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Journal

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August/août 1999

Journal

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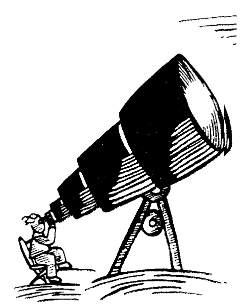

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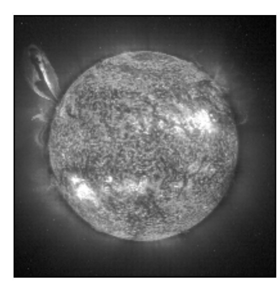

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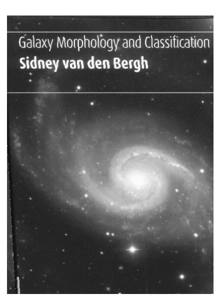

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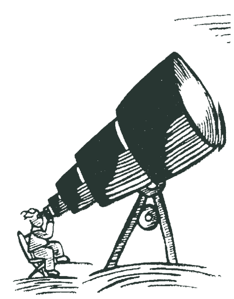

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Cover:
A feast of summer delights is included in this issue - enjoy!

(PhotoMontage by Brian G Segal)

From the Associate Editor

by Patrick M. Kelly

It has been said that the only thing that never changes is change itself. As the editor of any periodical will tell you, one of the changes that they truly hate to see is the loss of a good columnist. Orla Aaquist, the author of "The Light Side of Research," has decided to go into "retirement." He is moving from Fort McMurray to take up a new position at Grant MacEwan College in Edmonton and "will not have much time to be inspired to write anything that concerns research (humorous or not) until I am settled… Before I leave Fort McMurray I hope to produce a CD of some of my astronomy songs; if all goes well, I'll send a copy… Perhaps you can include a sampler CD with one of the issues." His sense of humour will be missed, but he has promised that if he is able to start doing research again, he will try to send the occasional missive.

It has also been said that with every ending there is a new beginning. I would like to welcome our newest contributor, Barbara Silverman of the Montreal Centre. If I did not know better, I would swear that in order to become a member of the Montreal Centre you first have to show that you can write well about astronomical topics by making submissions to *Skyward*, the Centre's newsletter. She will be making semi-regular contributions on the subject of the history of astronomy. She plans to write on the history behind astronomy, including biographies of the well-known and not-so-well-known people who have contributed to our knowledge of the stars, as well as the legends and stories that have evolved down through the years. In this issue you will find her first submission, a look at the life of Leslie Peltier. I hope that you enjoy reading it as much as I did.

Lastly, for many amateur astronomers, the summer and early fall is their favourite observing season, no doubt because of the combination of warm weather and a plethora of objects to choose from. If you have ever wished to go to the tropics to enjoy the "winter" sky under conditions more amenable to the human body, there is a way to do it from Canada if your schedule allows it. In late summer and early fall, the winter skies are there for the viewing, as long as you do your observing before dawn. Even in mid-September, Orion is high in the pre-dawn sky. If you are a "night owl" like me and do not enjoy getting up in the early morning, your best bet is to wait for a good observing night, bring along the I.V. bag full of Tim Horton's coffee, and stay up all night. You will get to observe the winter skies without snow underfoot or frozen toes. One suggestion: do not attempt to be at work for 8:00 A.M. the next day.

Journal

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

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President's Corner

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

To coincide with the General Assembly and Partners in Astronomy conference, Toronto Mayor Mel Lastman proclaimed that for the week of July 1–7, Toronto was to be known as the "Centre of the Universe." By the weekend, when the humidity made it feel like it was 45°C, it felt more like Toronto was at the centre of the Sun! Fortunately, all the sessions during the week were held in air-conditioned buildings.

The 1999 General Assembly, Astronomical Society of the Pacific (ASP) Universe '99 lecture series, American Association of Variable Star Observers (AAVSO) papers session, and Partners in Astronomy symposium were a complete success. For seven days we were treated to interesting lectures, papers, and discussion groups. It was an opportunity for many RASC members to meet and share ideas with members of other organizations with similar interests.

The General Assembly began with the traditional Murphy slide night, which is evolving into a National Members night — an evening where members can present whatever they wish — slides, videos, reports on activities at their centre, observing reports, and the odd, unexpected song or poem — a great evening. Although it was a little cloudy on Canada Day, many members visited the observatories of the McLennan Physics Building and had a beautiful view of downtown Toronto from the roof.

