Table of Stock objects (Source: `Messier45.com` by Mikkel Steine)

Object	RA	Dec	Constellation	Dia. (′)	# of Stars	Conc	BrightestStar
Stock 1	19 35 48.0	+25 13 00	Vulpecula	60	40	III	7.0
Stock 10	05 39 00.0	+37 56 00	Auriga	25	15	IV	7.0
Stock 11	23 32 54.0	+55 29 00	Cassiopeia	10		IV	8.0
Stock 12	23 37 12.0	+52 26 00	Cassiopeia	20		IV	8.0
Stock 13	11 13 06.0	−58 55 00	Carina	3.0	15	I	10.0
Stock 14	11 44 00.0	−62 30 00	Centaurus	4.0	10	III	10.0
Stock 15	12 06 54.0	−59 30 00	Crux	12		IV	10.0
Stock 16	13 19 06.0	−62 34 00	Centaurus	3.0	20	III	10.0
Stock 17	23 46 00.0	+62 11 00	Cassiopeia	1.0		I	
Stock 18	00 01 36.0	+64 39 00	Cassiopeia	5.0		IV	
Stock19	00 04 24.0	+56 02 00	Cassiopeia	3.0		III	8.0
Stock 2	02 15 00.0	+59 16 00	Cassiopeia	60	50	I	8.2
Stock 20	00 24 54.0	+62 39 00	Cassiopeia	1.0		II	13.0
Stock 21	00 30 06.0	+57 59 00	Cassiopeia	5.0	10	IV	12.0
Stock 22	01 15 18.0	+60 08 00	Cassiopeia	2.5	15	III	9.0
Stock	23 03 16 18.0	+60 02 00	Camelopardalis	14	25	II	
Stock 24	00 39 42.0	+61 57 00	Cassiopeia	4.0	20	III	11.0
Stock	3 01 12 18.0	+62 20 00	Cassiopeia	2.0	8	IV	11.0
Stock 4	01 52 48.0	+57 04 00	Perseus	20	15	IV	11.0
Stock 5	02 04 30.0	+64 26 00	Cassiopeia	14	25	III	7.0
Stock 6	02 23 42.0	+63 52 00	Cassiopeia	20	20	III	11.0
Stock 7	02 29 36.0	+60 39 00	Cassiopeia	4.5	6	III	8.8
Stock 8	05 27 36.0	+34 25 00	Auriga	5.0	40	I	9.0
Stock 9	05 31 21.3	+34 13 43	Auriga	1.0	20	I	11.5

Space Science, Space Art, and the Classroom[1]

by William K. Hartman (hartmann@psi.edu)

One day, probably in 1950, I came home with a popular book called the *Conquest of Space*. When I was growing up near Pittsburgh, we used to drive from our suburb into the great city on shopping expeditions, and I used to be allowed to spend time browsing in the book sections of the department stores. In those days it was a point of honour among publishers that what they published be factually correct, a quaint practice which was given up in the 80s and 90s in the name of entrepreneurial success. This particular book contained amazing illustrations by a painter named Chesley Bonestell. Bonestell became a boyhood hero of mine, whom I later met. He had been trained in architectural drafting and prided himself on accurate renditions of the geometry and phenomena that might exist among the planets. His paintings showed astronauts exploring the Moon, Jupiter seen from its satellites, and Saturn hanging in a blue evening sky of Titan, based on Gerard Kuiper's 1944 discovery of Titan's atmosphere.



A view of the sodium glow from the surface of Io. The glowing gas occupies a torus around Jupiter in Io's orbit, and so the glow is strongest in the direction looking down the orbit from Io's surface, 90° from Jupiter. The glow also depends on the Doppler shift between the Io gas and the sun, and hence is visible only when Io is at quadrature, with Jupiter (if visible from the site) being half-illuminated. (Painting by William K. Hartmann.)

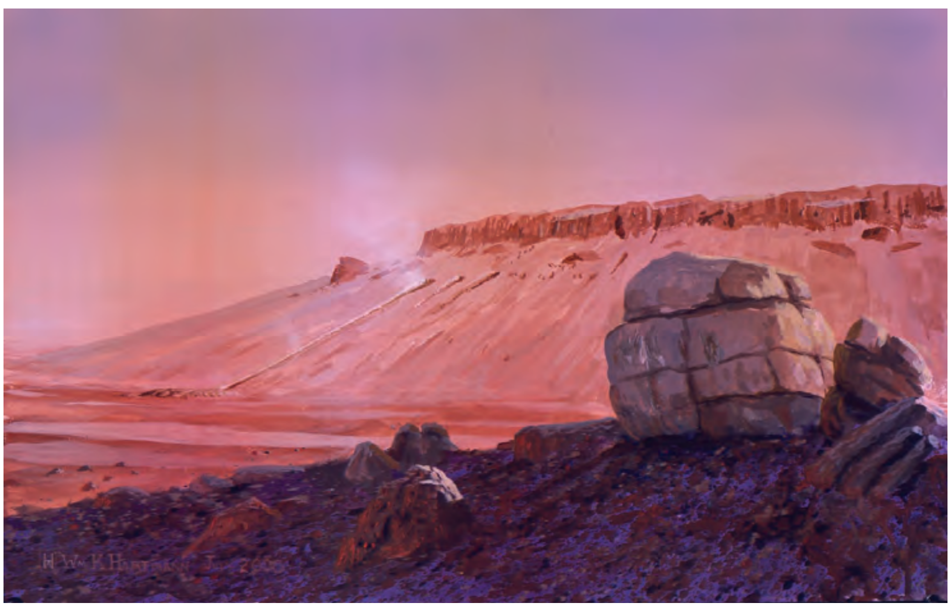
These paintings not only excited me about becoming an astronomer, but also subliminally helped to define for me a concept of what science is all about. To me it wasn't just data gathering or theoretical calculations or hypothesis testing, but also an attempt to understand what the rest of the universe *is like*. What is it like to stand on the Moon? What would it be like to visit Mars, or see a landscape on enigmatic Titan? What is the basic nature of nebulae or galaxies? How did the Earth form? Where did life come from?

By that time I was about 11 years old, and I've learned since then that the questions that 11-year-olds ask are the best ones. By the time you clear graduate school, you've been browbeaten into asking questions about esoterica like the ratio of boron isotopes in the ionospheric layer at polar latitudes on the night side of Titan, and you forget that the reason for asking that question is that you want to understand how Titan's atmosphere evolved, and the reason for asking that is that you want to know what planets are like and the reason for that is that you want to know what it is all about and where life came from. Scientists get lost in the boron details, and as a result the public loses touch with the excitement of the scientific quest to understand our place in the cosmos.

Bonestell's paintings, and astronomical art in general, still offer a path to get back from modern science to what the universe is all about. Each astronomical painting is an attempt to answer the question, "What is the universe about, what is it like out there?" These are the questions that intelligent teenagers ask. Thus, space art, especially realistic astronomical painting, offers a terrific opportunity to link student training in the arts and sciences. This is a worthy goal. As the English scientist C. P. Snow pointed out several decades ago in an essay about "The Two Cultures," science has become divorced from the liberal arts

[1] William K. Hartmann was the invited Ruth Northcott Lecturer at the 2001 London General Assembly of the RASC.

Homage to Bonestell. The rocket in this painting is the design that Chesley Bonestell based on discussions by the post-war German-American rocket scientists, and put on the Moon in his cover painting for his 1949 book, *The Conquest of Space.* Bonestell, sharing the beliefs of his time, put this rocket on a craggy, mountainous Moon. Apollo era data showed that the lunar landscape was softened by aeons of micrometeorite "sandblasting." This painting renders homage to Bonestell by putting his rocket, astronaut, and transit on a more realistic Moon. (Painting by William K. Hartmann.)



Steam vent and gully on Mars. In 2000, the Mars Global Surveyor mission discovered gullies on Martian hillsides. The gullies emanate in rocky layers, run a few hundred metres downslope, and often have a fan of debris at the bottom. Some debris fans are atop sand dunes, and the gullies are believed to be geologically contemporary features, probably due to release of water from aquifers. Virtually identical features have been found in Canada, Greenland, and Iceland. This painting shows formation of such features on a distant hillside, with accompanying release of steam. The painting was made from life in Tucson Mountain Park, Arizona, with colours and other aspects altered to match Mars. (Painting by William K. Hartmann.)

in the last couple of centuries, to the detriment of both. Indeed, in the 21st century, there is a renewed desire for a more holistic outlook — a better fusion of ideas about our place in the universe. This is a valid goal. For every scientist's attempt to bring a healthy outlook to the public, there are a hundred junk science influences. Religious fundamentalists try to put 17th century values, namely creationism and a 6000-year-old Earth, back into the classrooms. American political conservatives, trying to protect wealthy business empires, claim that research on freon effects, greenhouse gases, and climate change are "junk science" and that their business-supported think tanks will produce better understanding than the 500-year tradition of free scholarly research. And, in 2001, a Fox network TV program which claimed to prove that the Apollo expeditions to the moon were frauds drew one of the highest viewerships of any recent "documentary." Thus, we live in a world where students, not to mention adult citizens, are rarely able to get exposure to a broad cross-section of current thinking in science, the arts, medicine, religion, philosophy, *etc*. In bookstore "science" shelves, works on astrology, the "face on Mars," and alien abductions are mixed in with the honourable works of Sagan, Feynman, and Ferris.

The goal of this article is to suggest the rich opportunities that arise if teachers of science and teachers of art — at almost any grade level — join forces for days or weeks to carry out art projects that are linked to subjects being studied in the science class. The goal of this linkage is to encourage students to learn about the real nature of the universe around them.

One of the first class projects to result in such a scheme would be a joint discussion of whether the sciences and arts are related at all! In our culture, they seem to be treated as opposites: the precise, objective scientist vs. the spaced-out, subjective artist is an all too common stereotype. This can be contrasted with the view of Leonardo da Vinci, who arguably belonged to the last generation in which science and art were the same thing.

Leonardo made hundreds of drawings of clouds, waves, and human anatomy to learn more about their nature; on the other hand, he studied nature and dissected human cadavers in order to become a better painter. "Big science" in its modern guise had not yet been invented, and those endeavours all fit under the heading of one person trying to understand our place in the natural universe.

In contrast, modern training in the sciences and the arts, from high schools to college, might be characterized as being divided according to the human personality. Left-brained students are identified as science nerds and given rigourous training in ever-narrowing scientific specialties; right-brained students may find themselves classed more as artsy types and nudged toward non-technical fields. Schools and society filter these two groups and send them in different directions. Yet, strangely, modern large research projects have more and more need for both ways of thinking, especially in communicating results to the public. Some projects are even creating so-called "renaissance teams" of scientists and computer-literate graphic artists who combine their talents to uncover and communicate new results.

If you zero in on astronomical inspirations for reasonably realistic art works, you encounter a host of interesting questions and learning opportunities. For instance, a second class project could involve discussions of ways of seeing. How does an image relate to reality? For example, if you are going to paint a landscape on another planet (or Earth), or a view in deep space, will you paint: (a) what the human being would perceive; (b) a view that simulates a photograph, with photographic limitations and compensations for light levels; (c) a picture that attempts to use paint pigments that match colours and reflectivities of the materials in the scene; or (d) a view that allows imagery in wavelengths that the eye cannot see?

In category (d), it is now common knowledge that astronomers and others produce "false-colour" images that may involve infrared or ultraviolet wavelengths.

On the night side of a comet. In astronomy, comets have been studied traditionally primarily by gas spectroscopists, and not considered geological bodies. This painting was an attempt to visualize the actual surface environment of a comet nucleus. The view is from the midnight side; the shadow of the nucleus is visible in the sky, cast outward through the dust coma. Tail streamers converge in the anti-solar direction. This painting is the first known instance of such phenomena being depicted. (Painting by William K. Hartmann.)

Surprisingly, it took years and some pressure to reach the point where technicians choose redder colours to represent longer wavelengths so that there is some semblance of meaning in the colour schemes; other researchers still ignore this and make no rational connection between the colours chosen and the wavelengths they represent.

Surprisingly to many students and art-lovers, method (c), with "accurate" pigments, has been rejected by generations of artists, and there is a real difference between method (a), which is true to perception and (c), which is true to materials. My favorite example emerges in the case of a lunar landscape. The Moon soils and rocks are fairly dark gray, in

In the heart of our galaxy. The elements of this view are based on direct observations of the central region, including dust clouds, a close-packed abundance of red giants, and the mysterious central nucleus, but the resulting painting has an almost abstract quality. (Painting by William K. Hartmann.)

absolute terms; overall, the Moon reflects only about 11 percent of the light striking it. If you painted a lunar landscape, especially the lava plains, in true colours, the painting would be all dark gray with a black sky. It would be "true," in some sense, but it would be a murky mess. Surprisingly, Apollo astronauts often commented on the "bright" lunar surface, and I heard astronaut Harrison Schmitt once describe his landing site as like an Alpine ski valley. How can we reconcile this with the dark rocks? The answer is that the astronauts described what they perceived. If you stand on an asphalt parking lot at midnight under a very bright streetlight, you will quickly see what is happening. With a black sky overhead, the eye adjusts, and the brilliantly lit asphalt takes on the character of a bright landscape. I recall astronaut Alan Bean, who took up a painting career after returning from the Moon, agonizing over how to render the lunar grays. He settled on an impressionists' technique, using dashes of light colours — greens, tans, browns, blues, pinks — that merge into a sunlit gray plane full of light and life. To put it another way, an image is not a reproduction of the materials, themselves, but (as the impressionists realized) a reproduction of the interaction of light with the materials. Bean's paintings have brighter tones and more colour than actual lunar rocks, but they convey a certain physiological objectivity of "what it was like" to stand in blazing, unfiltered sunlight on the Moon.

Again, thinking in terms of how we see, consider the difference between approach (a) and approach (b) in terms of light level. Suppose you paint a sunlit landscape in an impact crater on Pluto and on the Moon. The landforms, shaped by impact explosion, might be the same, but the light level would be different. Do you try to convey the difference in light level? If we sent a camera to Pluto, we would simply open the iris in the lens wider to compensate, and the Pluto photo might look not much different than the Moon photo. The human visitor, however, would be quickly aware of the duller light, brighter than moonlight, but more like the light level inside a room. The painter might choose not only lower "value" pigments (the painter's term for reflectivity of the pigments, *e.g.* as registered by brightness on a black and white photo), but also colours of lower chroma (the painter's term for colour intensity, *e.g.* high-chroma "day-glo" colours versus low-chroma earthy tones.

This emphasizes the issue of the relation between "reality" and our perception of it. How can a painting give you a cue about the time of day? How is it that you can walk into a museum and immediately tell that a certain painting represents a night view? After all, if you take a moonlit night time exposure on fast enough colour film, you will see natural colours in the photo, not subdued grays. Yet painters have learned to do something different than what a camera does. Night paintings are not always black, and can be surprisingly light in tone, but the colour levels are subdued. The painters, being scientists of the human-cosmos interaction, empirically discovered an effect of physiology: the eye's sensitivity to colour declines at low light level. Painters, especially western landscape painters of the last century such as Charles Russell and Frederick Remington, invented greenish gray monochromatic tones that typify night vision, and give a visual cue that the view is at night. Thus, again, the painter has to make a choice whether to represent what a spacecraft camera might record, or whether to show what the human being would perceive in a given environment.

An example of this comes in renderings of nebulae and galaxies. The surface brightness of an angularly extended source does not increase as you change distance; as you move toward such a source, it covers more of the sky and you get more total light, but the light per square degree does not change. Yet most space artists make the mistake of painting "close-up" views of these objects as too bright. Worse yet, they may copy photos of galaxies and nebulae, showing garishly bright spiral arms in galaxies and even copying the over-exposed, burnt-out, central regions. For example, many classic photos of the Andromeda galaxy often show a broad, white central bulge. In actual fact, the central region increases in brightness toward a star-like core — a fact I once confirmed in graduate school by taking shorter and shorter exposures with a large telescope on Kitt Peak. You can easily see how bright galaxies look by stepping out at night and looking at the brighter parts of the Milky Way or the smudge of the Andromeda galaxy. To the naked eye, galaxies, except for the bright central cores, are ghostly apparitions. When we ask "how do they really look," we need to be aware of the difference between a CCD image and the experience of the human eye. If we choose to paint not what the eye sees, but what more sensitive eyes might reveal, then we should be aware of the limitation of various photo-imagery systems that can give us misleading ideas.

One more example of tying art, science, and even math together comes from any attempt to paint a planet as seen from one of its satellites. For example, suppose we want to paint giant Jupiter as seen from its volcanic moon, Io. One of the first issues is the true colours of Jupiter and the landscape of Io. This leads to questions of surface composition and brings us back to the problem of ways of seeing, and could offer a lesson in the visual spectrum. Interestingly, Io is probably the most notorious case in the solar system, in terms of true colour, since spacecraft technicians have argued over the true colour calibration. Its sulfur has been rendered in all shades from the red and creme tones of a tomato pizza (by the Voyager spacecraft team technicians) to pale olive-gray (by later astronomers). The "truth" (*i.e.* as perceived by a human observer near Io) probably lies in between.

Suppose the student has a 16 × 20-inch panel and has settled on the colours and landscape features, and is about to lay out the painting. How big should Jupiter be? This leads to two subjects — angular sizes and the distances of satellites from planets. The characteristic angular dimension of a normal snapshot or postcard is roughly 40 degrees. (A wide-angle shot might run up to 80 degrees, and a telephoto shot, 20 degrees. With digital imagery, postcards indeed are increasingly manipulated, often combining telephoto and wide-angle components in supposedly realistic, yet obviously fake perspectives). Bonestell tended to like mildly telephoto-ish views with angular width of 30 to 35 degrees. If the artist decides to represent a typical "snapshot" view, then the 20 inch board could represent 40 degrees, and each half inch represents one degree. Now we have to figure how big Jupiter looks from Io.

It's a geometry question — and easily solvable ever since the Greeks discovered that triangles laid out in your backyard have the same relations as triangles in the cosmos. In general, the student will need a table of planetary sizes and distances. In this case, Jupiter is 143,000 km across, and Io is 422,000 km away from it. There are three ways to figure the angular size of Jupiter. The first is purely graphical, using a scale drawing. For example, the student could draw a circle 14.3 cm across to represent Jupiter, and mark off a distance of 42.2 cm from the centre of the circle. Then use a protractor to measure the angle subtended by Jupiter from that distance.

The second method is to use a simple equation, called the small angle equation. Assume that the diameter of the planet is d and the distance of the satellite is D. Based on the fact that a radian is 57.3 degrees, this equation sets up a simple ratio,

$$\text{angular size of planet in degrees} / 57.3 = d / D.$$

The equation is accurate only up to angles of around 20 degrees. In this case it gives 19.4 degrees for the size of Jupiter seen from Io. In other words, Jupiter would fill half the 20-inch width of the painting. If you were an astronaut taking a snapshot on Io, Jupiter would seem huge in the sky, and would fill half your field of vision.

The most accurate way to do the problem involves a nice lesson in trigonometry. If we say that the radius of the planet is r, then a simple sketch shows that,

$$\sin\,[\text{angular radius of planet}] = r / D.$$

In the case of Io, this gives an angular radius of Jupiter of 9.75 degrees, or an angular diameter of 19.5 degrees.

Teachers using this lesson could challenge students to find which satellites in the solar system offer the most impressive (*i.e.* largest angular size) views of planets. Alternatively, if you were on the surface (or flying above the clouds) of each planet, which satellites in the solar system would have the largest angular size? Our own moon is one of the more impressive satellites at ½ degree.

What impresses me about these examples is that they represent a search for tractable, objective knowledge about the universe, but it involves kinds of questions that scientists rarely ask. This has led me to a view that, contrary to my beliefs when I studied physics as an undergraduate, science investigates only a relatively small portion of the phenomenology of the universe. Perhaps surprisingly, painters have dealt with a number of issues that scientists don't consider. For example, Leonardo wrote about how the intensity of colour is often much stronger in shadows. Consider a red-rock canyon. Leonardo's discussion and diagram showed how light bouncing off the sunlit red wall becomes reddened, and then illuminates the red rock on the shaded side, producing a multiplicative effect, even though the light level is lower. A painter would say the red chroma is higher but the value is lower. Probably there has never been a physicist who went around measuring the colours of rocks in shadow, yet painters utilize this real phenomenon in nature all the time. In a related example, impressionists discovered that shadows cast on snow under a clear sky are blue because only blue sky light falls into the shadows. So shadows cast on the frosts of the Martian polar caps would be — weirdly — pink.

A related case is the portrayal of sky colour on Mars. Before the Viking landings in 1976, scientists routinely pointed out that the air pressure on Mars was like that at perhaps 100,000 feet on Earth, and thus the sky on Mars would be deep blue. Bonestell and other astronomical painters so rendered it. Nobody thought about trying to measure this as a scientific goal. Indeed, during the first day of the Viking landings, the lander images were processed with a blue sky colour. Then James Pollack and others noted that there was more light in the red channel than the blue channel. Today we know that the Martian sky is fairly bright, apricot-greyish-pink, due to abundant micron-scale reddish dust lofted by winds. To my mind, this story illustrates a value of astronomical art. Scientists are trained to break nature down into measurable phenomena. One scientist measures spectra, another polarization, and another rock chemistry. But it is the artist who *synthesizes*, putting all the data together to ask "*what is it like to be there*." A museum curator might be tempted to throw out the old blue-sky Mars paintings, because they were "wrong." On the contrary, they are a valuable scientific record of what we thought Mars was like during the decade when they were painted. It is hard to reconstruct this information by going back through old *ApJ*s or *JRASC*s, because the papers are analytic. One is about spectra, one is about polarization, and so on. Good astronomical art, in my view, thus serves one of the functions of science by synthesizing the human view of the nature of the rest of the universe.

The question of whether science deals with our complete experience of the universe was brought home to me some years ago when some colleagues of mine discovered that Jupiter's moon, Io, has a yellowish sodium aurora-like glow around it, caused by sunlight interaction with sodium atoms knocked off the surface. I attended a meeting where the discovery paper was given. My friend described in great detail the attempt to detect the glow, isolate it, and measure its brightness. Difficult observations were made with a large telescope at a major observatory. Difficult data reductions and calibrations were made. The glow was actually detected and the brightness was expressed as a certain number of kilorayleighs. I had been sitting listening to this and thinking, here at last is a chance to paint a Moon without that boring black sky! Maybe this sodium D-line glow is actually visible! I could paint Io with a yellow glow in the sky. At the mention of kilorayleighs, I was at a loss. How bright is that number of kilorayleighs? After the talk I asked a question, could this brightness be seen by the naked eye? Would you see it if you were on Io? My friend's mouth dropped open. The question of whether it was visible had not occurred to him. Indeed, he didn't know.

This episode left me wondering not about Io but about science. How is it that a leading researcher can spend months of his career measuring a phenomenon, and yet have no idea how the phenomenon actually relates to the human organism. Is this a black mark against the way we do science? Or not? (After the talk, an aurora expert came by, and based on his knowledge we concluded that the sodium D glow of Io could be seen by the naked eye from that moon's surface, but I've never confirmed this more critically.)

The whole story reinforces my feeling that in the 20^{th} century we let science get too far removed from the human experience. There is a hunger abroad, among all people, to understand what the universe is really like, how humanity really fits into it, and perhaps to replace some superstition-based systems of thought with verifiable knowledge. My feeling in this direction was reinforced when I was a graduate student, when I discovered that the elderly, widowed landlady who rented me a room had become a firm convert to a fundamentalist TV religious sect. Her shelves were lined with their literature, which promised, for various levels of contributions, to free her of the effects of various demons. The demons were illustrated. They had horns and pointed tails. My rent money was going to these people. My landlady was absolutely living in the pre-Copernican middle ages. There was little I could do to change her mind and it made me sad and angry.

In summary, the seemingly straightforward amusement of creating pictures of other parts of the universe leads directly to a very fertile and educational fusing of art and science. And that is a valuable function of space artists. In an age when one scientist studies the visual spectrum of an object, another the infrared spectrum, and another the polarization or a spacecraft photo, it is left uniquely to the artist to SYNTHESIZE all these independent lines of evidence to deduce our best human understanding of what it would be like to visit one of these objects and experience the totality of its environment at first hand. This alone proves the need for a further cross-disciplinary mixing of scientific and artistic sensibilities — "sensibility" being a particularly apt word for what we have been talking about. We need to have a better sensory connection to the real universe around us.

William K. Hartmann is a senior scientist at the Planetary Science Institute in Tucson and was the first recipient of the Carl Sagan Medal from the American Astronomical Society. He is known for work on Mars, asteroids, and the origin of the Moon, as well as paintings and popular books of fiction and non-fiction, including a novel, Mars Underground.

Families of Moons

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

Brett Gladman of the Observatoire de la Côte d'Azur and his colleagues, including J. J. Kavelaars of McMaster University in Hamilton, Ontario, have recently discovered twelve new irregular moons of Saturn (see the July 12, 2001 issue of *Nature*). This is an amazing feat of modern observational astronomy and the largest number of moons discovered since the *Voyager I* and *II* spacecraft flew by the giant planets during the 1980s. The giant planets in our Solar System each have two groups of moons associated with them: regular and irregular ones. The regular moons — like Jupiter's Galilean moons — have nearly circular orbits, moving in the same direction as the parent planet's spin and roughly in line with its equator, while the irregular moons have large orbital eccentricities and/or inclinations, or even retrograde orbits. The regular moons generally are larger, which means that they are more easily discovered. Making reasonable assumptions about the albedos of the moons — the fraction of sunlight they reflect — Gladman and his colleagues have found all objects with radii greater than 4 km that orbit Saturn, which now has the most known moons (30) of any planet in the Solar System.

> **"The combination of [large-format] sensitive chips on 3–5 metre class telescopes and the capacity to search rapidly for moving sources in the mountain of data has led to a quadrupling of the number of known irregular satellites since 1996."**

The current general belief is that regular moons formed along with each parent giant planet, out of the same accretion disk of material, because this provides a natural explanation for the orbital properties of the moons. By contrast, the irregular satellites are most probably captured bodies.

Gladman and his team found that the irregular moons of Saturn (and those of the other planets as well) fall into "orbital families." For graphic illustrations check the following Web sites: `janus.astro.umd.edu/solarsystem.html`, and `www.obs-nice.fr/gladman/satpress2001.html`. This means that there are several groups of moons around each planet, each group with similar orbits. The only reasonable way this could have happened is if each group had been created in the break-up of a larger precursor moon. Presumably the break-up occurred as a result of a massive collision during the early history of the Solar System, though the researchers are unable to say anything about when the collision occurred. There was period of about half a billion years, from about 4.4 billion years ago to about 3.9 billion years ago, during which bodies in the Solar System were subjected to a massive bombardment of comets and asteroids as the debris of Sun and planet formation was cleared out.

In addition to the twelve moons reported, Gladman, Kavelaars, and their colleagues briefly found three very faint objects moving near Saturn — right at the limit of detectability — but were unable to find them again, so orbits could not be determined. These faint objects make up probably just a tiny fraction of the total number of small moons, because collisions that only knock (say) 1 km chunks off larger moons will be much more frequent than those that throw off 10 km fragments (see Doug Hamilton's *News & Views* in the July 12, 2001 issue of *Nature*). Each of the giant planets could easily have swarms of hundreds of small moons.

We could detect such small moons much more easily around Jupiter than around Saturn, but there's a lot more space to search. In general, the larger the telescope, the fainter the objects that can be detected. However, a larger telescope generally has a smaller field of view, which means many more pointings of the telescope are needed in order to search the same area of the sky. Moreover, the closer the planet is to us, the more area on the sky needs to be searched for moons. For Saturn, the team had to search about 12 square degrees on the sky, which is almost 60 times the area of the full Moon. In order to search around Jupiter to the same extent of completeness, about 48 square degrees will need to be scanned for moons.

One technical advance that has made these searches practical is the construction of "large-format" CCD cameras and their installation at a number of medium-sized telescopes. Such cameras can take pictures of areas of the sky up to about the size of the full Moon, with quantum efficiencies of 90 percent or greater (meaning that 90 percent or more of the photons that fall onto the chip are recorded). The other important advance is the ability to handle the large amounts of data such chips can generate — up to 30 gigabytes per night! The combination of sensitive chips on 3–5 metre class telescopes and the capacity

“The next step will be a complete search for the irregular moons of Jupiter, to the same limiting magnitude … Because Jupiter is at only about half the distance from the Sun as Saturn, such a search would reveal objects down to about a quarter the size of the smallest ones found around Saturn — about 1 km in radius.”

to search rapidly for moving sources in the mountain of data has led to a quadrupling of the number of known irregular satellites since 1996.

The next step will be a complete search for the irregular moons of Jupiter, to the same limiting magnitude (23) as attained by Gladman *et al*. Because Jupiter is at only about half the distance from the Sun as Saturn, such a search would reveal objects down to about a quarter the size of the smallest ones found around Saturn — about 1 km in radius. Once we have tabulated those moons, we will have a much better idea of the total number of small bodies orbiting the giant planets, and Jupiter will almost certainly reclaim the title of the planet with the most moons. From a scientific standpoint, it will be very interesting to see if Jupiter or Saturn has the greatest number of small moons, because that will presumably reflect differences in the rate of bombardment between those two planets.

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

Education Notes
Rubriques pédagogiques

LATER LIFE LEARNERS A SIGNIFICANT AND RECEPTIVE AUDIENCE FOR INTRODUCTORY ASTRONOMY

by John R. Percy
Erindale Campus, University of Toronto
Electronic Mail: jpercy@erin.utoronto.ca

and Mirjan Krstovic
Erindale Campus, University of Toronto
Electronic Mail: mirjan123@hotmail.com

Each year, millions of students study astronomy in North American schools, and over 200,000 students take courses in introductory astronomy in colleges and universities. These, in addition to various types of informal education, are the main vehicles by which North Americans acquire an awareness, understanding, and appreciation of astronomy. See Fraknoi (2000) for an excellent review of astronomy education in North America. There is, however, a small but significant number of individuals who take a different road to astronomical understanding — lifelong learners, including later-life learners. In this paper, we discuss the nature and importance of this group, and experiences in presenting them with lectures and courses in introductory astronomy. These experiences include both lifelong learners in general, through the School of Continuing Studies, University of Toronto, and later-life learners groups in particular.

Later-Life Learners

Later-life learners are here defined as learners who are 60–65 years or older and generally retired. Later-life learners will form an increasing fraction of our population as the "baby boom" retires. Between 1950 and 2000, the fraction of Americans over 65 rose from 8 per cent to 12 per cent. The connection between education and ageing is therefore an active area of research, and much is known about both the biomedical and psychosocial aspects of this topic. To quote Withnall and Kabwasa (1989): "In general, it is felt that physically-active adults decline substantially less than sedentary adults and, whilst vision, hearing, smell, touch, and the related ability of speech tend to be reduced, any observed decline in intellectual functioning is usually attributed to poor health, social isolation, economic plight, limited education, lowered motivation, and other variables not related to the ageing process. Recent research suggests that adults over 65 years of age can learn, given good health, if material is clearly presented and appeals to all learners, if each learner is given sufficient opportunity and time for practice, if material is organized to assist memorizing, and if different contexts for learning are provided ...". In fact, learning opportunities are protective of intellectual decline.

Later-life learners take courses for a variety of reasons; in the case of astronomy, the main reason is surely interest. Not surprisingly, later-life learners who sign up for such lectures and courses tend to be well educated; they are also interested and highly interactive, and bring a wealth of life experience to the course. All of this, put together, makes later-life learners a joy to teach. Later-life learners are also a strong link with the community. Taxpayers fund most of astronomy, so we have an obligation to inform them of what we are doing and why. Many later-life learners have a strong connection with the university, as alumni, donors, and volunteers. They certainly have a very positive and supportive attitude to scholarship and research, and to colleges and universities.

At our university, we remember it was after one such lecture that a gentleman by the name of David Dunlap approached the lecturer, Professor C.A. Chant, and expressed a strong interest in astronomy. The eventual result was the David Dunlap Observatory of the University of Toronto. At the time that it opened in 1935, it housed the second-largest telescope in the world.

Experiences at the University of Toronto

Toronto is a large and diverse city of over two million people, and the University of Toronto is typical of large public universities across the continent, so we have every reason to believe that our population of later-life learners is typical. There are several organizations that organize courses of lectures for later-life learners — some attached to the university and some not. This past year, one of us (JRP) organized one course of four 2-hour lectures for a group of 150 participants outside Toronto, and unattached to the university, and one course of twelve 2-hour lectures for another group of 150 participants, attached to one of the colleges of the university. There are also series of lectures at the University of Toronto (often at lunchtime), organized by the School of Continuing Studies, the Senior Alumni, the University Arts Women's Club, and others.

Later-life learning courses are extremely popular, and are almost always sold out. In one group, registration for three courses accommodating 180 participants each began at 9:00 a.m. Potential registrants began lining up as early as 5:30 a.m. on a bitterly cold

Saturday morning. By shortly after 9:00 a.m., the courses were full. Believe it or not, the courses cost $15.00 each. Still, the lecturers received a generous honorarium. You can easily work out the budget for yourself!

Most later-life learning courses and lecture series tend to be in the arts, humanities, and social sciences. When they stray into the sciences, they tend to deal with nature or with health — topics that always attract a large general science audience. Mathematical and physical sciences are normally avoided in these courses and series, so astronomy can play the useful role of demonstrating the nature, techniques, rationale, and excitement of science for this important audience.

Course Format and Structure

In some of the courses, the organizer (JRP) gave most or all of the lectures; in others, he gave very few. The others were given by other professional astronomers and by advanced amateur astronomers with special interest and expertise in topics such as eclipses, or Canada's space program. Sessions typically began with a one-hour lecture, followed by a 15-minute coffee break, then a 45-minute question period. The lecturers used a range of visual aids, ranging from basic to complex. The auditorium and AV facilities were excellent by undergraduate standards, but not perfect, as mentioned later. No textbook was assigned for the course — partly because the participants have a range of interests in and approaches to astronomy, and partly because none exists for this audience. A reading and resource list was distributed instead.

In multi-instructor courses, it is absolutely essential for the organizer to co-ordinate the lectures and their content, to ensure that each instructor begins with the basics of his or her topic, and to remind the instructors of the problems of level, math, and jargon mentioned below.

Later-Life Learners: Interests in Astronomy

In one later-life learning course we administered a questionnaire, asking the participants to record their level of interest in each of 39 topics. They were allowed to add topics that were not on the list, but few did. The participants also recorded their gender and their age range: 50–64, 65–79, and over 80.

We looked for trends with gender and with age. Since there were many more women than men, we were only able to look for trends with age among women. We noted that the *overall* level of interest was moderate among the women under 65, lowest among the women 65–79, and highest among the women over 80. It is tempting to conclude that those over 80 have a high interest in *everything* in life, though our sample, of course, is biased.

Men expressed a higher interest in "gee-whiz" topics such as collapsed stars, quasars, and extra-terrestrial life, and in physics topics such as gravity, atoms, and light. Women expressed a higher interest in human-interest topics such as calendars, archaeo-astronomy, constellation stories, eclipses, aurora, and even science fiction. For men and women combined, the top ten topics (starting at the top) were: the origin of life on earth and elsewhere, the aurorae, cosmology, the appearance of the sky, identifying stars and constellations in the sky, the earth as a planet, the sun, astronomy in early cultures, gravity, and the planets. Thus, there was a wide range of topics that appealed to both women and men, ranging from the appearance of the sky, to cosmology. Almost every area of classical and contemporary astronomy was included.

The only topics that had a generally *low* appeal were (in order from the lowest): science fiction, astronomy as a hobby, telescopes for backyard astronomy, telescopes and tools of astronomy, atoms, and light. Clearly we were dealing with "armchair astronomers", not backyard astronomers!

Later-Life Learners: Conceptual Skills

For fun and interest, we administered a short, optional, anonymous, distracter-driven misconceptions questionnaire, based on the work of Philip Sadler at Harvard. We found that the participants had exactly the same spectrum of misconceptions as high school students, undergraduate non-science students, and elementary school teachers, as far as concepts such as seasons, moon phases, and gravity are concerned (see Percy 2000, for instance; also the Web site `www.oise.utoronto.ca/~ewoodruff`). As always, instructors should be aware of the spectrum of misconceptions their students hold, and should be aware that these misconceptions are very resistant to change.

Later-Life Learners: Course Evaluations

At the end of the course, we administered a simple course evaluation, with two questions: (i) please list up to three things that you particularly liked about the course, and (ii) please list up to three things about the course that could be improved. I should point out that, unlike undergraduates, later-life learners have a tendency to blame *themselves*, rather than their instructors, if there is something they don't understand. An evaluation like this one might well be given early in the course, so that adjustments can be made as soon as possible.

Responses to the first question, in order of decreasing frequency, were: the excellent lectures; the breadth and variety of the content; the organization of the course; the visuals; the specific content of the course; the lecturers' enthusiasm; the clear and simple presentation; and the campus observatory visit (to which only a small fraction of the participants could come).

Though many participants thought that there was *nothing* about the course that could be improved, there were two significant negative issues raised. One issue surrounded the technical content of the lectures, including the use of graphs and equations. In teaching undergraduates, even non-science students, we often feel compelled to introduce simple math for the sake of promoting both numeracy and scientific literacy. Many later-life learners have little or no contact with graphs and equations, and are many decades from their schooldays. Scientific concepts can be introduced, but I would recommend that math be kept to an absolute minimum. Likewise, technical jargon should be avoided. Vocabulary is one of the few cognitive functions that does not normally decline with age, so we should take advantage of this and use everyday language and analogies as much as possible.

The second issue was sight and sound. On the visuals, text and pictures should be even simpler and clearer than usual. A well-adjusted microphone is essential, except in the smallest rooms. Questions from the audience should be repeated, before being answered. In the course that was surveyed, the participants wrote down their questions during the coffee break between the presentation and the question period.

This allows the lecturer to think carefully about the answers, to answer the questions in a logical order, and, of course, to read the question to the audience, using the microphone.

Discussion and Conclusion

How can you promote astronomy among later-life learners in your area? In Canada, there is a loose affiliation of later-life learners groups called CATALIST (`www.catalist.org`), but none of the groups with which I have worked belong to it. There is also the well-known ElderHostel organization (`www.elderhostel.org`) that offers a very specific kind of program, which combines later-life learning with travel or vacation. You may have to track down the later-life learners groups at your institution or in your community. Certainly, be responsive when they ask for a lecture or course in astronomy. It can be a great benefit to all.

Acknowledgements

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John R. Percy *is a Professor of Astronomy, and of Education at the University of Toronto and an RASC Past President.*

Mirjan Krstovic *is an undergraduate major in Molecular Biology and Mathematics at the University of Toronto. He was a student in John Percy's undergraduate Science Education Seminar in 2000–2001.*

Research Papers
Articles de recherche

CANADIAN THESIS ABSTRACTS

Compiled by Melvin Blake (blake@aries.phys.yorku.ca)

Techniques in High Resolution Observations from the Ground and Space, and Imaging of the Merging Environments of Radio Galaxies at Redshift 1 to 4

by Eric Steinbring (steinb@ucolick.org), University of Victoria, Ph.D

High-resolution imaging and spectroscopy are invaluable tools for extragalactic astronomy. Galaxies with redshifts of 1 or more subtend a very small angle on the sky — typically, only about an arcsecond. Unfortunately, this is also approximately the angular resolution achieved with a ground-based telescope regardless of its aperture. Atmospheric turbulence ruins the image before it reaches the telescope but the emerging technology of adaptive optics (AO) gives the observer the possibility, within limitations, of correcting for these effects. This is the case for instruments such as the Canada-France-Hawaii Telescope (CFHT) Adaptive Optics Bonnette (AOB) and the Gemini North Telescope (Gemini) Altitude-Conjugate Adaptive Optics for the Infrared (Altair) systems. The alternative is to rise above the limitations of the atmosphere entirely and put the telescope in space, for example, the Hubble Space Telescope (HST) and its successor, the Next-Generation Space Telescope (NGST).

I discuss several techniques that help overcome the limitations of AO observations with existing instruments in order to make them more comparable to imaging from space. Examples are effective dithering and flat-fielding techniques, as well as methods to determine the effect of the instrument on the image of, say, a galaxy. The implementation of these techniques as a software package called AOTOOLS is discussed. I also discuss computer simulations of AO systems, notably the Gemini Altair instrument, in order to understand and improve them. I apply my AO image processing techniques to observations of high-redshift radio galaxies (HzRGs) with the CFHT AOB and report on deep imaging in near-infrared (NIR) bands of 6 HzRGs in the redshift range $1.1 < z < 3.8$. The NIR is probing the restframe visible light — mature stellar populations — at these redshifts. The radio galaxy is resolved in all of these observations and its 'clumpier' appearance at higher redshift leads to the main result — although the sample is very small — that these galaxy environments are undergoing mergers at high redshift. Finally, I look to the future of high-resolution observations and discuss simulations of imaging and spectroscopy with the NGST. The computer software NGST VI/MOS is a 'virtual reality' simulator of the NGST observatory providing the user with the opportunity to test real observing campaigns.

Tidal Disruption of Substructure in Galaxy Clusters

by Eric Hayashi (ehayashi@beluga.phys.uvic.ca), University of Victoria, MSc.

Overmerging in the context of cosmological N-body simulations is defined as the absence of substructure in the dark matter halos of galaxy clusters due to numerical or physical disruption mechanisms. In early simulations of galaxy clusters the rapid disruption of bound clumps of N-body particles produced a smooth, featureless cluster mass distribution that did not resemble a real galaxy cluster, in which luminous matter is concentrated in discrete galaxies. We investigate recent claims (Ghigna *et al.* 1998; Klypin, Gottlöber & Kravtsov 1999) that the overmerging problem has been resolved in the latest generation of cosmological simulations simply as a result of increased numerical resolution. To this end we perform a series of simulations of the evolution of satellite halos in bound orbits within a static cluster potential in order to investigate the effects of varying mass and force resolution on the mass loss experienced by substructure due to tidal stripping. We find that satellite galaxies on radial orbits with apocentre-to-pericentre ratios greater than about 3:1 lose approximately the same fraction of their remaining mass each time they pass through pericentre. Conversely, tidal stripping of satellite galaxies on circular orbits is characterized by a sharp decline in mass during the first orbit followed by continuous mass loss at a reduced rate in subsequent orbits.

We use our results to test semi-analytic models for predicting mass loss and to establish a correlation between the disruption timescale of a satellite galaxy and the fraction of mass it loses during its first orbit. These tools are used to construct a toy model for the dynamical evolution of a galaxy cluster. We find that tidal disruption of satellite galaxies is sufficient to erase most substructure within the central regions of the cluster after a Hubble time. The number density of surviving substructure halos predicted by our model is compared with the results of cosmological simulations and observations from the Canadian Network for Observational Cosmology (CNOC) cluster survey. The density profile of surviving satellite halos is similar to that of the Virgo cluster simulation of Ghigna *et al.* 1998, and is not consistent with the observed distribution of galaxies in the CNOC ensemble cluster.