On Friday, papers were presented on various topics. A paper on a dark sky reserve in an Ontario park received much media attention. The evening activity was a trip to the Ontario Science Centre. After a reception and light meal, the IMAX movie Cosmic Voyage was viewed.

Saturday was a busy day. One requirement at a General Assembly is that we hold our Annual Meeting. I am pleased to announce to the membership that, at that meeting, the Bylaw Amendments were adopted. An up-to-date copy is available at the Society's web site (`www.rasc.ca`). Congratulations to Michael Watson and the other members of the Constitution Committee on their hard and excellent work. Congratulations and welcome to our new National Secretary Kim Hay.

The series of Universe '99 lectures was extremely interesting. Topics included astrophysics, comets, astrology, and cosmology — definitely something for everyone. The Ruth Northcott lecturer was Geoff Marcy. During his talk on the Revolution in Planetary Systems, he discussed his team's discoveries of planets around nearby stars. His talk was preceded by an organ recital by University of Toronto organist John Tuttle. He played the Jupiter movement from Holst's *The Planets* on the magnificent organ in Convocation Hall — it was a real treat. The Awards Banquet on Saturday evening consisted of award presentations for all three societies.

After the Universe '99 weekend, the three day Partners in Astronomy symposium began. I must admit I was amazed at the number of amateur astronomers who are involved in research programs with professional astronomers. Hopefully, the Partners in Astronomy symposium will be held again in the future. Congratulations must go to Dr. John Percy and his team of volunteers for organizing and running a superb seven-day meeting. I suggest everyone make plans now to visit Winnipeg in July 2000 for the next General Assembly.

I am afraid my busy schedule has prevented me from getting out to some dark skies to work on my Messier certificate. I am glad to see that many members are getting out to work on their lists and completing them. Some London Centre members will soon be making special Messier and NGC pins available to those who have attained their certificates.

During the entire Partners in Astronomy week there was one theme which kept popping up. The theme was astronomy education — educating the public and students. A two-day Teachers' Symposium was held on the Friday and Saturday of the General Assembly, and was attended by 200 teachers. This fall a new school curriculum will be in place in Ontario which will make astronomy education mandatory in Grades Six and Nine. At the National Council meeting, a new education committee was created. I hope the committee will be active in providing assistance to the hundreds of teachers who will be teaching astronomy for the first time.

A year ago in this column I told you what my objectives were to be during my two-year term of office. Now at the half-way point, I am glad to tell you that my first year's objective — to have a new computer system up and running at the National Office — is nearly complete. Over the next year I hope to promote the Society to Canadians through our publications, increase communications with schools, and ensure that procedures in the National Office and throughout the Society are completely documented. We still have a lot of work to do.

I invite members to contact me with any ideas or suggestions regarding the running of our organization.

Photo Opportunity!

The group picture taken at the 1999 General Assembly in Toronto is available from the National Office. Please send a cheque for $7 (postage and handling included) made payable to "RASC." Information on who is who will be posted on the RASC web site.

Correspondence
Correspondance

ONE HUNDRED AND FIFTY MESSIER CERTIFICATES

Dear Sirs,

This is just a note to say how thoroughly I enjoyed Peter Broughton's article (One Hundred and Fifty Messier Certificates) in the April 1999 issue of the *Journal*. May I be allowed to add a few tidbits of information from a Montreal perspective?

The first "published" mention of the Montreal Centre Messier Club was in the March 1947 "Observatory Activities" bulletin (the Centre's precursor to *Skyward*), where it was noted that Delisle Garneau was in first place in number observed while F. W. Henshaw and Isabel K. Williamson were tied for second place. Miss Williamson regularly reported on Messier Club activities in the pages of *Skyward*. In September 1949 she published the latest scores: twenty-three members of the Centre were involved, with Delisle Garneau in first place with 91 objects observed. Buried in 16th place was "T. Noseworthy" with 8 observed. By June 1951 Tom Noseworthy had raced past everyone on the list to become the Centre's first Messier Club graduate. Other significant graduates over the years were Dr. T. F. Morris (October 1957), who helped provide positive identifications for two "missing" Messier objects, M47 and M48 (see *Sky & Telescope*, October 1960), Dr. Heinz Lehmann (companion of the Order of Canada) in June 1960, and Dr. David Levy (July 1967), an amateur astronomer of some note!

The Montreal Centre has had twenty-seven Messier Club graduates over the years (with a 28th in the process of applying for his Messier Certificate). In addition to receiving a certificate from National Office, Centre members have their names engraved on a plaque at the I. K. Williamson Observatory.