We conclude that overmerging due to physical disruption mechanisms remains a problem in the central regions of cluster simulations. This suggests that a dissipational hydrodynamic component is needed to properly model the dynamics of galaxy clusters, as was originally proposed by White & Rees (1976).

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THÉORIE ET MODÉLISATION DES ÉTOILES SOUS-NAINES DE TYPE B PULSANTES: CONFRONTATION AVEC LES OBSERVATIONS[1]

par Stéphane Charpinet
Laboratoire d'Astrophysique de l'Observatoire Midi-Pyrénées, Toulouse, France
Electronic Mail: scharpin@ast.obs-mip.fr

(Reçu le 17 avril, 2000)

Résumé. Cet article dresse un bilan sur l'état présent des connaissances théoriques acquises sur une classe d'étoiles pulsantes nouvellement découverte: les étoiles sous-naines de type B (ou sdB) pulsantes (aussi connues sous le nom d'étoiles EC14026, d'après l'acronyme du prototype de la classe). Un bref historique de l'étude ayant conduit, sur des bases purement théoriques, au postulat que de telles étoiles pouvaient osciller est proposé. Il est suivi d'une comparaison détaillée des modèles actuels de sdB pulsantes avec les données d'observation existantes. L'identification, suppléé par une modélisation adéquate, du mécanisme d'excitation des modes propres d'oscillation dans ces étoiles — un mécanisme κ engendré par le fer présent localement en quantités fortement sur-abondantes en raison de processus de diffusion microscopique (triage gravitationnel et lévitation radiative) dans l'enveloppe riche en hydrogène — permet ainsi aujourd'hui de reproduire remarquablement bien la bande d'instabilité observée, ainsi que les propriétés sismiques globales de cette classe d'objets. Ces résultats permettent d'ores et déjà d'envisager à moyen terme un retour scientifique appréciable du sondage de la structure interne de ces étoiles par la méthode de l'astéroséismologie.

Abstract. In this paper, we summarize the current status of our theoretical knowledge of a recently discovered class of pulsating stars: the pulsating subdwarf B (sdB) stars (also referred to as the EC14026 stars, after the prototype). We first provide a brief history of the main steps that ultimately led us, based exclusively on theoretical considerations, to postulate that some sdB stars should develop oscillations. This is followed by a detailed comparison of the pulsation properties derived from current models of sdB stars with the existing observational data. The identification, along with an accurate modelling, of the eigenmode driving mechanism — a κ-mechanism triggered by iron that locally accumulates due to microscopic diffusion (gravitational settling and radiative levitation) in the H-rich envelope — allows us to remarkably reproduce the observed instability strip, as well as the global seismic properties seen in this class of objects. From these results, one can already envision a very fruitful application of the methods of asteroseismology to probe the internal structure of these stars.

1. Introduction

En septembre 1995, nous nous sommes engagés dans la première étude théorique systématique des propriétés sismiques de modèles d'étoiles appartenant à la Branche Horizontale Etendue (EHB[2]), l'objectif étant d'en évaluer le potentiel astéroséismologique (soit la possibilité d'utiliser d'éventuelles oscillations stellaires pour sonder la structure interne de ces étoiles). Une telle approche était devenue possible grâce aux progrès récents réalisés dans la modélisation de cette phase jusqu'alors relativement négligée de l'évolution stellaire (Dorman *et al.* 1993). Ces modèles représentent des étoiles de faible masse ($M \leq 0.5\ M_\odot$) constituées d'un coeur en hélium surmonté d'une enveloppe riche en hydrogène trop mince pour que celles-ci puissent rejoindre la branche asymptotique des géantes (AGB[3]) après épuisement de leurs réserves nucléaires centrales (comme c'est habituellement le cas pour les étoiles de la branche horizontale classique). Durant la phase de brûlage nucléaire de l'hélium dans le noyau, ces modèles sont identifiés aux étoiles sous-naines de type B (Heber *et al.* 1984). Puis, le combustible nucléaire venant à manquer au centre, les modèles se contractent rapidement, entrent dans une phase de combustion de l'hélium et de l'hydrogène en couches (la phase dite post-EHB) — ils correspondent alors aux étoiles sous-naines de type O (Dorman 1995), — pour finalement rejoindre la séquence de refroidissement, où ils sont identifiés aux étoiles naines blanches de type DAO (Bergeron *et al.* 1994).

Rien sur la base des observations de l'époque ne laissait présager une possible variabilité des étoiles en phases EHB ou post-EHB. Mais la présence, dans tous les modèles canoniques de sdB, d'une mince couche convective associée à une région d'ionisation partielle He II/He III attira notre attention. Par analogie avec d'autres types d'étoiles pulsantes, pour lesquelles cette région est révélatrice du mécanisme responsable des instabilités observées (un mécanisme d'opacité ou mécanisme κ), nous avons imaginé que cette zone d'ionisation partielle He II/He III pouvait peut-être également provoquer l'excitation de modes d'oscillation dans les étoiles sous-naines de type B. De plus, il nous est apparu que la région de brûlage de l'hydrogène en couche se développant au cours de la phase post-EHB pouvait potentiellement conduire à la déstabilisation de modes de pulsations via le mécanisme ε (mécanisme engendré par les réactions nucléaires). De telles possibilités méritaient, à nos yeux, que l'on s'attarde davantage

[1]En partie basé sur la revue présentée par S. Charpinet lors de la conférence annuelle de la Société Canadienne d'Astronomie (CASCA) tenue à Halifax en juin 1999 en réception de la médaille J.S. Plaskett.
[2]de l'anglais *Extended Horizontal Branch*.
[3] de l'anglais *Asymptotic Giant Branch*.

à l'exploration théorique du potentiel astéroséismologique de ces modèles d'étoiles évoluées.

Au cours de cette investigation, nous avons découvert que des pulsations radiales et non-radiales correspondant à des modes *p, f* et *g* de faible degré *l* et de faible ordre radial *k* pouvaient effectivement être excitées dans certains modèles d'étoiles sdB par un puissant mécanisme κ engendré, non pas par l'ionisation partielle de l'hélium comme nous le pensions alors naïvement, mais par l'ionisation partielle d'un élément chimique plus lourd: le fer. Ces résultats nous conduisirent à postuler l'existence d'une sous-classe d'objets pulsants parmi les étoiles sous-naines de type B (Charpinet *et al.* 1996), ainsi qu'à élaborer, en collaboration avec plusieurs collègues, un programme d'observation spécifique visant à rechercher des modulations de luminosité dans ces étoiles. Le premier résultat positif de ce programme d'observation fut publié par Billères *et al.* (1997), mais, entre-temps, la découverte indépendante de 4 sdB pulsantes (maintenant appelées étoiles EC14026 d'après le nom du prototype de la classe) avait été annoncée par une équipe d'astronomes de l'Observatoire Astronomique d'Afrique du Sud (Kilkenny *et al.* 1997; Koen *et al.* 1997; O'Donoghue *et al.* 1997; Stobie *et al.* 1997). Ces découvertes posèrent véritablement les fondations de la sismologie des étoiles sdB. Elles motivèrent également très fortement l'élaboration de modèles plus sophistiqués pour rendre compte en détail des propriétés de cette nouvelle classe d'étoiles pulsantes. Mais le fondement de l'approche théorique proposée par Charpinet *et al.* (1996) fut largement validé par cette découverte des sdB pulsantes.

Dans cet article, nous résumons brièvement l'état dans lequel se trouvent nos connaissances théoriques sur les propriétés oscillatoires de cette nouvelle classe d'étoiles pulsantes pour ensuite dresser un bilan, à partir de données récentes, sur la capacité qu'ont ces modèles à reproduire les observations. Nous discutons également brièvement les prochaines étapes qui se dessinent dans notre quête vers une meilleure compréhension de la nature de ces étoiles, de leur structure interne et des mécanismes qui les conduisent à devenir pulsantes.

2. La théorie des étoiles sous-naines de type B pulsantes

2.1 La nature des étoiles sous-naines de type B

Il est aujourd'hui bien établi que les sdB sont des étoiles évoluées de faible masse appartenant à la branche horizontale étendue. Elles descendent directement de la branche des géantes rouges (RGB[4]), bien que la manière dont elles se forment soit très mal connue. Les sdB sont relativement nombreuses en terme de densité de surface, puisqu'elles dominent les populations d'objets bleus pour $V \leq 16$ (par exemple dans les catalogues Palomar-Green, Montréal-Cambridge-Tololo ou Edinburgh-Cape).

L'analyse quantitative de spectres d'étoiles sdB (Saffer *et al.* 1994, et reférences incluses) révèle que leurs paramètres atmosphériques se situent dans les domaines 22,000 $K \leq T_{eff} \leq$ 42,000 K et $5.2 \leq \log g \leq 6.2$, les valeurs moyennes dans l'échantillon de 213 étoiles de Saffer (communication privée) étant $<T_{eff}> \approx$ 30,740 K et $<\log g> \approx 5.68$. De plus, leurs atmosphères présentent des anomalies d'abondances chimiques. Ces dernières sont dominées par l'hydrogène avec des abondances d'hélium typiquement inférieures (en nombre) de plus d'un ordre de grandeur à l'abondance d'hélium solaire. Les éléments chimiques plus lourds (en particulier C, N et Si, qui firent l'objet d'études approfondies) montrent également des anomalies d'abondance importantes (Heber 1991). De telles anomalies sont attribuées à l'existence de mécanismes de diffusion (principalement le triage gravitationnel et la lévitation radiative) opérant en compétition avec de faibles vents stellaires (Michaud *et al.* 1985; Fontaine & Chayer 1997). Il est à noter que de tels processus doivent également conduire à la formation d'importantes inhomogénéités dans l'enveloppe des étoiles sous-naines de type B, un fait d'importance capitale dans le contexte de la stabilité des modes de pulsation dans ces étoiles (voir plus bas).

La position des sdB dans un diagramme $\log g - T_{eff}$ (ou, de manière équivalente, dans un diagramme HR) conduit à l'identification de ces étoiles aux modèles de faible masse ($M \leq 0.5\ M_{\odot}$) en phase EHB (brûlage nucléaire de l'hélium dans le noyau) mentionnés précédemment. Ces modèles possèdent des enveloppes externes riches en hydrogène trop minces pour développer un brûlage actif de l'hydrogène en couche. En conséquence, après épuisement des réserves centrale d'hélium, ces modèles ne rejoignent pas la branche asymptotique des géantes. Ils se dirigent au contraire vers les hautes températures durant leur évolution dans le diagramme HR pour ultimement devenir des étoiles naines blanches de faible masse. La durée de vie typique d'une étoile durant la phase sdB est d'environ 100 millions d'années.

2.2 Mécanisme d'excitation et métallicité

Lancée en septembre 1995, l'étude systématique de la stabilité des modes de pulsations à partir de modèles d'étoiles sous-naines de type B a permis de mettre en évidence la présence d'un puissant mécanisme d'excitation pouvant conduire, à priori, à l'existence d'étoiles pulsantes parmi cette catégorie d'objets. Les modèles utilisés à l'époque comprenaient un ensemble de structures stellaires complètes issues de 7 séquences évolutives (Dorman 1995, communication privée), ainsi qu'un groupe de modèles statiques d'enveloppe, moins réalistes que leurs contreparties évolutives, mais permettant d'étudier la stabilité de ces étoiles pour diverses valeurs de la métallicité dans l'enveloppe riche en hydrogène (une étape fondamentale dans la reconnaissance du mécanisme d'excitation; voir plus bas).

Le calcul détaillé des propriétés oscillatoires de ces modèles a été effectué à l'aide de codes de pulsations adiabatiques et non-adiabatiques respectivement décrits dans Brassard *et al.* (1992) et Fontaine *et al.* (1994). Ces codes numériques permettent de résoudre le système d'équations linéaires couplées décrivant les oscillations stellaires telles que décrites, par exemple, dans Unno *et al.* (1989). L'exploration fut menée dans une fenêtre de périodes comprises entre 80 et 1500 secondes — l'intervalle de périodes le mieux adapté aux

[4] de l'anglais *Red Giant Branch*.

[5] Les modes de degré $l \geq 4$ ne sont pas considérés car, même s'ils sont instables, leurs amplitudes sont très probablement en dessous des limites de détection offertes par les techniques de photométrie rapide standards en raison des effets d'atténuation géométrique de la variation de luminosité totale intégrée sur la totalité du disque visible de l'étoile.

techniques actuelles de photométrie rapide — en considérant les modes radiaux ($l = 0$) et non-radiaux jusqu'au degré[5] $l = 3$. Les premiers calculs menés sur les modèles évolutifs ont montré qu'un spectre très riche constitué de modes acoustiques radiaux et non-radiaux, ainsi que de modes de gravité non-radiaux, existe dans la fenêtre de périodes choisie (Charpinet *et al.* 1996). Mais aucun de ces modèles évolutifs ne présentait d'instabilité pouvant conduire à des oscillations observables. En dépit de ce résultat peu encourageant, du moins en apparence, un regard plus attentif sur les propriétés des modes de pulsation dans ces modèles a révélé une situation des plus intéressantes.

Nous avons remarqué qu'une région particulière de l'étoile située dans l'enveloppe riche en hydrogène possède un fort potentiel déstabilisateur sur certains modes d'oscillation. Cette région d'excitation des modes coïncide avec une zone d'ionisation partielle du fer produisant localement une hausse importante de l'opacité moyenne du gaz (connue sous le nom de *Z-bump*). Il s'agit donc d'une région où un mécanisme engendré par une modulation particulière de l'opacité (un mécanisme κ) est à l'oeuvre. Ce résultat constitua une petite surprise en soi puisque nous pensions alors naïvement que la déstabilisation éventuelle de modes proviendrait plutôt d'une région d'ionisation partielle He II/He III. Cette dernière, bien que présente dans les modèles utilisés, s'avère ne produire en réalité qu'une contribution négligeable à l'excitation parce qu'elle est située trop haut dans l'enveloppe stellaire. La reconnaissance de ce lien entre la présence de fer dans l'enveloppe riche en hydrogène (c.à.d. la métallicité de l'étoile) et l'existence d'un puissant mécanisme d'excitation fut la première étape fondamentale vers le postulat de l'existence de sdB pulsantes.

Les modèles évolutifs utilisés pour nos premiers calculs exploratoires avaient été calculés en supposant une métallicité solaire ($Z \approx 0.02$; appropriée pour des étoiles du champ) dans l'enveloppe riche en hydrogène. Or les résultats des calculs de stabilité mentionnés précédemment ont montré qu'à ce niveau de métallicité, la puissance du mécanisme d'excitation demeure insuffisante pour conduire à des instabilités (en pratique, les mécanismes de stabilisation qui se produisent dans d'autres zones de l'étoile surpassent les effets déstabilisateurs de la région d'excitation). Mais ce lien entre métallicité et excitation des modes suggérait néanmoins que des modèles à plus grandes métallicités pouvaient éventuellement développer des instabilités. Pour explorer cette hypothèse, nous avons appliqué les mêmes calculs de stabilité sur des grilles de modèles statiques d'enveloppe construites pour diverses valeurs *uniformes* de la métallicité dans l'enveloppe riche en hydrogène (Z = 0.02, 0.04, 0.06, 0.08 et 0.10). Les résultats obtenus ont ainsi démontré qu'il était effectivement possible d'obtenir des modes instables pour certains modèles avec $Z \geq 0.04$, le nombre de modèles où ces instabilités apparaissent étant une fonction directe de la métallicité.

Bien entendu, ce dernier ensemble de modèles construits avec de telles sur-abondances *globales* en métaux ne pouvait prétendre reproduire de manière réaliste les étoiles sous-naines de type B. Mais nos calculs ont néanmoins indiqué la voie à suivre: puisque le mécanisme d'excitation ne nécessite à priori, pour être pleinement efficace, qu'un enrichissement *local* en métaux dans la région d'excitation uniquement, il était alors possible d'envisager une situation ne requérant pas de quantités *globalement* extra-solaires de métaux dans l'enveloppe riche en hydrogène. Ce qu'il nous fallait, c'est un mécanisme en mesure de produire une distribution *non-uniforme* du fer en fonction de la profondeur dans l'étoile, celle-ci conduisant à une sur-abondance *locale* dans la région déstabilisatrice où le mécanisme κ identifié opère. Etant donné que les sdB sont toutes anormales en terme d'abondances chimiques de surface, une situation attribuée à l'existence de phénomènes de diffusion dans l'enveloppe de ces étoiles, il devenait alors naturel de considérer ces mécanismes de diffusion comme une source possible d'enrichissement en fer de la région d'excitation des modes de pulsations.

2.3 Le rôle fondamental de la diffusion

La diffusion microscopique des éléments chimiques émerge principalement de deux processus en compétition: le triage gravitationnel et la lévitation radiative. Le champ gravitationnel d'une étoile force la sédimentation des éléments présents dans le plasma selon leur masse: les éléments plus lourds sombrant plus rapidement. Ce processus porte le nom de triage gravitationnel. Il est compensé, jusqu'à un certain point, par une force opposée insufflée par le champ de radiation de l'étoile. Le flux de photons sortants est absorbé par les différentes espèces chimiques constituant le gaz, leur transférant ainsi une impulsion nette qui les pousse vers la surface. Ce mécanisme est connu sous le nom de lévitation radiative. L'intensité de cette force dépend directement de la structure atomique détaillée de chaque espèce chimique. Elle est donc fortement sélective, affectant principalement les éléments qui peuvent absorber beaucoup de photons tout en ayant peu d'influence sur les éléments essentiellement transparents. En conséquence, les espèces chimiques présentes dans le plasma sont différemment affectées par la pression radiative conduisant, en l'absence d'autres mécanismes perturbateurs (convection, turbulences, vents stellaires intenses, *etc...*), à la formation de distributions anormales d'abondances chimiques dans l'atmosphère des étoiles assujetties à ces mécanismes de diffusion. Bien entendu, les anomalies d'abondance engendrées par la diffusion ne se limitent pas à l'atmosphère stellaire. Les régions plus profondes — qui ne peuvent donc pas être directement observées — sont également chimiquement anormales. En fait, les processus de diffusion conduisent à la formation de profils d'abondance fortement *non-uniformes* en fonction de la profondeur dans l'étoile.

Des calculs diffusifs détaillés menés à partir de modèles d'étoiles sous-naines de type B ont montré qu'un équilibre entre sédimentation et lévitation radiative conduit très rapidement (comparativement au temps évolutif typique de ces étoiles) à la formation d'une distribution d'abondance fortement *non-uniforme* pour le fer. Or celle-ci entraîne, pour certaines valeurs des paramètres de surface (T_{eff} et $\log g$) des modèles, une accumulation importante (fortement extra-solaire) de fer dans la région où le mécanisme d'excitation des modes est actif. Dès lors, tous les éléments théoriques rassemblés semblaient indiquer que les conditions physiques étaient réunies pour que certaines de ces étoiles développent des pulsations d'amplitudes observables. Sur cette base, une prédiction théorique de l'existence d'étoiles sous-naines de type B pulsantes fut proposée par Charpinet *et al.* (1996), puis confirmée par Charpinet *et al.* (1997), à partir de modèles plus sophistiqués (dits de seconde génération, par opposition aux modèles de première génération mentionnés jusqu'à présent) incluant un traitement de la diffusion du fer. Mais c'est bien entendu suite à la découverte indépendante de véritables sdB pulsantes par une équipe d'astronomes de l'Observatoire Astronomique d'Afrique du Sud que ce travail théorique prit toute sa dimension.

Tableau I
Liste et paramètres des 16 etoiles sous-naines de type B pulsantes connues

#	Nom	T_{eff} (K)	log g	N_{obs}	P (s)	Δm (mmag)	Référence
1	EC14026–2647	34,700	6.10	2	134–144	4–12	Kilkenny *et al.* (1997)
2	PB8783	35,700	5.54	5(6)	120–134	1–9	Koen *et al.*. (1997)
				7(11)	94–136	1–9	O'Donoghue *et al.* (1998b)
3	EC10228–0905	33,500	6.00	3	139–152	4–14	Stobie *et al.* (1997)
4	EC20117–4014	34,800	5.87	3	137–159	1–4	O'Donoghue *et al.* (1997)
5	PG1047+003	34,370	5.70	5	104–162	2–9	Billères *et al.* (1997)
				16	91–162	0.7–8.5	CFHT, en préparation
		35,000	5.90	7(9)	104–162	1.5–10.2	O'Donoghue *et al.* (1998a)
6	PG1336–018	33,000	5.70	2	141–184	5–10	Kilkenny *et al.* (1998)
				(24)	97–204	0.5–4.8	Kilkenny, comm. privée
7	KPD2109–4401	31,200	5.84	5	182–198	2–9	Billères *et al.* (1998)
				15	104–213	0.2–7.6	CFHT, en préparation
				5	182–198	1–6	Koen (1998)
8	PG1605+072	30,000	5.20	~ 21(>50)	290–601	1–25	CFHT, en préparation
		32,100	5.25	~ 17(>30)	350–539	2–64	Koen *et al.* (1998a)
				~ 22(>50)	295–573	0.5–28	Kilkenny *et al.* (1999)
9	Feige 48	28,900	5.45	4	340–380	1–7	Koen *et al.* (1998b)
				6	258–376	0.4–6.2	CFHT, en préparation
10	PG1219+534	32,800	5.76	4	128–149	2–9	Koen *et al.* (1999)
11	PG0911+456	31,900	5.80	3	155–166	2–7	Koen *et al.* (1999)
12	PG0014+067	33,310	5.79	13	80–169	0.4–2.5	CFHT, en préparation
13	KUV0442+1416	30,900	5.72	3	184–231	2.8–13	Koen *et al.* (1999)
14	EC05217–3914	31,300	5.76	3	213–218	1.6–5	Koen *et al.* (1999)
15	KPD1930+2752	33,280	5.61	~ 15(44)	146–332	0.2–3	Billères *et al.* (2000)
16	PG1618+563B	33,900	5.80	2	139–144	1–2	Silvotti *et al.* (2000)

3. Comparaison entre théorie et observations

3.1 Les étoiles EC14026

Kilkenny *et al.* (1997) rapporta la série d'observations accidentelles qui conduisit à la découverte de la première sdB pulsante, EC14026–2647. Trois autres membres de cette nouvelle classe d'étoiles variables furent rapidement repérés (Koen *et al.* 1997; O'Donoghue *et al.* 1997; Stobie *et al.* 1997), montrant des variations de luminosité multi-périodiques et de faibles amplitudes, avec des périodes comprises entre 90 et 170 secondes, caractéristiques de ces étoiles. Depuis leur découverte en 1997, on dénombre 16 sdB pulsantes, leurs propriétés étant résumées dans le tableau I: pour chaque étoile, T_{eff} et log *g* indiquent les valeurs de la température effective et de la gravité de surface évaluées à partir de données spectroscopiques et de modélisation d'atmosphère; N_{obs} donne le nombre de modes de pulsation extraits de la courbe de lumière (en excluant les composantes de multiplets dus, par exemple, à la rotation de l'étoile, ces dernières étant incluses dans le nombre donné entre parenthèses, le cas échéant); *P* (en secondes) et Δm (en milli-magnitudes) indiquent respectivement l'intervalle de période et l'intervalle d'amplitude observé.

Un examen rapide de cette liste d'étoiles EC14026 montre que celles-ci se regroupent, dans le plan log $g - T_{eff}$, principalement autour des valeurs caractéristiques log $g \approx 5.8$ et $T_{eff} \approx 34{,}000$ *K*, où leurs périodes s'échelonnent approximativement entre 80 et 250 secondes. Il existe cependant quelques objets "atypiques" dont les températures effectives et gravités de surface sont plus faibles et les périodes observées plus longues (c'est le cas par exemple pour PG1605+072 et Feige 48).

La découverte des quatre premières sdB pulsantes confirma la prédiction théorique de Charpinet *et al.* (1996), en particulier concernant la nature du mécanisme d'excitation des modes. Elle motiva également la construction de modèles plus réalistes en mesure de rendre compte plus quantitativement des propriétés oscillatoires de ces étoiles. Ces modèles dits de seconde génération sont des structures statiques d'enveloppe intégrant les profils d'abondance *non-uniformes* du fer résultant de l'équilibre entre les processus de triage gravitationnel et de lévitation radiative. Ce sont actuellement les modèles les plus réalistes existant qui permettent de modéliser le mécanisme de déstabilisation et les propriétés des pulsations de ces étoiles. Nous allons donc dans ce qui suit comparer les résultats des calculs d'oscillation obtenus à partir de ces modèles de seconde génération avec les données d'observation collectées jusqu'à présent sur les sdB pulsantes.

3.2 Propriétés oscillatoires d'un modèle représentatif

Le tableau II illustre les résultats d'un calcul de pulsations non-adiabatiques obtenu à partir d'un modèle de seconde génération dont les paramètres de surface sont $T_{eff} = 34{,}000$ *K* et log $g = 5.8$. Ces valeurs correspondent bien sûr aux paramètres atmosphériques typiques des étoiles EC14026 listées dans le tableau I. Pour spécifier complètement un modèle, deux autres paramètres sont toutefois nécessaires: la

Tableau II

Périodes et stabilité d'un modèle de seconde génération représentatif

k	$l = 0$		$l = 1$		$l = 2$		$l = 3$	
	P (s)	τ_e (ans)	P (s)	τ_e (ans)	P (s)	τ_e (ans)	P (s)	τ_e (ans)
9			63.75	stable	62.40	stable	60.73	stable
8	64.59	stable	69.07	stable	68.02	stable	66.84	stable
7	69.95	stable	77.41	6.98×10^{-3}	76.26	stable	74.08	stable
6	78.05	2.56×10^{-3}	87.05	7.75×10^{-4}	83.95	9.94×10^{-4}	80.49	1.19×10^{-3}
5	88.83	6.32×10^{-4}	95.73	6.16×10^{-4}	93.70	5.12×10^{-4}	91.66	4.91×10^{-4}
4	97.56	7.60×10^{-4}	110.63	9.98×10^{-4}	108.57	9.47×10^{-4}	104.01	1.05×10^{-3}
3	111.64	1.08×10^{-3}	129.89	8.37×10^{-3}	121.77	5.36×10^{-3}	114.55	1.82×10^{-3}
2	134.05	7.74×10^{-3}	142.74	1.00×10^{-2}	140.66	7.27×10^{-3}	138.43	6.16×10^{-3}
1	144.64	1.55×10^{-2}	176.18	3.84×10^{-1}	174.25	3.14×10^{-1}	159.07	2.04×10^{-1}
0	176.66	4.09×10^{-1}			190.43	7.25×10^{1}	176.12	4.62×10^{-1}
1			597.12	stable	375.05	stable	290.26	stable
2			923.44	stable	559.50	stable	417.41	stable
3			1219.28	stable	717.53	stable	516.30	stable
4			1311.33	stable	770.64	stable	559.29	stable
5					944.33	stable	684.10	stable
6					1138.20	stable	819.51	stable
7					1335.92	stable	957.68	stable
8							1096.75	stable
9							1153.73	stable
10							1248.03	stable
11							1389.74	stable
12							1467.07	stable

masse de l'enveloppe riche en hydrogène déterminée par le paramètre $\log q(H) \approx \log(M_{env}/M_{tot})$ et la masse totale de l'étoile (M_{tot}). Pour notre modèle de référence, nous avons fixé ces quantités à $M_{tot} = 0.48\ M_{\odot}$ et $\log q(H) = -4.0$, qui représentent des valeurs typiques pour ces étoiles.

Le tableau II fournit les périodes (P, en secondes) et l'information sur la stabilité (en terme du temps caractéristique de croissance des périodes τ_e, donné en années pour les modes instables) des modes radiaux ($l = 0$) et non-radiaux (pour $l = 1$, 2, et 3) dans la fenêtre de périodes 60–1500 secondes. La partie supérieure du tableau montre les modes acoustiques (modes p) d'ordre radial $k = 1$ jusqu'à $k = 9$ (les périodes des modes p diminuent lorsque k augmente). La partie inférieure du tableau correspond aux modes de gravité (modes g) d'ordre radial $k = 1$ jusqu'à $k = 12$ pour $l = 3$ (les périodes des modes g augmentent avec k). Pour ce modèle, des modes radiaux et non-radiaux instables (ceux pour lesquels une valeur est assignée à τ_e) sont prédits parmi les modes acoustiques de faible ordre radial k (à noter que tous les modes g sont stables d'après ce calcul). Ces derniers définissent une fenêtre de périodes instables bien délimitée dont les temps caractéristiques de croissance sont très largement inférieurs à l'échelle de temps évolutif typique de ces étoiles (~ 10^8 années). D'un point de vue théorique, ces modes sont donc bien susceptibles de croître rapidement en amplitude pour devenir observables. Il est alors particulièrement frappant, lorsque l'on compare les résultats du tableau II avec les propriétés des pulsations des étoiles du tableau I possédant des paramètres spectroscopiques semblables aux paramètres du modèle utilisé, de constater que les périodes théoriques prédites pour être instables correspondent très bien aux périodes observées.

3.3 Comparaison détaillée des spectres de périodes observées et théoriques

Cet excellent accord entre périodes observées et périodes théoriques apparaît de manière encore plus significative dans la figure 1, qui illustre une comparaison détaillée entre les périodes de PG1047+003 (c.f., tableau I pour la liste des paramètres de cette étoile) et les périodes calculées pour le modèle présenté dans le tableau II. Nous avons observé PG1047+003 à haut rapport signal-sur-bruit avec le photomètre rapide LAPOUNE raccordé au télescope Canada-France-Hawaii de 3.6-mètres de diamètre. Ces observations ont révélé la présence d'au moins 16 modes de pulsation indépendants dans la courbe de lumière de cette étoile, leurs périodes se situant toutes dans l'intervalle de périodes excitées prédit par notre modèle de référence. De plus, nous constatons des similitudes flagrantes au niveau de la distribution des périodes dans le spectre de modes observé et le spectre de modes calculé représentés dans cette figure. En particulier, dans les deux cas, certains modes ont tendance à se regrouper dans l'espace des périodes alors que d'autres demeurent au contraire isolés. Cette ressemblance est d'autant plus remarquable que la figure 1 ne montre pas le résultat d'un "fit" formel des périodes observées, puisqu'il s'agit uniquement d'une comparaison entre les périodes observées de PG1047+003 et les périodes attendues pour un modèle aux paramètres atmosphériques semblables à ceux de cette étoile.

D'après nos investigations théoriques, de telles structures dans le spectre des périodes portent la signature de la profondeur à laquelle se trouve la transition chimique entre l'enveloppe riche en hydrogène et le cœur riche en hélium (Charpinet *et al.* 2001). Il est donc particulièrement intéressant de constater que cette signature semble également bien présente dans le spectre de périodes de PG1047+003. Ceci nourrit l'exaltante perspective de contraindre, à partir de leur spectre de périodes de pulsation, la masse de l'enveloppe riche en hydrogène des étoiles sous-naines de type B, un paramètre affectant de manière fondamentale l'évolution de ces étoiles mais qui n'a jamais pu être mesuré à ce jour.

3.4 Comparaisons globales entre périodes observées et théoriques

Une comparaison globale entre les périodes excitées prédites par la théorie et celles observées est proposée au travers de la figure 2. Pour chaque étoile EC14026 mentionnée dans le tableau I, le panneau gauche de la figure indique la fenêtre de périodes excitées définie par les données d'observation obtenues par différents groupes (c.f. la légende de la figure 2 pour plus de détails). Le panneau de droite donne le nombre de modes indépendants détectés dans les courbes de lumière correspondantes. Les segments de couleur représentant les observations selon ces différentes sources doivent être comparés aux segments noirs qui correspondent aux prédictions théoriques obtenues en considérant les modes d'oscillation de degré $l = 0$ à $l = 3$ (inclus) pour un modèle spécifique à chaque étoile, possédant les mêmes paramètres de surface T_{eff} et $\log g$ donnés dans le tableau I.

De manière générale, nous constatons d'après le panneau droit de la figure 2 que l'intervalle de périodes excitées prédit par le calcul correspond assez bien à la fenêtre de périodes observées pour toutes les étoiles du tableau I. En particulier, l'intervalle des périodes excitées pour des sdB pulsantes atypiques comme PG1605+072 et Feige 48, toutes deux possédant des gravités de surface bien inférieures à celles des autres étoiles EC14026, est bien reproduit par nos calculs théoriques. Il est cependant notable que de petits décalages entre les fenêtres de périodes excitées observées et théoriques existent pour certains objets (par exemple, EC14026–2647, PB8783 ou EC10228–0905). Ces différences sont très probablement dues aux incertitudes parfois élevées sur la valeur de la gravité de surface estimée à partir de l'analyse spectroscopique (les périodes des modes de pulsation sont particulièrement sensibles à ce paramètre). En conséquence, même pour ces quelques "cas difficiles", nous considérons que les périodes théoriques correspondent très bien aux périodes observées dans les limites d'incertitude sur la valeur du paramètre $\log g$.

La partie gauche de la figure 2 révèle, lorsque l'on considère des modes de degré $l = 0$ à $l = 3$, qu'un nombre plus important de périodes excitées que de périodes observées est généralement prédit. Il est très probable que cette situation résulte en partie de certaines approximations dans notre traitement de la diffusion pour les modèles de seconde génération (voir plus bas). Mais, il est néanmoins important de remarquer qu'il existe une très nette tendance à détecter plus de modes de pulsation lorsque de plus grands télescopes, comme le CFHT, sont utilisés (les sdB pulsantes observées au CFHT montrent typiquement de 10 à 16 modes, alors que celles observées avec de plus petits télescopes, comme ceux du SAAO par exemple, ne dévoilent typiquement que 5 à 6 modes). Il apparaît donc clairement qu'un nombre important de modes de plus faibles amplitudes sont systématiquement "manqués" lorsque les étoiles EC14026 sont observées avec de petits télescopes; ce qui, bien entendu, n'est guère surprenant. Mais ce simple constat illustre parfaitement la nécessité d'obtenir des données à haut rapport signal-sur-bruit lorsque l'objectif devient l'analyse astéroséismologique des sdB pulsantes qui dépend de manière critique du nombre de modes observés. Il est donc utile de le mentionner.

Enfin, nos calculs indiquent qu'à l'exception de PG1605+072, qui montre probablement des modes mixtes (c.à.d., des modes dont les caractéristiques sont un mélange entre modes *p* et modes *g*) dans son très riche spectre de modes, les périodes détectées jusqu'à présent dans *toutes* les autres sdB pulsantes connues correspondent à des modes acoustiques. PG1605+072 diffère des autres étoiles EC14026 principalement en ce sens qu'il s'agit d'un objet probablement déjà très évolué dans sa phase EHB (c.à.d., proche de la phase post-EHB).

3.5 La bande d'instabilité théorique

La figure 3 illustre les résultats obtenus suite à la construction d'une large grille de modèles de seconde génération couvrant l'espace des paramètres occupé par les sdB. Cette grille comporte 1053 modèles échantillonnant la région définie par $41{,}000\,K \geq T_{eff} \geq 22{,}000\,K$ (par pas de $500\,K$) et $6.4 \geq \log g \geq 5.1$ (par pas de 0.05). A chaque nœud de cette grille, la stabilité des modes a été évaluée par un calcul de pulsations non-adiabatiques. Pour cette grille, les deux autres paramètres à spécifier dans le calcul des modèles ont été fixés à $\log q(H) = -4.0$ et $M_{tot} = 0.48\,M_\odot$, ces derniers n'ayant que très peu d'influence sur la stabilité des modes.

Dans cette figure, toutes les étoiles EC14026 connues sont placées dans le plan $\log g - T_{eff}$ en fonction de leurs paramètres de surface donnés dans le tableau I. Sont également représentés dans ce plan les étoiles sdB observées en photométrie rapide mais ne montrant pas de pulsations (cercles pleins), ainsi qu'un échantillon de sdB n'ayant pas encore fait l'objet de recherche de variations de luminosité (cercles vides). Superposé à ces données d'observation, la grille de modèles apparaît sous la forme d'iso-contours indiquant le nombre N de modes radiaux ($l = 0$) instables obtenu à chaque nœud. Ce nombre est un bon révélateur de la puissance du mécanisme d'excitation en fonction de T_{eff} et $\log g$. Il peut donc être utilisé pour matérialiser une bande d'instabilité théorique. Le contour le plus large correspond à la limite entre $N = 0$ et $N = 1$ mode excité obtenu dans les modèles. Autrement dit, tous les modèles situés à l'extérieur de ce contour — qui définit les limites de la bande d'instabilité théorique — ne possèdent aucun mode instable. A l'intérieur de cette limite, d'autres contours indiquent les valeurs successives $N = 2, 3, 4,$ ..., jusqu'à $N = 7$ pour le contour le plus central. Ainsi, les régions où les valeurs de N sont les plus élevées dévoilent la partie du plan $\log g - T_{eff}$ où le mécanisme d'excitation des modes de pulsation est le plus efficace.

A ce titre, la figure 3 révèle un résultat particulièrement remarquable: le maximum d'efficacité du mécanisme d'excitation est situé vers $\log g \approx 5.8$ et $T_{eff} \approx 34{,}000\,K$, *précisément là où la majorité des sdB pulsantes se trouvent*. De plus, toutes les étoiles EC14026, y compris les plus "atypiques" d'entre elles (PG1605+072 et Feige 48), sont situées à l'intérieur (ou très proche) des trois contours les plus

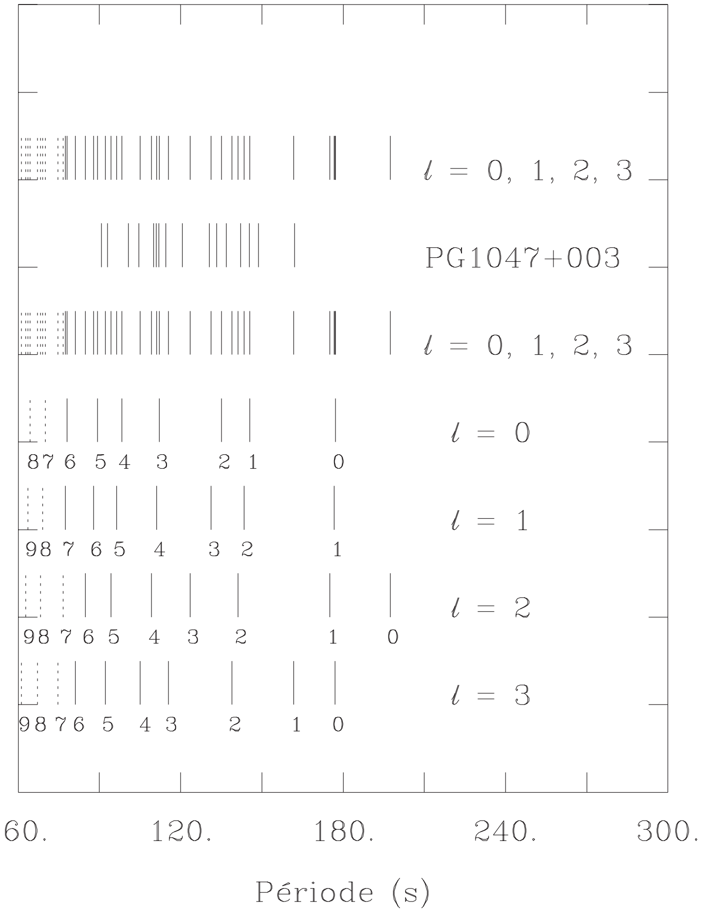

Figure 1 — Comparaison entre les périodes du modèle présenté dans le tableau II et les périodes observées pour PG1047+003. Pour les modes théoriques de degré $l = 0$ à $l = 3$, les segments verticaux continus représentent les modes instables, alors que les segments verticaux en pointillés correspondent aux modes stables. Le nombre donné sous chaque segment indique l'ordre radial k du mode. Les modes représentés sont des modes p de faible ordre radial.

élevés. Ces deux observations montrent sans ambiguïté que la bande d'instabilité théorique obtenue à partir de notre grille de modèles de seconde génération est très proche de la bande d'instabilité réelle déduite de la position des 16 sdB pulsantes connues. Deux points méritent néanmoins quelques commentaires supplémentaires.

En premier lieu, il semble d'après la figure 3 que la bande d'instabilité théorique soit sensiblement plus large que la région d'instabilité suggérée par la distribution dans le plan $\log g - T_{eff}$ des 16 étoiles EC14026 connues. Bien sûr, une certaine prudence est de rigueur à ce stade de nos connaissances, puisque le petit nombre de 16 étoiles pourrait ne pas suffire pour définir les limites précises de la bande d'instabilité réelle. Il demeure néanmoins plausible que nos calculs théoriques surestiment quelque peu la puissance du mécanisme d'excitation. Cette considération s'appuie sur certaines hypothèses de base imposées dans le calcul des profils d'abondance non-uniformes du fer. En particulier, nous avons supposé, dans le calcul de diffusion, qu'aucune autre espèce chimique n'entre en compétition avec le fer pour absorber une partie des photons disponibles dans le champ de radiation. En conséquence, les profils d'abondances non-uniformes utilisés dans nos modèles de seconde génération représentent une limite supérieure de la quantité de fer qui peut localement être supportée par lévitation radiative. De ce fait, la figure 3 illustre également une limite supérieure pour la puissance du mécanisme d'excitation et pour l'étendue de la bande d'instabilité théorique. Notons cependant que cet effet de compétition entre les différentes espèces chimiques pour l'absorption des photons est probablement suffisamment faible pour ne pas affecter nos principales conclusions sur la stabilité des modes dans ces étoiles. Mais des calculs de diffusion plus réalistes seront nécessaires pour traiter quantitativement de cette question.

En second lieu, la distribution dans le plan $\log g - T_{eff}$ des 70 étoiles sdB observées par photométrie rapide mais découvertes non-pulsantes suggère que des sdB pulsantes et non-pulsantes possédant des paramètres de surface similaires peuvent co-exister. Le fait que la bande d'instabilité ne soit probablement pas pure ne peut être expliqué par la théorie telle que formulée jusqu'à présent. Au moins un mécanisme additionnel, qui déciderait si une étoile caractérisée par un ensemble donné de paramètres peut osciller ou pas, est nécessaire. La nature de ce mécanisme demeure pour le moment inconnue. Nous pensons cependant qu'une explication plausible et naturelle pourrait provenir de la présence de faibles vents stellaires ($10^{-13} - 10^{-14}$ solar mass/an) qui n'ont pas été pris en compte dans les calculs de diffusion utilisés pour nos modèles de seconde génération. Les vents stellaires de faible intensité sont régulièrement invoqués pour expliquer les variations inattendues dans la distribution d'abondance de surface des éléments chimiques que l'on observe dans l'atmosphère des étoiles sous-naines de type B (Fontaine & Chayer 1997). Il est tout à fait concevable que de tels vents stellaires puissent à terme vider le réservoir de fer constitué par le processus de lévitation radiative, détruisant alors le mécanisme d'excitation des modes de pulsation. On pourrait ainsi imaginer que deux étoiles dont les températures effectives et gravités de surface sont similaires souffrent de pertes de masse à des taux différents. Dans ce cas, l'une des étoiles, celle possédant encore suffisamment de fer dans son réservoir, pourrait être pulsante, alors que l'autre, avec un réservoir vidé à cause d'un taux de perte de masse plus important, ne pourrait développer d'oscillations observables. Si un tel scénario s'avérait exact, alors le taux de perte de masse et l'âge d'une étoile sdB deviendraient les paramètres additionnels contrôlant la stabilité de leurs modes de pulsation. Ceci constitue l'une des voies théoriques qu'il reste à explorer pour mieux comprendre ces étoiles pulsantes.