Did other Centres have active Messier Clubs before the national certificate programme was instituted? Were there any graduates? I would be most interested in hearing from you.

Mark Bratton, mbratton@generation.net
President, Montreal Centre, RASC

Dear Sirs,

I note in Peter Broughton's interesting article "One Hundred and Fifty Messier Certificates" (JRASC, April, p. 71) that there are currently 110 members having observed the 110 Messier objects on the list in the *Observer's Handbook*. To increase the prestige of the award, and since we are happily at a numerologically favourable juncture, I propose that we limit the number of extant certificates held by living members to 110, and rename the award the 110–110 Award. (Messier would approve; he was looking for comets anyway.)

I also note your concern expressed in the editorial about the lack of appropriate material for an April issue, and also that there were no letters in the April issue. This letter is intended to remedy both omissions.

Martin Connors, martinc@athabascau.ca
Edmonton Centre

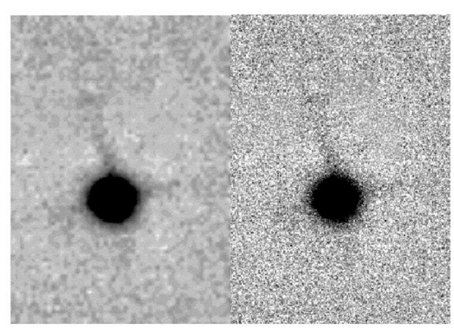
News Notes
En Manchettes

CFHT IMAGES QUASAR ENVIRONMENTS

Quasars are some of the most powerful and mysterious objects in the cosmos. Current thinking suggests that they may be driven by supermassive black holes lurking in the cores of distant, and hence early, galaxies. The relationship between quasars and their host galaxies are still unresolved, however. Do only certain types of galaxies support quasars? How does the host galaxy evolve with time? Those and other such inquiries are hampered by the enormous distances and luminosities of quasars, which make it difficult to view the host galaxy and its surrounding environment.

Using the Adaptive Optics Bonnette (AOB) on the Canada-France-Hawaii Telescope (CFHT), a group of Canadian astronomers has successfully imaged the immediate environments of nine such distant objects (March 1999 issue of the *Astronomical Journal*). The team, led by John Hutchings of the Herzberg Institute of Astrophysics' Dominion Astrophysical Observatory (DAO), included David Crampton, Simon Morris, Daniel Durand (all from the DAO), and Eric Steinbring of the University of Victoria.

Adaptive optics technology attempts to improve the resolution of a telescope



A *J*-band infrared image (covering wavelengths from 1.0 to 1.4 microns) of quasar 0804+499 (redshift $z = 1.43$), with full resolution on the left and with 4×4 pixel binning on the right to enhance visibility of the faint jet. The images are 8×11 arcseconds in size.

by minimizing the effects of atmospheric seeing. That is achieved by placing a small "rubber" mirror in the optical path of the telescope. Image distortion of a nearby guide star is detected by the adaptive optics system, and quickly analyzed. Commands are then sent to the rubber mirror, which is rapidly deformed in such a way that it corrects the distortion. Canadian engineers and astronomers have been world leaders in the development of such systems.

Hutchings and his team observed nine high–redshift quasars (with redshifts of between $z = 0.85$ and $z = 4.16$) at near-infrared wavelengths. Extensive and careful image processing revealed what appeared to be "tidal tails" extending from many of the quasars in the sample (see figure at left). Tidal tails are long filaments of stars and gas, gravitationally pulled out from a galaxy by either a nearby companion galaxy or the merger of two or more galaxies. The researchers also found that those quasars that are "radio-loud" have the richest surrounding environments, with numerous companions and possible tidal tails. Hutchings cautions that the sample is small, and definitive conclusions will have to wait until more quasars are imaged.

LIQUID MIRROR TELESCOPE GOES TO WORK

There have been only a handful of times in the history of astronomy when truly novel optical instruments have been introduced. Perhaps the strangest and most promising are parabolic mirrors made by spinning huge dishes of mercury. As the liquid metal spins, the centripetal acceleration combines with the Earth's gravity to shape the surface into a nearly–perfect parabolic reflector.

Large Liquid Mirror Telescopes (LMT) can be manufactured at a fraction of the cost of conventional solid mirrors. Of course, they are restricted to looking only at the zenith, since even the smallest tilt would cause the optical surface to become distorted, or even spill onto the floor of the observatory. Nevertheless, there are many important astronomical surveys that can be done with such unorthodox instruments. Astronomers are especially interested in surveying the sky for distant galaxies and quasars to help understand the large-scale structure and evolution of our universe.