4. Conclusion

Dans cet article, nous avons présenté un bref résumé de l'évolution de nos connaissances théoriques sur les propriétés d'oscillation des étoiles sous-naines de type B depuis les premiers travaux ayant conduit à la prédiction de leur existence, une prédiction qui fut confirmée par la découverte indépendante de sdB pulsantes, les étoiles EC14026. La théorie des étoiles EC14026 repose sur l'identification du mécanisme d'excitation responsable des pulsations: un mécanisme κ impliquant les éléments chimiques lourds, et tout particulièrement le fer. Elle repose également sur la reconnaissance du rôle fondamental joué par les mécanismes de diffusion qui, par triage gravitationnel et lévitation radiative, peuvent localement conduire à d'importantes accumulations de fer (en quantités fortement extra-solaires), en particulier dans la région de l'enveloppe où le mécanisme d'excitation opère. Ceux-ci sont indispensables pour que le mécanisme puisse réellement être efficace.

Sur cette base théorique, nous avons ensuite discuté et comparé aux données d'observation les résultats de calculs de pulsations non-adiabatiques effectués sur des modèles d'étoiles sous-naines de type B incluant un traitement des mécanismes de diffusion pour le fer. Cette comparaison montre que les prédictions théoriques quantitatives issues de ces modèles (périodes excitées, bande d'instabilité) sont remarquablement cohérentes avec les propriétés observées de la classe des étoiles EC14026. Dans ce contexte, il est important de mentionner que les spectres de périodes théoriques de ces modèles de seconde génération sont assez sensibles à l'effet rétroactif qu'induit la distribution non-uniforme de l'abondance de fer sur la structure générale de l'enveloppe des modèles. Notamment, les périodes des modes *p*, qui sont essentiellement des modes d'enveloppe, dépendent largement des détails de cette structure. Il sera donc essentiel, pour de futurs travaux d'identification des modes dans les étoiles EC14026, d'utiliser des modèles au minimum équivalents à nos modèles de seconde génération.

Bien entendu, certains raffinements dans la modélisation de ces objets pulsants seront certainement nécessaires pour pouvoir correctement reproduire dans le détail toutes les propriétés de la classe des étoiles EC14026. Par exemple, des calculs de diffusion plus réalistes, incluant les effets de la compétition entre éléments chimiques sur la force radiative et les effets de faibles vents stellaires, constituent la prochaine étape dans l'élaboration de modèles plus réalistes. Mais en dépit des progrès qu'il reste encore à accomplir dans ce domaine, il nous semble, à la lumière des résultats présentés dans cet article, que les idées fondamentales qui façonnent notre compréhension du phénomène des pulsations dans les étoiles sous-naines de type B sont exactes. Ceci devrait, dans un futur proche, ouvrir la voie vers une application potentiellement très fructueuse des outils de l'analyse astéroséismologique des étoiles EC14026 pour en sonder la structure interne.

Je souhaite tout particulièrement exprimer ma plus grande gratitude envers mes deux anciens directeurs de thèse: le Pr Gilles Fontaine et le Dr Pierre Brassard de l'Université de Montréal, sans qui ce travail n'aurait pu voir le jour. Merci également à mes collaborateurs Malvina Billères, Pierre Chayer, Ben Dorman, Claudio Iglesias, Forrest Rogers et Rex Saffer pour leur contribution essentielle à cette étude sur la sismologie des étoiles sdB. Enfin, merci à Dave Kilkenny, Chris Koen, Darragh O'Donoghue et Bob Stobie pour des discussions très stimulantes. Ces travaux ont été en partie supportés par le NSREC (Canada) et les fonds FCAR (Québec). S.C. souhaite aussi remercier le Centre National d'Etudes Spatiales (France).

Stéphane Charpinet
Laboratoire d'Astrophysique
Observatoire Midi-Pyrénées
14, Avenue Edouard Belin
31400 Toulouse
France

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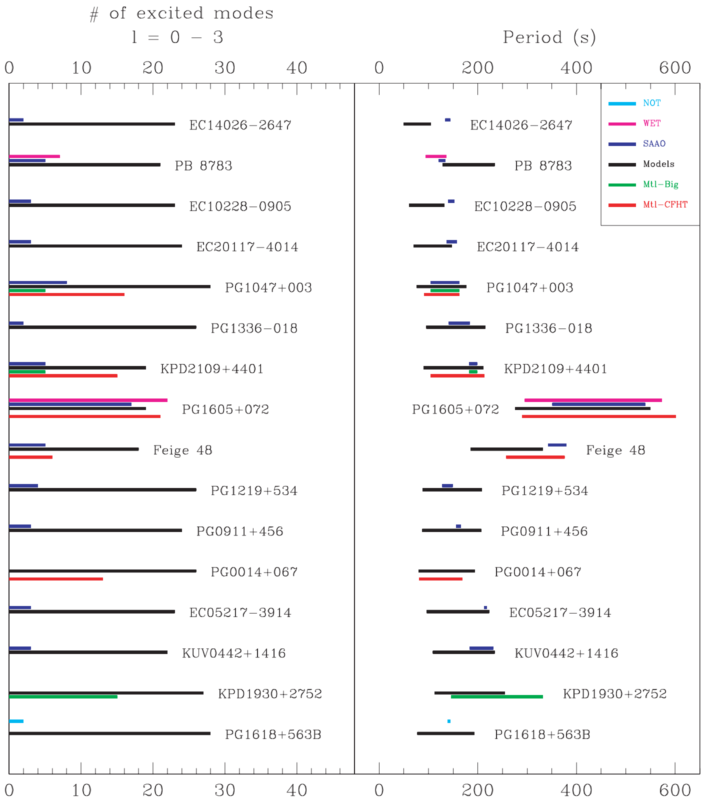


Figure 2 — Pour chaque sdB pulsante connue, le panneau de droite montre l'intervalle des périodes observées sous la forme de segments colorés associés à différentes sources d'observation (*Nordic Optical Telescope, Whole Earth Telescope, South African Astronomical Observatory, Steward Observatory* au Mont Bigelow ou le Télescope Canada-France-Hawaii). Le panneau de gauche indique le nombre de modes extraits des courbes de lumière correspondantes. Les segments noirs donnent la fenêtre des périodes théoriques des modes instables (panneau de droite) correspondant au nombre de modes excités pour $l = 0$ à $l = 3$ obtenus pour un modèle possédant les mêmes paramètres de surface que l'étoile considérée.

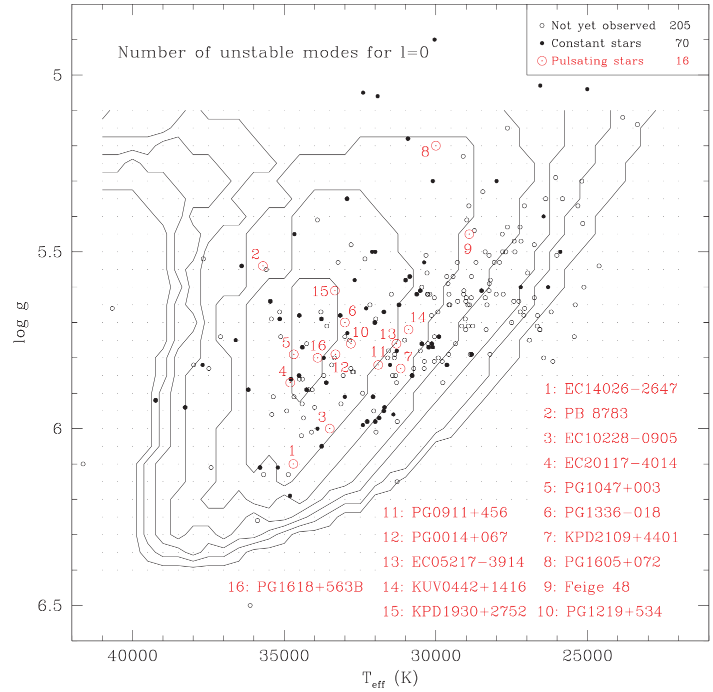


Figure 3 — Bande d'instabilité théorique dans le plan $\log g - T_{eff}$. Les iso-contours indiquent le nombre (N) de modes radiaux ($l = 0$) excités obtenus dans les modèles. Le contour le plus large, correspondant à $N = 1$, définit la limite de la bande d'instabilité en dehors de laquelle tous les modèles sont stables. A l'intérieur de cette limite, chaque contour est associé, du plus large au plus étroit, à $N = 2, 3, 4, 5, 6$ et 7. Les cercles vides numérotés correspondent aux 16 étoiles EC14026 connues. Les petits cercles pleins indiquent les sdB trouvées non-pulsantes. Enfin, les petits cercle vides sont des sdB qui n'ont pas encore fait l'objet d'une recherche de pulsations.

Stéphane Charpinet est détenteur d'une bourse CNES de perfectionnement post doctoral au Laboratoire d'Astrophysique de l'Observatoire Midi-Pyrénées à Toulouse (France). Il a obtenu son diplôme en physique de l'Université Joseph Fourier à Grenoble (France) en 1994 avant de s'inscrire à l'Université de Montréal où il lui a été décerné une maitrise puis un doctorat en astrophysique en décembre 1998. Il a ensuite passé seize mois en tant que coopérant militaire français au télescope Canada-France-Hawaii. Ses études professionelles portent surtout sur les pulsations stellaires et l'astéroseismologie, spécialement en ce qui concerne les étoiles compactes évoluées. Parmi ces loisirs, on compte la randonnée, le ski, la planche à voile et il apprécie aussi le cinéma et la littérature . . . il croit sincèrement que les jours sont bien trop courts.

Stéphane Charpinet is a CNES postdoctorial fellow at the Laboratoire d'Astrophysique de l'Observatoire Midi-Pyrénées in Toulouse (France). He obtained the BSc in physics from the Université Joseph Fourier of Grenoble (France) in 1994 before entering the Université de Montréal where he earned the MSc and the PhD of astrophysics in December 1998. He then spent 16 months as a French military cooperant at the Canada-France-Hawaii Telescope. His professional interests centre on stellar pulsations and asteroseismology, especially of evolved compact stars. Among other activities, he practices hiking, skiing, windsurfing and enjoys cinema and literature...he sincerely believes that days are way too short.

General Assembly 2001

Photo Gallery

A collection of images from the 2001 General Assembly (GA) held in London, Ontario

Photos selected and captions written by Dave Lane (dlane@ap.stmarys.ca)
(except where noted, all photos are by Clair Perry, Clair Perry Photography, Charlottetown, PEI)

The Group Photo (Photo by Joe O'Neil, O'Neil Photo and Optical)

(above) Imagine . . . observing at a GA! Spurred on by David Levy's enthusiasm for the sky, many were able to view Mars during the GA. Those who arrived on Thursday night were also treated to a visit to the University of Western Ontario's Hume Cronyn Memorial Observatory.

(left) James Tisdale of the Okanagan Centre chats with Bob Garrison (national president) during one of the coffee breaks.

(above, right) Dave McCarter (left) explains to the elated James Selinger of the Sarnia Centre just what he as won — a Meade ETX125 telescope donated by Meade Instruments!

Stargazer-Steve Dodson demonstrated how easy it is to build one of his dobsonian telescope kits.

There was perhaps the largest ever contingent from Prince Edward Island. Jim Crombie (left) lives in Summerside, but is a member of the Halifax Centre; Tony Sosnkowski (centre) lives in Brackley Beach, but is a member of the Toronto Centre; and finally, Clair Perry lives in Charlottetown and is actually president of that centre! (obviously Clair Perry did not take this picture, but it was taken with his camera).

The Ruth J. Northcott Memorial Lecturer: William Hartman and his wife Gayle. The written version of William's lecture appears elsewhere in this issue of the *Journal*.

Dave Nopper (left) chats with J. A. "Triple" Nickel as Mike Hanes looks on. "Triple" spoke enthusiastically about his profession at NASA where he trains astronaut pilots how to land the space shuttle.

Dave Lane (left) and Stan Runge at the banquet as *mischievous* Mark Kaye looks on. And no, Stan and I are **not** that close!

Chris Flemming (left) and David Levy discuss their "favourite faint fuzzies" during one of the many workshops. The GA committee chose a workshop format rather than the traditional paper sessions.

(above) Garry Dymond of the St. John's Centre makes a convincing argument to hold the 2003 General Assembly in St. John's near the time of the transit of Venus, which will be visible from there. I think he had everyone convinced, however, that decision will be made at next year's GA.

(above, left) You never know what will happen at a GA! This game of beach volleyball broke out after the Friday barbeque. Notice the society's executive secretary, Bonnie Bird (centre) right in the thick of it!

The songs went into the night… at least until after I went to bed on ~~Saturday night~~ Sunday morning!

The London Centre provided what turned out to be a very popular *Hospitality Suite* — so popular that is often spilled out into the hallway!

David Levy (left) and Peter Jedicke sing some of their favorite astronomy songs for those who stayed up late one night (Photo by David Clark).

ANOTHER SIDE OF RELATIVITY

Across the RASC
du nouveau dans les Centres

Society News/Nouvelles de la société

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

National Office

It is fall now, the leaves have changed colour, the winter constellations are on the horizon, and in the mail most members would have received or will receive their renewal notices for membership within the Society. Remember to look closely at the renewal amount. The fee increase was passed at this year's annual meeting held on July 1, 2001 in London, Ontario and each Centre will have a different renewal fee.

When you receive your first renewal notice, it would be a great jump on the year to send it in. This action not only saves on further renewal notices and postage, but when you pay it right away, you can be guaranteed that your subscriptions to both the *Journal* and *Sky News* will be delivered uninterrupted.

If anyone has any questions or problems, please do not hesitate to contact either Bonnie or Isaac, they will be glad to assist you.

Upcoming Event

There will be a National Council meeting on October 27, 2001 from 10:00 am till approximately 5:00 p.m., at the Scotia Plaza in Toronto, Ontario. Participation by all Centres is encouraged and observers of the RASC are welcome.

Congratulations To...

At the National Council meeting, held on June 30, 2001, we had several recipients of Messier and NGC Certificates. I extend congratulations on behalf of the executive and all members of the Society to Stan Runge (Winnipeg) on obtaining his Messier Certificate, and to John Douglas (Ottawa), Chris T. Adamson (Unattached), Geoff Gaherty (Toronto), and Paul Gray (Halifax), who have received their NGC Certificates (passed under motions 20010204/20010205)

Stan Runge (left) of the Winnipeg Centre receives his *Messier Certificate* from National President Bob Garrison. Does he look happy? (Photo by Clair Perry)

Paul Gray (left) of the Halifax Centre receives his Finest NGC Certificate from National President Bob Garrison (Photo by Clair Perry).

Remember, in order to receive these certificates once you have fulfilled the requirements, have your logbook reviewed by two witnesses, or send your completed logbook to along with the completed form to the attention of the National Secretary at the National Office.

Also passed under motion 20010206 was the acceptance of Membership Certificates for over 90 members of the Society. Listed below are the recipients.

Five-Year Service Certificates

A large number of recipients of the Membership Certificate were present to receive their certificates in person (Photo by Clair Perry).

Kingston Centre: Doug Angle, Tom Dean, Laura Gagné, Judith Irwin, Mark Kaye, Ian Levstein, Dave Pianosi, Ray Berg, Hank Bartlett.

London Centre: Stephen Arenburg, David L. Clark, Robert Duff, Christopher Fleming, Tom Glinos, Mike Hanes, Derek Hitchens, David McCarter, Phil McCausland, Dave Nopper, Shawn Osterberg, David Toth.

Niagara Centre: John Fishleigh, Denis Maheu, Ray Merrick, John Nemy, Brian Pihack, Dave Stremlaw.

Regina Centre: Al Andrews, Robert Klein, Steve Szuta, Darcy Kozoriz, Ross Parker.

Thunder Bay Centre: John K. Bakkelund, David R. Galley, Douglas L. Stuart

Toronto Centre: Spilios Asimakopoulos, Robert Chapman, Brian Cheaney, Heide DeBond, Frank Dempsey, John Ginder, David Hanson, Leslie Harvey, Anthony M. Horvatin, Tim Hunter, Stephen Keefer, Paul Markov, Robert May, Jean McMullan, Guy Nason, Paul Neal, John O'Dea, David Sage, Ivan Semeniuk, Frank Smith, Robert Taylor, Kirsten Vanstone, Wayne Yeo.

Winnipeg Centre: Jay Anderson, Ray Andrejowich, Kevin Black, Dr. Richard Bochonko, Chris Brown, Andora Jackson, Paul Paradis, Gil Raineault, Stan Runge, Gail Wise, Guy Westcott, Scott Young

Twenty-five Year Longevity Certificates

Calgary Centre: Craig Dunbar, Ruth Guengeric, Jim Himer, Ronald Stuart, Donald Scarlett

Kingston Centre: Frank Aldrich, Helen Brooks, Gordon Francis, Javier Ramirez

London Centre: Walter Campney

Niagara Centre: Ron Gasbarini

Thunder Bay Centre: Ted Bronson

Toronto Centre: Dr. C. M. Clement, G. L. Fairfoul, Dr. Mike Fich, Richard Freedman, Dr. A. W. Fullerton, Dr. Robert F. Garrison, George Hoshowsky, Peter Jones, C. Latremouille, J. F. A. Perkins, Alison A. Smith

Vancouver Centre: William L. (Bill) Robertson, Terry Taylor

Winnipeg Centre: Jack Iverson

In closing, I would like to extend my personal appreciation and gratitude to the 2001 General Assembly Committee, sub-committee and volunteers for the great gathering in London, Ontario from June 29 to July 1, 2001. This year's General Assembly festivities were less traditional than in past years, but very successful and very well attended by members of the Society. Congratulations to all the members of the London Centre for hosting the 2001 GA. Perhaps in keeping with the 2001 mood, London might host the 2011 GA(?); then again there is 2061?

We look forward to the 2002 General Assembly, which will be hosted by the Montreal Centre on May 18-20, 2002. Updates on the upcoming General Assembly will be made at the October National Council meeting, and will be posted to the National Web site, www.rasc.ca.

GA 2001

Award Citations

At the 2001 General Assembly, five national RASC awards were presented to the individuals named below. The nominations from their centres list the achievements that make them deserving of recognition.

Service Award — John Rousom, London Centre

Mr. John Rousom joined the London Centre in 1984. At that time, the Centre was not very active, and John's enthusiasm in the late 1980s and early 1990s was a significant factor in revitalizing it. John is a friendly, open individual who has always been receptive to new ideas — even ideas that were far from established practices and patterns. With John's participation, the constitution of the Centre was re-written in 1990, and this helped smooth the growth of the Centre in the mid- to late-1990s. John served as Treasurer from 1990 to 1992, as Chair of the Observer's Group from 1993 to 1995, and then as President from 1996 to 1998. John's professional knowledge as an accountant has been extremely valuable to the Centre. The guidance and leadership he demonstrated were characterized by wisdom, balance, and good humour. Since 1999, John has served as Past President and as a vocal member of the host committee for the 2001 General Assembly. John and his wife Darle often host committee meetings, executive meetings, and Observer's Group meetings at their rural home. John's astronomical interests, particularly as a seasoned observer of sunspots, and his other hobbies, such as blacksmithing, make him a key personality at a time when the Centre is very vibrant. The London Centre is pleased to propose Mr. John Rousom for the Society's Service Award.

Service Award — Dr. David Turner, Halifax Centre

The Awards Committee (minus David Turner) of the Royal Astronomical Society of Canada unanimously nominates David Turner for the Society's Service Award in the year 2001. The nomination is made primarily on the basis of his 6-year term of office as the Editor of the Society's *Journal*, but also on the basis of service to the RASC Centres he has been associated with.

David is currently a member of the Halifax Centre, but began his RASC membership in the London Centre, where — by his own account — he probably edited that Centre's newsletter before he was officially an RASC member. One often hears lip-service paid to the importance of communication, but it is clear that Dave Turner's almost single-handed effort in publishing the RASC London Centre newsletter contributed much to the growth of that Centre in the early 1970s. We are talking typewriter and Gestetner process here, not PC and laser-printer!

David honed his writing and editorial skills during these days of graduate study and London RASC membership. Not content with dry facts and figures, he introduced amusement into the pages of his newsletters. One innovation was an astronomical "Jumble" complete with cartoon. Another innovation was the monthly meeting report — but not any old report. His reports were infused with wit and humour, and quickly became a must-read for members. In time, David settled down at Saint Mary's University in Halifax and transferred his membership to the Halifax Centre. One of his principal contributions there was the suggestion that his new Centre also initiate monthly meeting reports in the newsletter. This suggestion was warmly received, and Dave Turner is a frequent and popular meeting reporter. Additionally, he has served as a Centre Councillor for many years, providing general advice to the Centre President.

Over and above all these things, the Committee feels that the most outstanding service David Turner has provided the RASC is his leadership as Editor of the Society's *Journal* from April 1994 to June 2000. A "normal" term of office of this type (just over 6 years) might be sufficient to earn a Service Award; however, during this time, David led the RASC from the old *Journal/Bulletin* format into the new *Journal* format beginning in February 1997. Without taking any credit away from the other RASC members who contributed to the publications revitalization, it must be said that editing the *Journal* during this transition was an extra challenge. The Society was reaching out to its members for new authors, and Dave Turner was the perfect Editor for the time, having a foot in both RASC camps: professional and amateur. David was not content to be an "executive" editor, but was willing to roll up his sleeves and work with the incoming manuscripts to ensure a high-quality product, and he had the stamina to resist those who did not always agree with his decisions!

Randy Attwood (right), Chair of the Awards Committee, presents the Service Award to David Turner (Photo by Clair Perry).

The RASC owes David Turner a vote of thanks, and there is no better way to express this than through a Service Award. If he were to receive this in 2001, there would be an added poignancy to the event, as the London Centre is hosting the RASC GA this year.

Chant Medal — Richard Huziak, Saskatoon Centre

The Saskatoon Centre would like to nominate Mr. Richard Huziak for the Society's Chant Medal, in recognition of his significant contributions as an amateur astronomer in generating, over a 25-year period, a substantial body of high-quality variable-star observations.

A longtime member of the RASC and an accomplished observer, Rick has completed over 14,500 professional-quality observations. The American Association of Variable Star Observers recently recognized his valuable contributions with an AAVSO Observer Award. As Janet Mattei, Director of the AAVSO, points out in her letter (quoted below), in addition to his observations Rick has made other significant contributions to variable star observing, including improvements to the accuracy of star charts, and actively encouraging other members. Recently he has brought to the attention of the astronomical community the large number of variable stars that appear to be mislabeled or missing in the *Millennium Star Atlas*.

Rick has been a member of the RASC since 1977 and has been actively involved in many of the observational and organizational activities of the Saskatoon Centre. He has served on the Saskatoon Centre Executive in many positions, most notably President from 1993 to 1997. In the opinion of most members, his observational skills are exceptional to the point of being legendary, and he gives much of his time to freely impart his knowledge and skill to newer members and to assist in their development as observers. His commitment to public outreach and education is amply demonstrated by over 1100 talks and presentations he has made during the last 15 years to groups as diverse as elementary school classes, Beaver Creek Conservation Authority public star parties, and the Saskatoon Engineering Society. He has been a volunteer fireball investigator with the Canadian Space Agency's Meteorites and Impacts Advisory Committee and an active member of both the International Dark Sky Association and the RASC's Light Pollution Abatement Committee. It is a source of mystery and admiration within the Saskatoon Centre that Rick is able to produce so much quality work and maintain an active outreach and education program while maintaining a full time position as a Manufacturing Technician at SEDSytems in Saskatoon.

We believe Rick is worthy of recognition for his efforts, since his contributions as an amateur observer are both significant and valuable, and as such, we wish to recommend that the Society present Richard Huziak with the Chant Medal.

Excerpt from a letter by Janet Mattei, Director AAVSO: "Richard observes a variety of types of variables, from the binocular gamma CAS and R CrB stars to fainter long-period and cataclysmic variables and pays particular attention to making long-term, regular and very valuable observations of known suspected variables and filed stars and comparison stars suspected of variability. Richard has also contributed very valuably to the observing resources used by AAVSO observers, specifically variable star charts. His helpful comments on comparison star sequences in variable star fields have often resulted in our providing improved charts to the AAVSO observers. He has also been working on correlating AAVSO suspected variables with HIPPARCOS variables.

"Richard has also been active in encouraging other observers whether through the *Observer Forum* in the AAVSO Newsletter or through the AAVSO's online discussion group in which he is an active participant contributing especially to chart related topics. Richard Huziak is a valuable AAVSO observer and contributor to variable star research. On behalf of the AAVSO and personally I am grateful to him for his astronomical contributions. Richard Huziak has been a member of the AAVSO since Nov. 1979 and has contributed over 14,523 visual variable star observations to the AAVSO International Database."

Simon Newcomb Award — Dan Falk, Toronto Centre

Dan originally joined the RASC in 1980 as a youth member of the Halifax Centre, and remained so through his university days at Dalhousie. Earning an honours physics degree in 1989, he entered the graduate journalism program at Toronto's Ryerson Polytechnic University, graduating in 1992. He transferred his RASC membership to Toronto, but still maintains links with Halifax.

Over the last 8 years or so, Dan has built a productive and creative career as a science writer and broadcaster, many of his topics being on astronomy or related themes. He has covered just about every aspect of astronomy in his reporting: the solar system, the Earth, the Sun, astrophysics (including black holes), gravity waves, cosmology, the Big Bang, fate of the universe, specific space missions, light pollution, amateur astronomy, biographical sketches of astronomers, etc.

He has written for newspapers and magazines, prepared radio broadcasts, and prepared television documentaries. He not only researches and writes these pieces, but — where appropriate — he handles the technical aspects of the work, including photography, recording, video camera operation, and editing. This work is international in scope, with clients in Canada, the USA, the United Kingdom, The Netherlands, France, and Australia. His work has earned him several awards, from the U.S. National Association of Science Writers (1999), the American Institute of Physics (1999), and the Canadian Science Writer's Association (1997).

Dan Falk (left) is presented the Simon Newcomb Award by past award winner Michael Watson (Photo by Clair Perry).

Dan is probably best known in Canada as the author of the monthly column *Skywatch*, which appears in the *Globe and Mail* newspaper. His complete output is too vast to list in detail, but a selected annotated bibliography of his "best" work in astronomy was sent to the Chair of the Awards Committee with this letter. A recent contribution was the two-part CBC Radio documentary, *The Question of Design*, which was broadcast in October 2000 and considered the cosmological and biological consequences of an intelligent designer for the Universe.

The Halifax Centre Executive proposes that Dan Falk is an ideal recipient for the Simon Newcomb Award. He is a productive and professional writer and broadcaster whose output promotes the public understanding and appreciation of astronomy, both in Canada and abroad.

Ken Chilton Prize — Michael Boschat, Halifax Centre

Michael Boschat has been a keen amateur astronomer and a member of the Halifax Centre for many years. He is well known for his keen sight, including an ability to find objects that are normally hidden by city lights.

Frustrated as all of us often are by cloudy skies, he is always finding new ways to indulge his passion for astronomy. For example, a few years ago he turned his hand to radio meteor observing, and has had considerable success in that field. With the advent of the RASC email list, he can always be relied upon to give us warnings of upcoming interesting events, along with his monthly posting of sunspot numbers. These sunspot observations were recognized by an award from the Solar Division of the AAVSO in October 1999.

However, the piece of astronomical work we wish to focus on here is Michael's discovery of many sun-grazing comets from the archive of *SOHO* (*Solar and Heliospheric Observatory*) images. In the News Notes column of the April 2000 issue of JRASC, Russell Sampson described Michael's careful, painstaking technique for finding, recording, and reporting the comets.

Beginning with his first discovery on March 4th, 2000, Michael discovered 24 of these comets through to the end of the year. As noted on the "Science@NASA" Web site (`science.nasa.gov/headlines/y2000/ast07jul_1.htm`), he is one of the most successful amateur comet hunters. Since he began his hunt for them, he has discovered 20% of all *SOHO* comets.

Consequently, we are delighted to nominate Michael E. Boschat for the Ken Chilton Prize of the Society.

RASC Supports Young Astronomers

by Frederick R. Smith, National Awards Committee (frsmith@morgan.ucs.mun.ca)

Canada Wide Science Fair 2001

For the second year in a row I have had the great fortune to represent the RASC Awards Committee at the annual Canada Wide Science Fair (CWSF). This year the CWSF was held from May 13 to19 at Queen's University, Kingston, Ontario. During the fair 260 judges worked for two days to evaluate 344 projects submitted by 430 students. The first day of judging was for medals and the second for special awards. There are many special awards and when students registered for the fair weeks in advance, they "self-nominated" for up to seven special awards. This year two students self-nominated for the RASC Junior Award, two for the Intermediate Award and six for the Senior Award. Judging was done by Dr. Kayll Lake (Queen's University, Physics) and myself as sponsor representative.

Awards

Fifteen-year-old Maran Ma with her "Low Obstruction Reflector" telescope at the 2001 Canada Wide Science Fair held in Kingston, Ontario."

Fred Smith presents a special award on behalf of the RASC to fifteen-year-old Jonathan Sick,a member of the RASC's Calgary Youth Group. Jonathan's project on "Sunspot Morphology & Magnetic Shear" also won the overall award for best Intermediate-level entry at the 2001 Canada Wide Science Fair in Kingston, Ontario.

When students self-nominate for special awards they do so with the help of their teachers and parents. During judging, it is often the case that some projects do not fall within the guidelines established by the sponsors, but to avoid embarrassment to the students, these projects are judged and the students are interviewed and given suggestions for future work. On the other hand, a project may fit the criteria but not be of high enough quality to merit an award. In such a situation, it is standard practice not to give an award in that category. In judging for the RASC Junior Award both of these circumstances were encountered and we did not give an award this year.

However, at the Intermediate level both entries were excellent and of equal merit and we decided that we would give an RASC Intermediate Award ($200) to both projects.

At the Senior level the six entries varied from good to absolutely outstanding. We had no problem determining a winner because the young man submitted and defended a project that was clearly at the Masters degree level.

I was also pleased to present the RASC Awards at the Awards Ceremony. Even though the monetary value of the Awards is not great (especially compared with the $50,000 award our senior RASC student won for his project at the International Science and Engineering Fair the week before), recognition by the RASC is very important to these young people for whom astronomy is their big interest.

The Winners are…

This years winners of the Intermediate award were Maran Ma, (Waterloo, Ontario) for her project titled "A New Eye for the Universe: The Low Obstruction Reflector", and Jonathan Sick (Calgary, Alberta) for

The Senior Award was presented to Francis Boulva of Collège Jean de Brebeuf, Montreal, for his "Galactic Champagne" project.

his project "Sunspot Morphology and Magnetic Shear".

The Senior award went to Francis Boulva (Mont-Royal, Quebec) for his project "Galactic Champagne: Morphology, Dynamics & Evolution of a Cluster".

Preparation for CWSF

Students who attend a Canada Wide Science Fair have spent considerable time developing proposals, building equipment or writing software and then collecting and analysing their data.

Getting to a CWSF is a long process. Students develop their research ideas with the help of their teachers, parents and friends. In many cases they will also seek help from university researchers and are often given space in university labs to do their research. In order to attend a CWSF the student must be a winner in an annual school science fair and also obtain top marks in one of the over-100 regional science fairs held across Canada. In some provinces there are other levels of competition (*e.g.* Super Expo-sciences Bell, finale québécoise) before reaching CWSF. It doesn't stop there; every year Canadian students participate and do well in the annual International Science and Engineering Fair (ISEF) usually held in the United States. When Dr. Amelia Wehlau (Professor Emerita, UWO) and I judged for the RASC awards at CWSF 2000 at UWO we met, among the many students we interviewed, several young participants whose projects had already been accepted for publication in international journals.

Participation of RASC Centres

Regional science fairs are held in March and April and CWSFs in May. Encourage your Centre to offer a regional RASC award for the best astronomy related project; a $50 award would be really appreciated by a young astronomer. Also, there may be people in your Centre who would like to judge in a regional fair, especially for your local RASC award. If the student has the confidence, invite her or him to give a talk at a Centre meeting.

The 2002 Canada Wide Science Fair will be held in Saskatoon, 2003 in Calgary, and 2004 in St. John's. If you live near one of these sites, you should not miss the opportunity to visit during open house hours and talk to the students and view their projects; you will be very impressed.

National Light Pollution Abatement Award

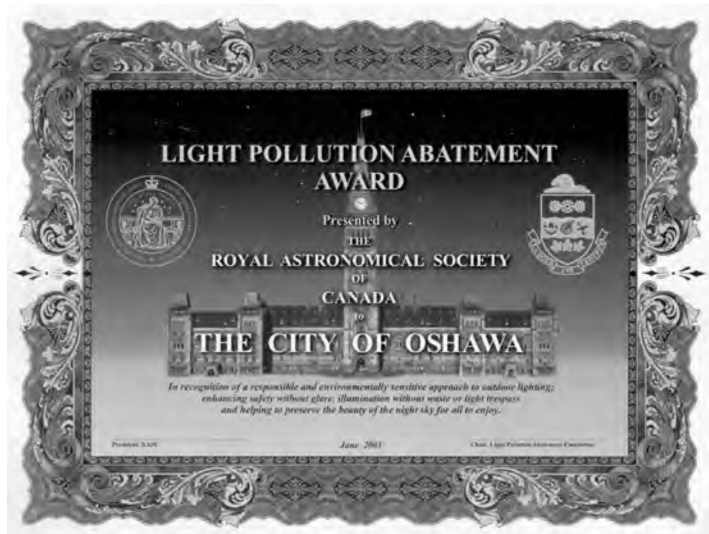
by Robert Dick (rdick@ccs.carleton.ca)

The RASC Light Pollution Abatement (LPA) Award was presented to the City of Oshawa at the RASC's 2001 General Assembly in London, Ontario. It was presented by the RASC to the City of Oshawa in recognition of "a responsible and environmentally sensitive approach to outdoor lighting, enhancing safety without glare, illumination without waste or light trespass, and helping to preserve the beauty of the night sky for all to enjoy."

At the London General Assembly, Dr. David Crawford (left), president of the International Dark-Sky Association, presented this year's Light Pollution Abatement Award to Roy Vanderkwaak who represented the City of Oshawa (Photo by Clair Perry).

The new policy was adopted in October 2000 after Oshawa resident Mike Cook, a member of the RASC, approached City Council in April 2000. He increased their awareness of the adverse effects of uncontrolled lighting and offered suggestions for possible solutions. This case demonstrates how a single individual can make a strategic impact on the lighting policy of their city. It will have long-term benefits for both citizens and astronomers in the city and the surrounding region.

Oshawa earned the RASC award for its new policy, which mandates the use of "full cut-off" luminaires for all new streetlights as well as for the gradual replacement of worn-out fixtures with full cut-off designs. Full cut-off fixtures are designed to shed light only where it's wanted (downwards), instead of spilling unwanted light wastefully upwards into the night sky, into the eyes of drivers, or into homeowners' windows.



The RASC's Light Pollution Abatement Award certificate that was presented to the City of Oshawa.

The adoption of such a policy by a city like Oshawa is cause for celebration. It means less overall city-light pollution and glare to contend with, helping to ensure a safer environment and a clearer view of the night sky for everyone. Along with establishing its new internal policy, Oshawa City Council has indicated that it intends to encourage private developers in the city to follow suit with "full cut-off lighting and lighting designs that minimize the scattering of light into the atmosphere."

The Award was presented by Dr. David Crawford of the International Dark-Sky Association to the City of Oshawa, represented by Roy Vanderkwaak of their Transportation Depart-ment. Dr. Crawford was introduced by RASC National President, Dr. Robert Garrison. The presentation took place on the evening of Friday, June 29, at Fanshawe College Residence & Conference Centre in London, Ontario. "The City's initiative will result in a more attractive night environment and darker night skies for all citizens," said Dr. Garrison, an astronomy professor at the University of Toronto.

"The City of Oshawa is to be congratulated for listening to the concerns of citizens and for implementing an effective, economical program that will not only improve our view of the night sky but will also enhance civic safety and security through better lighting," said Robert Dick, chair of the RASC's National Light Pollution Abatement Committee.

The London General Assembly is the first to incorporate a number of workshops. Light Pollution was covered in one session. Based on the number of attendees to the session, the topic was of great interest to many members. They benefited from the comments from Dr. Crawford, Mike Cook and political and engineering representatives from the City of London.

The award ceremony and the Workshop were videotaped. The LPA Committee would like to have the tape edited for the use by RASC Centres and to produce a very short video clip for video journalists to augment their LPA news stories. If you have video editing capabilities, please contact the LPA Committee Chair, Robert Dick (`rdick@ccs.carleton.ca`)

Committee Reports:
National Observing Committee

New Observing Certificate Launched on Canada Day!

At the National Council meeting of July 1, 2001, the RASC adopted a new observing certificate program aimed at observers who are new to astronomy. The program leads to the RASC's new *Explore the Universe Certificate* and provides the beginning observer with an introduction to bright stars and constellations, deep-sky objects, the Moon, the solar system, and double stars.

The National Observing Committee has developed the *Explore the Universe Certificate* program with the following objectives in mind:

- That it be suitable for beginners.
- That it be easily completed using only binoculars.
- That it be focused on the "prime time" summer and fall observing seasons.
- That it can be started at any time during the year.
- That it is possible to complete in 6–9 months.

In developing the program, the Observing Committee drew upon many programs already established by various centres across the country. By providing a complete survey of all aspects of observational astronomy, the Committee hopes to introduce new members to the joys of the night sky and to lay the foundation for a lifetime of observing accomplishments.

While this is a National program, the expectation is that it can be used as a catalyst for a lot of local activity. Using a certificate program as a theme can provide a focus for new member nights and observing sessions. It is hoped that all Centres embrace the program warmly and take advantage of its educational potential.

Not Just Another List

The *Explore the Universe Certificate* program is supported by a complete package including:

- A detailed program guide providing information on all 110 available objects.
- A sample observing logbook and guidelines that can be used to record observations (optional).
- A submission form for applying for the Certificate.

The Program Guide will tell you what to look for and what you are seeing when you find it. Observers are encouraged to invest in a good guidebook or star atlas to find exact locations for most objects. The new program is also cross-referenced to the RASC's own *Beginner's Observing Guide*.

RASC Explorer Contest

As part of the launch of the new certificate program, the National Observing Committee is sponsoring a contest. In order to enter you must complete the requirements of the Explore the Universe certificate by **October 31st, 2002**. Winners for each of the Atlantic, Central and Western Regions will be drawn. As part of the contest entry form, we are asking for you to write about your "Finest Observation." The best entries will be shared in an upcoming issue of the *Journal*.

More Certificates Proposed

At the same National Council meeting, the National Observing Committee proposed adding additional observing certificates to the three certificates now offered (Explore the Universe, Messier, and Finest NGC). At present, the committee is considering an advanced Lunar Observing Certificate (I. K. Williamson Certificate), an advanced deep-sky program (Fr. L. Kemble Certificate), as well as an advanced double star and extended binocular observing certificate.

Building a certificate program requires enthusiasm, attention to detail, as well as some observing experience. If you would like to help, the National Observing Committee would welcome your assistance. Please send e-mail to Christopher Fleming, Chair, National Observing Committee at chrisfleming1@sympatico.ca or Denis Grey at dgrey@fido.ca

GA 2001

Report on the 2001 General Assembly Council Meetings

by Scott Young, Winnipeg Centre National Representative (Scott_Young@ManitobaMuseum.MB.CA)

The 2001 General Assembly (GA) in London, Ontario was one of the best I've been to, in terms of both the business and social sides of the RASC. Over 200 delegates representing 25 of our 26 Centres were in attendance, giving a good cross-section of our Society. Great job to all those involved!

The official reason for the GA is the Annual Meeting of the Society, where all members are able to voice their concerns and suggestions, and vote on RASC policy. Before this, however, is one of the quarterly National Council meetings. These meetings tend to handle many of the day-to-day operations of the Society, and tackle some of the bigger questions before they are put to the general membership.

A meeting of council, held during the London General Assembly, where the business of the society is conducted (Photo by Clair Perry).

Meeting #1: 29 June 2001

The first National Council meeting was held in Room G1021 of Fanshawe College in London. Besides the Executive and 28 Centre Representatives, there were over a dozen observers interested in seeing the inner workings of the Society. I find these meetings fascinating — you can see there are many people who care deeply about the RASC and its goals. If you've never been to a National Council meeting, come on out and see what it's all about!

President's Report

The RASC's National President, Dr. Robert Garrison (Toronto), spent the first full day of his retirement chairing the National Council meeting. Council congratulated Dr. Garrison on his retirement from the University of Toronto after 33 years. Dr. Garrison highlighted some of the events and issues of the last year, including the issue of "decoupling," and the dearth of professional papers being submitted to the *Journal*. Dr. Garrison also congratulated the City of Oshawa on receiving the Light Pollution Abatement Award. Dave Lane (Halifax Centre), the Production Manager for the *Journal*, will be retiring next year, and Dr. Garrison invited applications for the position.

National Secretary's Report

Kim Hay (Kingston), our National Secretary, informed us of the varied correspondence she has undertaken on behalf of the society. Some of the highlights were letters from our past Honorary President Dr. Jack Locke, and honorary member Sir Patrick Moore. The list of new unattached members was approved, and a moment of silence observed for those members who passed away during the previous year. Messier, Finest NGC, and Membership Certificates were all approved (for the list of names, see the Society News section).

Executive Secretary's Report

Bonnie Bird is a familiar face (or at least voice) to anyone who has contacted the National Office in Toronto. Bonnie reported on the goings-on at the National Office, including the refining of the in-house membership system, renovations to the office, and the success of the new e-store on the RASC Web site.

Treasurer's Report

Michael Watson (Unattached), Society Treasurer, described the financial report and answered questions on the state of the Society's finances. At the previous Council meeting, a fee increase of $4 had been recommended, and this would be dealt with in the Annual Meeting (see below). Mike also described the status of the Special Projects funds, by which Centres can apply for funding for special projects including observatory repairs. Susan Yeo (Calgary) has submitted a request for funding on behalf of the Calgary Centre for their Eccles Ranch Observatory, which will be considered at the next Council meeting.

Publications

The Editors of the various publications reported on their areas. Dr. Rajiv Gupta (Vancouver), the Society's 1st Vice President, described the growing success of the e-store, selling publications such as the *Observer's Handbook*, *Observer's Calendar*, and *Beginner's Observing Guide*. A motion to spend $3300 on Internet advertising to promote the e-store was approved, and it will be interesting to see whether this foray into e-commerce pays off.

There was strong concern that not enough professional papers are being submitted to the *Journal*. This is a recurring issue that has been dealt with in a variety of ways, including wholesale revamping of the publication over the past several years. Despite this effort, it is still not attracting papers from Canadian professional astronomers. This year, Dr. Garrison will approach members of the Canadian Astronomical Society (CASCA) to encourage use of the *Journal* as a peer-reviewed, professional publication.

We also were treated to previews of the *2002 Observer's Calendar* by Rajiv, full of stunning images captured by RASCals from across the country. It's no wonder that this high-quality publication is such a strong seller.

Committees

I reported on the success of Astronomy Day 2001 in my capacity as National Astronomy Day Coordinator. Next year's event on April 20, 2002 promises to be a great one: most of the naked-eye planets are lined up in the evening sky, with the crescent moon passing each of them in turn during the week leading up to Astronomy Day. Free advertising in the sky!

Then came the Constitution Committee, chaired by Michael Watson. It seems that whenever there are contentious issues to be discussed they are either found in the Constitution Committee report or the Treasurer's report, also prepared by Michael. Whether this is correlation or causation is left to the reader.

Michael presented some draft by-law changes for discussion that would address the issue of "decoupling." For those of you unfamiliar with the term, it does not refer to problems keeping your observing pier from contacting the floor of your dome. As it stands, only 60% of the National fee actually goes to National — the other 40% is distributed to your Centre. Some Centres also add (or subtract) a surcharge to cover local expenses. This confuses things when fee increases are proposed. Since the two portions are linked, in effect the Centre's portion increases whenever the National portion does, whether the Centre wants that money or not. Also, unattached members pay the full amount, even though they don't gain the many benefits of Centre membership. With concerns about keeping membership affordable, combined with differing financial demographics across the country, this is a serious issue.

The proposed bylaw changes would essentially split the fees into two separate parts: a National fee, set by the general membership at Annual meetings, and the Centre fee, set by each Centre however they want. The fees would show up separately on a membership invoice, making it clearer to members where their money is going.

The proposal sparked much debate on the pros and cons of decoupling, including how to handle life members (who have already finished paying but have not finished using National and Centre services) and how to handle transfers between Centres. Several people felt that this would cause people to become unattached members to save money, or that it would look like National fees had decreased and Centre fees had increased (due to the 60-40 split). Others felt that decoupling was a way of making things more transparent to the member.

It is a complicated issue, but one that deserves our full attention in the coming year. All Centre representatives were instructed to take the discussions back to the Centre level — if your Centre representative hasn't done so, then go and beat it out of them! While it may seem to be mostly semantics, this issue is one that can have a large effect on membership of the Centres.

Other Issues

Peter Broughton (Toronto) reminded us that the RASC would soon be celebrating the centenary of its "Royal" status. There was discussion about inviting a royal representative to the 2003 GA, which was tabled until the next National Council meeting.

The long-awaited "Beginner's Observing Program" developed by Chris Fleming (London) and the Observing Certificates Committee was approved. This program has been a long time in development, and will hopefully encourage new observers by giving them a program and goal to work towards. The Certificate is also available to non-members who complete the program, making it a potential membership tool as well.

Robert Dick (Ottawa) described the efforts of the Light Pollution Abatement Committee, including the award to the City of Oshawa, and the possible establishment of another dark-sky site on Manitoulin Island in Ontario.

David Orenstein (Toronto) gave the final report of the meeting, highlighting the Public Education Committee's activities, including the publication of a resource in the Ontario Science Teacher's newsletter, and the many educational resources available through the RASC Web site (`www.rasc.ca`).

With the first National Council meeting behind us, we went on to enjoy some great workshops, programs and social events. I'm sure many reports will have surfaced by now, and I deny them all categorically.

On Canada Day, we filed into the big auditorium at Fanshawe for the RASC's Annual Meeting. These meetings are always a lot of fun. It is a chance for members who aren't on the National Council to voice their opinions and vote on the business of the society, either in person or by proxy. All major changes such as fee increases and bylaw changes must always be approved at an Annual Meeting by the membership, so the members always have final say.

The Executive reported on various items to the membership; as many of the reports were similar to the ones in the earlier meeting, I will skip them and mention only one new item. Michael Watson was acclaimed as Treasurer for another three-year term. No other Council positions were open this year, although next year most of the Executive positions become available as various peoples' terms expire.

Then came the moment that everyone had been waiting for: the fee increase. The motion was to increase the regular membership fee by $4 (to $44), the youth membership fee by $2.50 (to $27.50), and the life membership fee by $80 (to $880). Some of the reasons for this increase were given as:

- There have been unusually high deficits over the past few years (to get the new membership system in place and running), and we should be aiming for a modest surplus of between 5-8% of revenue to re-establish our assets.

- There is the potential of higher staff expenses due to the demands placed by the large increase in membership. We have added three new Centres in the last year alone. If a third employee is needed to service these members, additional space may be required at National Office. If this occurs, we may need to stop renting out the top floor of the building, losing $14,000 a year in revenue.

- There is the potential that the Society's main revenue-generator, the *Observer's Handbook*, may become less attractive to users compared to computer-based almanacs. If the Handbook sales decrease, we will be in a tough financial position.

If these seem like far-off "maybes," consider that it takes one to two years for a fee increase to actually increase the revenue, since members renew their fees at the end of their membership year. However, a loss in revenue or increase in expenses due to one or more of the above can be immediate. The fee increase was proposed to ensure the Society would be in a financial position to fulfill its mandate of funding special projects, supporting light pollution abatement, and public education, plus providing services to its members.

After a lengthy debate both for and against, the fee increase motion was carried with opposition. You will likely see this increase on your next renewal form, although some Centres are "absorbing" the increase by dropping their surcharge by the same amount.

After the fee increase debate, the rest of the Annual Meeting was quite sedate. David Levy read a letter from Arthur C. Clarke sending the RASC greetings and commenting on the GA's theme: "2001: A Space RASC." Leo Enright recognized the efforts of several members in attempting Messier Marathons: Michael Watson managed 108 objects, and both Paul Gray and David Levy (who live farther south than most of us) have managed 109 of the 110 objects. It was a fitting note on which to end the Annual Meeting, bringing our focus back to the reason we were there: our love of the sky and all of its splendours.

A final short Council meeting brought the weekend to a close; the various committees were reconstituted, and we accepted an invitation from the Vancouver Centre to hold the 2003 GA. St. John's Centre has expressed interest in hosting the 2004 GA in conjunction with the transit of Venus that year, and we will hear more from them at a future meeting.

Your National Representatives will have full details of the meetings, including more depth and discussion than I have presented in this brief summary. The next National Council meeting will be in the fall, and the decoupling issue will be front and centre. Make sure your Centre Council discusses the issue and determines their position beforehand; there are a lot of pros and cons, and it is not a decision that can be made lightly. At the fall meeting, the National Council will prepare some recommendations on the issue for the 2002 GA in Montreal. Hope to see you there!

Reviews of Publications
Critiques d'ouvrages

Rare Earth, by Peter D. Ward and Donald Brownlee, pages 333 + xxviii, 60 cm × 24 cm, Copernicus Books, 2000. Price $27.50 US, hardcover (ISBN 0–387–98701–0).

It is a near-consensus amongst scientists that a serious book about extraterrestrial life cannot be written at present. Many contend that a "science without data" is not science at all. Yet that view has not discouraged the legions of writers, scientific and otherwise, who presume to tackle the problem from a unique perspective. In *Rare Earth*, paleontologist Ward and astronomer Brownlee mount an attack against the essentially aesthetic — often better characterized as numerological — view that the cosmos must flourish with life of some variety. While the authors admit that "absence of evidence does not equal evidence of absence," they advocate a different approach to the recurring question of our cosmic solitude: the study of our own planet's eventful history.

The authors build their book upon a bold hypothesis, one sure to send shivers down the spine of the hopeful SETI-ite: Earth and its peculiar brand of animal life are likely to be rare, perhaps even unique, in the universe. According to Ward and Brownlee, Earth is a planet "…perfectly positioned for a history replete with animal life," yet also one whose history was fraught with difficulties from a biological perspective. Life only arose as the physical environment allowed, then teetered on the brink of extinction as one chance calamity proceeded another through the aeons. A hundred "what if…"s cast doubt on whether different circumstances would have led to a world anything like the one we occupy today. So, if the character and perhaps the very existence of life is strongly tied to the physical properties of a "rare" Earth, then such life might be equally rare.

Ward and Brownlee do not quibble with the now common view among scientists that "elementary" life forms — *e.g.* bacteria — are likely to be widespread in the cosmos. Rather, their focus is on the nontrivial next step in the reconstructed evolutionary history of life on Earth: the origins of animal life. Many scientists have expressed incredulity at the simple fact that it apparently took only 500 million years for simple bacteria to arise on Earth, while the jump to eukaryotic and multicellular life took another 1.5 and 2.5 *billion* years, respectively. The authors nicely summarize what is known about this mystery up until the Cambrian Explosion about 550 million years ago, when organisms underwent a sudden burst of diversity that created the basic templates for most of today's animals.

A good deal of the book is concerned with the physical character of Earth itself, and the authors make clear the myriad connections between the planet and its attendant life forms. The effects on habitability of Earth's land-to-sea ratio, atmospheric evolution, and location in the solar system are each discussed, along with important mechanisms such as long-term climate change, comet and meteorite impacts, and plate tectonics. The authors stress how the interplay between such elements makes for a tremendous variety of habitats on Earth, from the mantle to the atmosphere. At the same time, they point to the absence of the same properties on the other planets and moons of our solar system.

While *Rare Earth* has gained considerable attention as an iconoclastic perspective on life beyond Earth, it does suffer from two evident weaknesses. First, Ward and Brownlee's case for the rarity of Earth-like planets beyond the solar system depends on astronomical arguments that are weakly made. For example, at one point we read, "The mere fact that [in our Galaxy] 95% of all stars are less massive than the Sun makes our planetary system quite rare." The implicit argument here, that low-mass stars have unsuitable habitable zones for life as we know it, is not new. But in strict numerical terms, the statement is only true if the few million or so stars like our Sun are considered trifling. Later in the book, after arguing that Jupiter played a beneficial role as gravitational guardian to the inner solar system, the authors posit, "It is likely that many planetary systems do not have Jovian planets." Yet the success rate of extra-solar giant planet detection (5–10 percent of all Sun-like stars within 100 light years of Earth) argues strongly for the opposite conclusion.

The second and more serious weakness, in my view, is the authors' tendency to confound necessity and sufficiency. In hindsight, certain events in Earth's past, impacts by comets and asteroids for example, appear to have threatened the extinction of the most complex life forms then occupying the planet. But were they actually close calls for the subsequent development of life? Ward and Brownlee fail to establish that the properties of Earth they highlight were absolutely minimal, and therefore necessary, for organisms as complex as animals to arise. Here they flaunt the most basic observational selection effect, the weak anthropic principle, that limits claims of necessity in sciences with a large historical component, paleontology, geology, and astronomy for example. The authors continually employ language that betrays such anthropocentric confusion.

In one paragraph we read that, "Earth is quite a charmed planet. It has the right properties… it formed in the right place…," making the world a "congenial," "near-ideal," and "appropriate" habitat for life. Such Goldilocks-like statements are found throughout the book.

As a popular read, I found the language to vary between dry and saccharine, with little variation in between. It is sufficiently detailed in parts (predictably, on subjects that are nearest to the authors' expertise) to turn off many general readers. Repetition, as distinguished from reinforcement of difficult concepts, is also a problem. On the other hand, some terms are used repeatedly without satisfactory definition; in this respect, "evolution" was probably the most egregious omission. For example, the somewhat counter-intuitive idea that a "Snowball Earth" event (an episode of massive, planet-wide glaciation suspected to have occurred twice in Earth's history) could stimulate new and vigorous evolutionary change cannot be understood without a brief review of how natural selection and speciation work.

I was disappointed that Ward and Brownlee chose to end their wide-ranging account by presenting an "updated" form of the famous Drake equation. I had hoped that they would resist such a major example of abject numerology that masquerades as an "equation of everything" for astrobiology. Worse still, in presenting their form of the equation, the authors make an embarrassing mistake by including a factor representing "galactic habitability," the chance that a star lies in a part of its host galaxy that is suitable for life, as a pure number (*i.e.* the number of such stars) rather than as a probability. As a consequence, what they intended to represent as a pessimistic estimate for the number of planets with animal life becomes much more optimistic. Since the authors make no further use of their version of the equation, the error is not apparent.

What *Rare Earth* does well is to introduce readers to the wide variety of research currently being brought to bear on the fascinating question of life in the universe. Particularly good is the discussion, early in the book, of recent exciting discoveries in the area of extremophile bacteria and the implications of their resilience for life elsewhere. I also enjoyed the chapters on mass extinctions, Snowball Earth, and the origin and diversification of animals. Ultimately, however, the contingency of Earth's biological history sufficiently undermines the authors' arguments that the book becomes more a statement on the origins of Earthly biology than a judgement on the likelihood of extraterrestrial life.

Charles Curry

Charles Curry is a postdoctoral fellow in physics at the University of Waterloo, and a visiting astronomer at the University of Western Ontario. He lives in London, Ontario.

The Astrophysical Journal: American Astronomical Society Centennial Issue, Selected Fundamental Papers Published This Century in The Astronomical Journal and The Astrophysical Journal, edited by Helmut A. Abt, pages 1283 + ix, 22 cm × 295 cm, University of Chicago Press, 2000. Price $50 US, clothbound (ISBN 0–226–00185–7), plus add $20 US for shipping outside the U.S.A.

The Centennial Issue of *The Astrophysical Journal*, officially designated as Volume 525, Number 1C, Part 3, is a collection of 53 papers published in *The Astronomical Journal* and *The Astrophysical Journal* during the past millennium. It was published as a special centennial project to honour the first century of existence of the American Astronomical Society (AAS), the official publisher of the two journals in question. The special issue is a hefty volume that weighs 3.3 kg, probably about the same amount as a standard volume of *The Astrophysical Journal* of today.

As noted in the introduction by Helmut Abt, the collection of 53 fundamental papers that comprise the *Centennial Issue* also includes short commentaries by 50 selected astronomers indicating why they feel that the selected paper was of fundamental importance to the field. It is the commentaries that make the volume a "must read" for historians of astronomy, since they nicely summarize the characteristics of the chosen papers that qualified them for inclusion in the special issue. But, as also noted by Abt, the actual selection of articles depended very much upon the selection of "experienced and expert astronomers" who were asked to take part in both the selection process and the writing of short commentaries. The articles eventually included in the special issue are therefore in large part a product of the criteria used to create the volume. Indeed, gaps were noted in the original selection of paper topics, so an attempt was made to include a few additional papers that would "fill those gaps."

I suppose that just about anyone could take issue with what is and is not included in the *Centennial Issue*. I noticed a few rather glaring gaps myself (I would have voted for Upton's 1970 *Astronomical Journal* paper on a new technique for measuring the Hyades distance modulus), and also took note of the fact that 46 of the 53 papers are from *The Astrophysical Journal*, while only four are from *The Astronomical Journal* and three from The *Astrophysical Journal Supplement Series*. On the other hand, the 53 selected articles are a reasonably good collection of what are undoubtedly some of the more obvious fundamental papers published over the last one hundred years, at least in AAS publications. A true compendium of fundamental papers published over the last century would undoubtedly have included many additional articles published in European journals, and I am thinking of some of the works of Eddington, for example. But it is only a minor quibble. It seems only fair that the AAS celebrate its centennial by republishing articles from its own publications.

A truly thorough review of the

Centennial Issue would mean reading all of the reprinted papers and their commentaries, something that proved beyond the grasp of this reviewer. However, one cannot peruse the volume without delving into it closely. It is something like eating salted peanuts. Often the commentaries entice one into reading the selected paper. Sometimes the selection of the paper for inclusion in the volume seems obvious to the reader, but one is curious to know what someone else had to say about it. It is certainly a fascinating read throughout, if one has the time to examine the individual entries closely.

If you are interested in having a collection of some of the most fundamental articles in astronomy and astrophysics published in the last century, the *Centennial Issue* is well worth adding to your collection. Nearly all of the milestone papers in their fields are included here, along with additional commentaries by those scientists who selected them. I initially wondered about the selection by Jesse Greenstein of his own paper with Maarten Schmidt on the quasars 3C 48 and 3C 273. Surely self-selection must be against the rules of the game? But the commentary actually adds a lot of background information and further details help to elucidate the thinking of the era — the mid-'60s — when the paper first appeared. Likewise, it was interesting to see included a few papers that are now well-worn, dog-eared photocopies in my own files. Johnson and Morgan's 1953 paper on stellar photometry is one of them.

The selected papers are also good reads in their own right. As noted by Abt in his introduction, the writing style for scientific papers during the first half of the century was more sedate and instructive than it is at present. One cannot help but be impressed, for example, by Fritz Zwicky's marvelously instructive paper from 1937 on the masses of galaxies in clusters. Current researchers might be tempted to ignore the paper based upon all of the negative stories they may have heard about Zwicky's personality. But, as noted by Jeremiah Ostriker in his commentary on the article, "I have chosen to report on an extraordinarily prescient paper...," followed by an excellent summary of all of the features of the paper that made it a milestone in its field.

It is also instructive to see all of the *short* papers that made it into the volume, such as Nancy Roman's delineation of high-velocity weak-lined F and G stars as well as Salpeter's brief note outlining the details of the triple-alpha nuclear reaction sequence. Likewise, there are papers included that I had previously heard were fundamental papers in their field but had never had reason to refer to because they lay outside my own realm of interests. Roger Ulrich's 1970 paper on the five-minute oscillations of the Sun is an example. Nor is there any obvious bias towards recently published papers. The earliest paper included is from 1905 (Schuster's paper on radiation through a foggy atmosphere), and the most recent from 1990 (Lasker *et al.*'s paper on the Guide Star Catalogue). There is perhaps some selection bias towards papers from the '50s and '60s that may have been engendered by the choice of the selection panel. Otherwise, the only complaint one might have is that more papers were not included. This volume is an excellent addition to the library of any serious researcher in astronomy and astrophysics.

David G. Turner

David Turner teaches astronomy and physics at Saint Mary's University and is the review editor for the Journal.

The Star of Bethlehem: The Legacy of the Magi, by Michael R. Molnar, pages xvi + 187, 14.5 cm × 21.5 cm, Rutgers University Press, 1999. Price $25.00 US hard cover. (ISBN 0–8135–2701–5)

Ah yes, the mystery of the Star of Bethlehem continues to haunt us some two thousand years after the event in question, if it indeed occurred. Who among us has not looked out at the clear skies of late December and not wondered about that most ancient of all puzzles — the miraculous star described in the Book of Matthew and how it guided the Magi to Bethlehem where they paid homage to the newborn messiah? The appearance of yet another monograph on the Star of Bethlehem is something that I look forward to every Christmas, because it is at about that time of year that book promotions for such items begin in earnest. That was indeed the case for *Legacy of the Magi* when it hit the book stands around December 1999.

Before I even received a copy of *Legacy of the Magi* for assessment, I had read a glowing review of the book by Bradley Schaefer published in *Sky & Telescope* (December 1999) and also received an e-mail message indicating that the book was the ultimate astronomer's solution to the age-old riddle of the Star of Bethlehem. It was therefore with some anticipation that I began my own perusal of *Legacy of the Magi*.

My impressions of the book clearly differ from those of others. To me the book is a great disappointment and does not live up to its advance billing. The background information presented on the Star of Bethlehem is not as thorough or enlightened as in some other works, and the "solution" to the Star presented here leaves a number of questions unanswered. I also thought that the author went a bit too far in deriving an exact date and time for the birth of Jesus, but I suppose that is a typical complaint for someone raised as a skeptic.

The basic premise of *Legacy of the Magi* is that there is no point in searching for an astronomical origin for the Star of Bethlehem. According to Molnar, the language used to describe the Star in the Book of Matthew is that of astrology, not astronomy. One must therefore look for an explanation of the Star using astrological, not astronomical, knowledge. It is here where *Legacy of the Magi* takes a completely different tack from most other books on the Star of Bethlehem. Molnar goes to great lengths to describe the basic concepts of the astrology of the Ptolemaic era and how they can be used to identify a likely time when all of the astrological precepts would have been favourable for the birth of a Jewish messiah. The most favourable date, according to Molnar, was April 17, 6 BCE at sunrise.

It takes a bit of development for Molnar to reach the stage of introducing the full details of ancient astrology and how they were used to create natal horoscopes. Since Molnar has no interest in other explanations for the Star, they are given only short descriptions in *Legacy of the Magi*. Molnar also has interests in numismatics as well as the Star of Bethlehem, and uses evidence from the faces of minted coins from ancient imperial Rome to back up his astrological arguments for the origin of the Star. In short, the portends for April 17, 6 BCE include, if I understand them correctly: the location of the Sun exalted in Aries, a constellation associated with Palestine, a regal portent in Venus being exalted in Pisces, the Sun located in its trine of Aries along with its two co-rulers Jupiter and Saturn, which also serve as the Sun's attendants rising immediately before sunrise, Mars and Mercury serving as attendants of the Moon and rising after moonrise, a beneficent configuration, Mars present in the trine (Taurus) of which it is co-ruler, and an occultation of Jupiter by the Moon.

Of course, all of the previously-stated favourable aspects apply to anyone born on the date in question, so one would need a special reason to select one individual in particular as the expected messiah. And there are a variety of other dates where one could find comparably good portends, so why should April 17, 6 BCE be different? But such quibbles apply to just about every solution ever proposed for the Star. In addition, the details listed apply not to the planets as they appeared in the actual sky but to where they fell in an astrological chart. The existence of precession of the equinoxes guarantees that, even two thousand years ago, the vernal equinox was no longer located in Aries, but in Pisces. That is a minor point according to Molnar, who has derived his astrological lore by using the literature to infer information about astrology of the Ptolemaic era.

It is here that I take issue with the arguments presented by Molnar. The implication is that the Magi referred to in the Book of Matthew were simply astrologers of that era rather than more enlightened astronomers. By that I mean they were more interested in examining astrological charts than the actual sky, perhaps something like "arm-chair astronomers" of the present era. I am not sure that is a correct assumption. Sumerian astronomers appear to have been keenly interested in everything that happened in the actual sky, for example, and there is apparently evidence from preserved clay tablets that they *did* record the triple conjunction of Jupiter and Saturn in Pisces during 7 BCE. On astrological charts that triple conjunction occurred in Aries not Pisces, but it was recorded as having taken place in the latter. Likewise, once the discovery of precession had been promulgated to other savants of that era, surely it must have played a role in the interpretation of astronomical events?

As noted by Alex Gurshtein, the dimensions and names of the zodiacal constellations argue strongly that they were first depicted at different epochs in the past when the main cardinal points of the ecliptic — vernal equinox, summer solstice, autumnal equinox, and winter solstice — were located in those particular portions of the sky, beginning initially with Gemini, progressing to Taurus, then Aries, and, by the time of Hipparchus and the discovery of precession, to Pisces, one of the four original constellations of the Gemini quartet. Gurshtein's arguments also imply that the existence of precession must have been well understood even before the time of Hipparchus. Why else would the ancients have gone to such trouble to identify new star groups with the celestial cardinal points? It is an interesting concept that leads one to believe that perhaps the Magi were simply the true astronomical, not astrological, savants of their era, that they recognized the triple conjunction of 7 BCE between Jupiter and Saturn in Pisces for the unique event that it was — the first and *only* triple conjunction of the two planets in the constellation symbolizing the new Piscean era — and journeyed to Judaea to set the wheels in motion for the story contained in Matthew. But I digress to my own personal favourite explanation for the Star.

An astrological explanation for the Star was first proposed by Michael Molnar in 1995 in the *Quarterly Journal of the Royal Astronomical Society* (QJRAS, 36, 109, 1995), although in somewhat greater detail. In that previous work he also argued that Jesus was born on March 20, 6 BCE, with the visit by the Magi taking place on April 17, so he clearly refined his views a bit in *Legacy of the Magi*. The latter is his first monograph-length treatise on the original arguments he made in 1995. There is actually a bit more detail in the earlier work, and certainly many more diagrams.

The author approaches the subject of the Star of Bethlehem from the viewpoint of a trained astronomer who is also the manager of the Physics Instructional Laboratories at Rutgers University, at least that is how he is described on the flyleaf of the book. It is not the first book about the Star of Bethlehem written by a professional astronomer/physicist, however. *The Star of Bethlehem: An Astronomer's Confirmation* by David Hughes is still in circulation (it was sold in Canada under the title *The Star of Bethlehem Mystery*). But simply having "proper" academic credentials does not necessarily imply a thorough knowledge of this field of astronomy. The Star of Bethlehem is a topic that involves a variety of different disciplines, from observational astronomy and ancient history to numismatics and theological studies. And any explanation for the Star at this late date must surely involve an argument that is convincing in all respects. My personal opinion is that the case is still open.

The true merits of Molnar's book lie in the collection of astrological lore that he brings to the study of the Star of Bethlehem. The book is a gold mine of information about how to construct and interpret astrological charts, and gives a few examples to illustrate the subject. Molnar does the scientific community a great service by bringing such information into an interesting setting, namely the scientific mystery of the Star of Bethlehem. I recommend it for that reason alone. But it is not the definitive book on the topic and presents only cursory information about alternative solutions. There are alternative solutions to the mystery that are just as informative, and perhaps slightly more convincing in some respects.

David G. Turner

David Turner teaches astronomy and physics at Saint Mary's University, and is the review editor for the Journal. *In a previous "life" he spent six years as director of the Doran Planetarium at Laurentian University in Sudbury, where, among his other responsibilities, he wrote, produced, and directed several Christmas Star shows.*

Star Map, by Rob Dick, 1 sheet, double-sided, laminated, 28 cm × 43 cm, Starlight Theatre, P. O. Box 79, Rideau Ferry, Ontario, Canada, K0G 1W0, 2001. Price $12.00 Cdn plus $6.00 shipping and handling. (ISBN 0–9685970–1–7)

The colloquium that day at Saint Mary's University was about computer modeling of Type Ia supernovae core collapse and was actually quite interesting. In spite of the fact that the subject matter was (literally and figuratively) AUs over my head, I learned a few things about what goes on when big stars cave in. The mistake that I made, however, was to wander into Dave Turner's office afterwards to ask him a question about stellar structure. He answered my question but then said, "Here. Review this for *JRASC*!" as he shoved something into my hands. The something in question turned out to be two versions of Rob Dick's all-sky charts.

Several Halifax Centre members have the charts, so I had at least a passing acquaintance with them. The first edition (1999) is black and white and the second edition (2000) is in colour and contains additional information to the earlier version. Both versions of the maps plot stars to fifth magnitude with an equatorial chart on one side and polar projections of the north and south polar skies on the other side. All of the charts are bounded by scales of date and right ascension, as well as declination. The equatorial chart clearly illustrates the ecliptic and celestial equator. All charts show the contours of the Milky Way through the star field.

The constellations are drawn as labeled stick figures, with the names of the brightest stars included. Thick gray lines illustrate the well known asterisms of the Big and Little Dippers, Cassiopeia's "W," the great square of Pegasus, the summer triangle, Orion, Leo, and the southern cross. The brightest Messier and NGC objects are included, as are the radiants for the Leonid, Quadrantid, Geminid, and Perseid meteor showers. The colour version shows many of the brighter stars with colour symbols corresponding to their spectral classification, and also includes the magnitudes of many of the stars.

Both versions of the chart contain a symbol key, brief instructions for getting the most use out of the chart, and a short list of suggested visual observing projects. There is also a note on light pollution tucked in the bottom corner of the chart.

The charts are obviously intended for novice sky watchers, and both serve the purpose very well. There is ample information here to help a beginner become familiar with the night sky and the annual parade of constellations. The newer colour version contains more information and is very attractive visually, but outside in the dark it does not serve as well as the black and white version. The very fine white lines and lettering against the blue background are hard to see — there is not enough contrast under a red light to distinguish easily the letters and numbers. The red, yellow, and orange stars all look the same under a red light, but that is not too important for a beginner's sky chart. The earlier black and white version is great when used at night with a red light. I had a fine time touring the sky with binoculars and picking off all the chart's objects that were visible in my midnight July sky. The fact that the chart is laminated makes it durable and resistant to moisture.

Both charts become educational and entertaining reading at lunchtime when they can also be put to use as astronomical place mats. Invite your neighbour over for lunch and see if the chart doesn't spark a conversation about the stars! I like the charts and find it handy to have such a quick sky reference readily available. They have made a welcome addition to the bookshelf at my cottage where they will be put to good use on clear, starry nights.

Mary Lou Whitehorne

Mary Lou Whitehorne is a life member of the RASC, and has been very active for many years at both the local and national levels. In recent years her energies have been directed towards improving astronomy education across Canada. Mary Lou holds both the Messier and Finest NGC Observing Certificates, as well as the Chant Medal.

The Bigger Bang, by James E. Lidsey, pages 134 + ix, 24 cm × 16 cm, Cambridge University Press, 2000. Price $19.95 US, hardcover (ISBN 0–521–58239–X).

James E. Lidsey is a Royal Society University Research Fellow at Queen Mary and Westfield College, University of London, UK. He has published in research journals many articles concerning cosmology, inflation, superstrings, and black holes, and is certainly an expert on the early universe. His book *The Bigger Bang* explains some of the important topics in cosmology, namely the Big Bang and the theory of inflation. The reader is taken through a history of the universe, from the Planck time up to today, with an emphasis on the early epochs where particle physics and grand unified theories are important. The book contains several simple diagrams and no formulae, and is written for the general public.

In the book's first five chapters, Lidsey discusses the structure of the universe, what makes stars shine, the expansion of the universe, space-time and gravity, and particle physics. Since Lidsey assumes that the reader has no prior knowledge of physics, several times the author explains in simple terms a physical principle before describing its application. For example, Lidsey first explains electronic transitions and the Doppler effect, and them moves on to emission spectra of distant galaxies and the expansion of the universe. Unfortunately, many of the descriptions of physical phenomena are worded in such a way that they are ambiguous or misleading. For example, to describe absorption lines in the solar spectrum, Lidsey writes: "An identical effect arises when sunlight is passed through a prism onto a piece of photographic film. Once the film has been developed, the resulting photography resembles a picture of a rainbow. However, a closer look at the picture reveals dark bands. These regions are so thin that they look as if someone has drawn a vertical line on the photograph with a black pen." Anyone familiar with stellar spectra would skim over that excerpt with familiarity, and mentally picture a rectangle containing the colours of the rainbow in vertical bands, with dark vertical lines superimposed. The non-expert quickly runs into trouble, since they will recall a picture of a rainbow with a big circular arch, and then have no idea where the dark vertical lines are supposed to be.

There are a few instances where the problems are more serious. For example, while discussing the expansion of the universe, Lidsey shows a plot of the size of the universe (technically called the scale factor) versus time. There are three different cases, depending upon whether the universe is closed (eventually collapses), open (expands forever), or critical (the threshold between open and closed). Lidsey states that an "important feature" of the three different lines indicating the evolution of the scale factor with time is that they never intersect (disregarding the intersection at time zero), and then makes several points regarding that observation. However, the lines on his diagram are not accurate; careful plotting reveals that the lines do indeed intersect.

Lidsey frequently makes use of simple, easy to understand analogies to explain complicated physics. In most cases the analogies work well, but there are some notable exceptions. For example, when describing the spin of a particle, Lidsey writes: "The amount of spin that a particle carries determines its rate of rotation. We can view spinning particles as rotating about an axis." That leads the reader to believe that an electron is a little spinning ball. However, electron spin is *not* a classical top-like rotation; it is purely a quantum mechanical effect.

There are also several instances where Lidsey should have given more detail. Inflation produces a flat universe, and Lidsey explains the concept by stating that the lines on the plot of the scale factor versus time get closer to the critical case, but he never provides any physical reasoning. When explaining supernovae, he gives no mention of the explosion mechanism, and the reader is left wondering what causes the star to blow itself apart.

The final chapter of the book discusses the birth of the universe. In one scenario, Lidsey describes how conditions inside of a black hole might lead to inflation, and subsequently form another universe. It does make for interesting reading, but the highly speculative nature of the ideas could have been emphasized more.

Overall, the book would be satisfactory for someone who already has some knowledge of physics and cosmology. Someone wanting an introduction to cosmology should look elsewhere.

Todd Fuller

Todd Fuller has recently completed a Ph.D. in astronomy at the University of Western Ontario. His research interests include cosmology, and specifically hydrodynamic simulation of primordial objects in which the very first stars formed.

Obituary
Necrologie

A. E. Covington
(1913–2001)

Arthur Edwin Covington died peacefully in his 88th year at home in Kingston, Ontario, on March 17, 2001 after a lengthy illness. He is survived by his wife Charlotte and their four children: Nancy, Eric, Alan, and Janet.

Canada's first radio astronomer and founder of the daily 10.7-cm solar flux patrol was born in Regina and educated in Vancouver. From his youth, Covington was deeply absorbed with radio science and astronomy. Graduation in mathematics and physics from the University of British Columbia in 1938 led to a Master's thesis on lens design for electron microscopes. In 1940 he began graduate studies in nuclear physics at the University of California, Berkeley, where he met and married fellow physics student Charlotte Anne Riche. The Covingtons moved to Ottawa in 1942 to contribute to Canada's wartime research effort in radar at the Radio Branch of the National Research Council's Laboratories (NRCL).

At war's end the greatly expanded NRCL turned to peacetime projects. Well aware of Jansky's and Reber's prewar discoveries of 'cosmic radio noise' at metric wavelengths, Covington proposed to use converted radar equipment operating at a wavelength of 10.7 cm to probe the galactic centre. He intended to measure the Sun's decimetric emission merely as a calibrator for deriving the cosmic-noise spectrum. His first attempts in July 1946 to measure the integrated flux over the solar disk did not produce consistent flux levels day-to-day. Uncertain whether the problem lay with his instruments, local interference, or the Sun — it was an active period with large sunspots — Covington struggled to interpret these inconsistencies until alerted by his wife to a forthcoming partial solar eclipse visible from Ottawa on 23 November 1946. He seized this chance to measure the solar flux variations as the Moon occulted a large sunspot. He thus provided the first decisive proof that dark sunspots are associated with discrete hot sources of decimetre-scale radiation. A year later, following months of uninterrupted daily measurements of the integrated flux, he established that the variability of the 10.7-cm flux closely matched that of the sunspot numbers as both were modulated by the comings and goings of active regions and the solar rotation.

Other wartime developments at NRCL were quickly adapted for advancing Covington's ground-breaking studies of what came to be called the slowly-varying component of solar radio emission. A unique combination of a 46 metre-long slotted waveguide and two parabolic cylinders, erected in 1951 south of Ottawa as one of the earliest compound microwave interferometers, was the first device built in Canada to detect radio emissions from discrete astronomical sources. Its narrow fan beam enabled Covington and N. W. Broten to measure solar limb brightening and the temperatures above isolated sunspots. Covington and W. J. Medd began a series of experiments in the early 1950s to improve the relative and absolute observation accuracies of the integrated flux, thereby laying the foundation for future confidence in the daily 10.7-cm flux as an objective index of solar activity.

These early successes paved the way in the next decade for the NRC to establish the Algonquin Radio Observatory for galactic and solar astronomy at a remote radio-quiet site beside Lake Traverse, Ontario. Covington chose to continue with solar research for the rest of his career. He had from the beginning grasped the practical importance for solar-terrestrial research of the 10.7-cm flux as a proxy for ionizing solar radiation. His persistence in raising the quality of the measurements to the highest standards was rewarded by the ever-growing list of applications for the daily 10.7-cm flux and the consequent extension of the monitoring program long past his retirement in 1978. The program, now in its 54th year, continues at the Dominion Radio Astrophysical Observatory near Penticton.

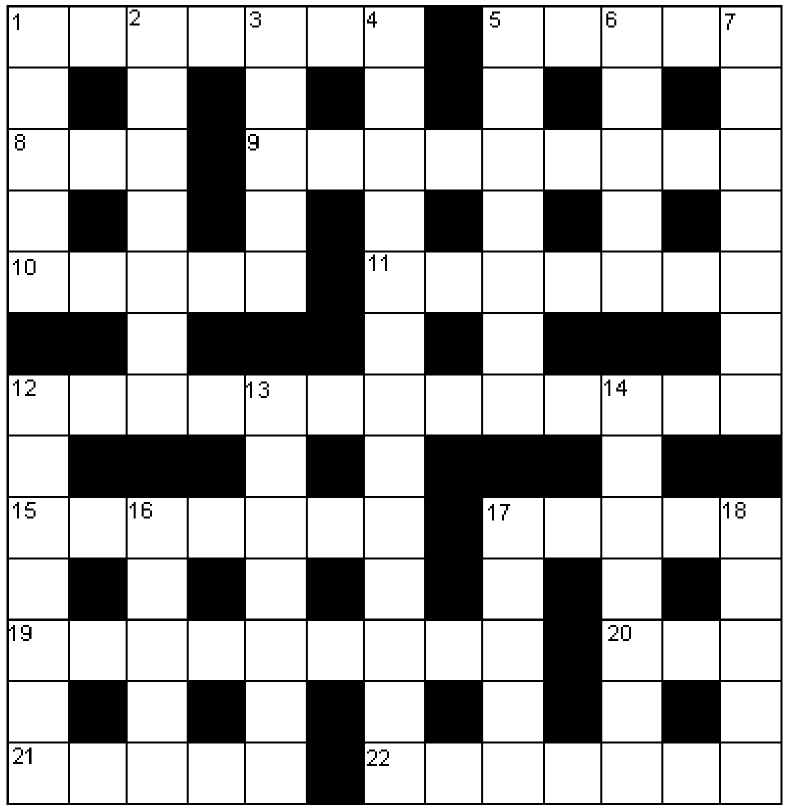
Shortly after he retired, Covington's colleagues at NRCL honoured him by erecting, at a site overlooking the building where he pursued his solar researches for over 25 years, a unique sundial: a 0.9-m parabaloidal reflector supported on a framework of 10-cm waveguide, with a 10-cm dipole feed at the focus as a gnomon.

Beneath his reserved, orderly exterior there lay a quirky sense of humour and a generous spirit. Covington never forgot that his youthful passion for astronomy was nurtured among amateur enthusiasts in the RASC. He contributed generously, and with evident pleasure in many ways throughout his career, to the Ottawa Centre. He was an avid collector of books — new and old — that reflected his wide-ranging interests, particularly in the history of radio science and the interrelationship of astronomy with other disciplines. He was fascinated by arcane topics as well, such as religious mysticism, especially if they had a solar connection. He and Charlotte set up the Riche-Covington Trust at Queen's University, Kingston, to house his collection on the development of radio science in Canada. He leaves these tangible legacies, but his many friends will fondly remember him as much for his devotion to his family and to solar science.

– V. Gaizauskas, Ottawa
(victor.gaizauskas@nrc.ca)

Astrocryptic

by Curt Nason, Moncton Centre



ACROSS

1. Celestial square corner mixed in bagel (7)
5. Didn't quite rise in the afternoon after the light bender (5)
8. Moore's new address is half of winter's luminary (3)
9. In the Virgo cluster, his karma is all wrong before a bad rain (9)
10. Lunar crater makes Ms. Rubin spin at the beginning of the year (5)
11. Requiring editor in negative of *Journal* staff photo (7)
12. Troubled clues misled starhopper near Cassiopeia (6,7)
15. Thousand dollar debts accrued around little shot when near full (7)
17. I leave Altair in the direction of Ara (5)
19. Pee matter abstracted from spectra of Jovian zones (9)
20. Born in Quebec City or northeast England's capital (3)
21. Caldwell and Messier made them sit around in Lake Superior (5)
22. Do they have a field of view of about 57 degrees?

DOWN

1. Tharsis ridge bulge in picture from Mars I and II probes (5)
2. Our astronaut within dubious range of an astronomical unit (7)
3. Leonard turns in at the return of a Hebrew day (5)
4. Unusual beer is in reach of Egyptian locks (9,4)
5. Baseball's home is 93 million miles from a filled crater (7)
6. Binary H radio wavelength (5)
7. Nagler lost fifty after mother was the boss (7)
12. Tail around after archaeologist's work to perform type of imaging (7)
13. Leo lost Regulus to her, knowing less about a particle (7)
14. Uranian satellite exploded, ain't it a shame? (7)
16. Placing three stellar classes in a barred spiral fails miserably (5)
17. Comet co-discoverer involved in stellar ending (5)
18. Birds can't fly around Saturn south (5)

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The most current contact information and website addresses for all centres are available at the society's website: **www.rasc.ca**

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c/o Calgary Science Centre, P. O. Box 2100, Station "M", Loc #73, Calgary, AB, T2P 2M5

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P. O. Box 842, Station B, London, ON, N6A 4Z3

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c/o Dr. Francis Leblanc, Departement de Physique et d'Astronomie, Université de Moncton. Moncton, NB, E1A 3E9

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c/o 206 Frecker Drive, St. John's, NF, A1E 5H9

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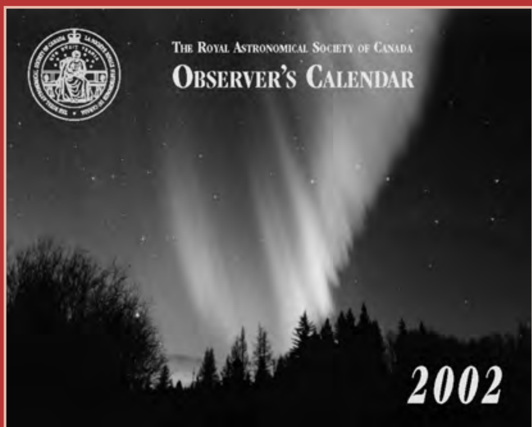

Observer's Calendar — 2002

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).

Price: $15.95 (members); $17.95 (non-members)
(includes postage and handling; add GST for Canadian orders)

The Beginner's Observing Guide

This guide is for anyone with little or no experience in observing the night sky. Large, easy to read star maps are provided to acquaint the reader with the constellations and bright stars. Basic information on observing the Moon, planets and eclipses through the year 2005 is provided. There is also a special section to help Scouts, Cubs, Guides and Brownies achieve their respective astronomy badges.

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

Price: $15 (includes taxes, postage and handling)

Promotional Items

The RASC has many fine promotional items that sport the National Seal. Prices include postage and taxes. Included are a *Cloth Crest* (size 11cm with the background white and the stitching in royal blue - $11), *Lapel pins* (blue, white, and silver - $5), *Golf shirts* (white, available in small and medium - $24), *Stickers* (size 7.5cm, blue with white overlay - $1 each or 2 for $1.50), *Thermal mugs* (in blue and white - $5.50), *Toques* (Black with Yellow lettering - $17), *Key chains* (Clear arcylic and Blue/white - $2.50).

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