Canadian astronomers and engineers have done much of the pioneering work on LMTs. Two groups from the University of British Columbia and Université Laval have led the way. Since 1982, large LMTs have been primarily engineering projects as the researchers attempted to tame the delicate technology. Now, after nearly two decades, actual scientific results have been published. A team led by Rémi Cabanac of the Université Laval, along with Ermanno Borra (Laval) and Mario Beauchemin (Natural Resources Canada), has successfully made use of an American LMT. The team used NASA's Orbital Debris Observatory (NODO) to search a narrow strip of the sky for peculiar celestial objects (December 10, 1998 issue of the *Astrophysical Journal*). Their instrument was a 3-metre telescope located near Cloudcroft, New Mexico, which was designed and built by Paul Hickson and his LMT team at the University of British Columbia. The original purpose of the telescope was to search for and analyze orbital space debris as small as 1 centimetre across.

Paul Hickson and Mark Mulrooney (NODO) provided the unprocessed observations used in Cabanac's study. For 34 nights in 1996, the telescope scanned a 20-arcminute wide strip of the sky that passed through the zenith of the observing site. Since the telescope itself could not be moved to compensate for the rotation of the Earth, tracking was done electronically in the CCD camera. As each object was carried across the detector's field of view by the Earth's rotation, its light was accumulated by the CCD electronics and stored in a computer, producing an equivalent guided exposure for each object of 97 seconds duration. Each object was imaged through 11 narrow-band filters that produced the equivalent of a very low dispersion spectrum for each object.

The survey produced 60 terabytes (60 trillion bytes) of data in total. Automated search routines then identified approximately 18,000 objects between visual magnitudes 10 and 19. From them, a statistical sorting method called hierarchical clustering analysis (HCA) divided the objects into groups by comparing their spectra with a "library" of typical stellar, galactic, and quasar spectra. After sources that were obviously variable were removed from the sample, there remained 206 objects that had spectra that did not match the library's database. The peculiar objects were then catalogued and examined. Included in the short list of oddballs were two optical counterparts to radio sources, two gravitational lens candidates, and 47 "blue objects" that may be hot subdwarf stars, white dwarfs, or quasars.

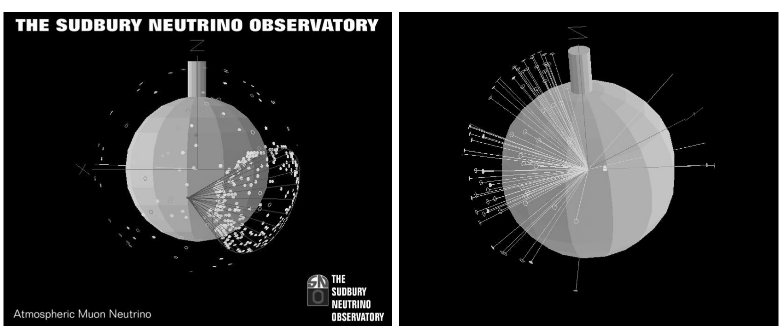
New LMTs up to 5.1 metres in diameter are currently being constructed, with even larger instruments on the drawing boards. Ermanno Borra is also experimenting with LMTs that can observe away from the zenith. Now that liquid mirror telescopes have moved from the inventor's machine shop into the observatory, the astronomical community may soon be swimming in data from liquid mirror telescopes.

SNO ON-LINE

The Sudbury Neutrino Observatory (SNO) has seen first light. As of April 1999, SNO had completed filling its detector with the required 1000 tonnes of heavy water inside an outer cavity filled with 7000 tonnes of ordinary water. In May 1999 SNO had begun to detect neutrinos, or rather the interactions of neutrinos in the detector. Those interactions produce charged particles (electrons or muons, depending on the neutrino type) that travel faster than the speed of light in water, while still slower than the speed of light in vacuum. The result is something analagous to a sonic boom, though we do not get a burst of sound, instead a burst of light radiating away from the particles path at a fixed angle — Cherenkov radiation.

Images from their Web site (www.sno.phy.queensu.ca) show the cones of Cherenkov radiation emitted as neutrinos, interacting within the detector, generated light that was captured by the array of photomultipliers surrounding a transparent sphere of heavy water. The first images, shown below, are of a solar neutrino (left) and a muon neutrino (right), the latter generated from cosmic ray interactions in the Earth's atmosphere. The solar neutrino produces an electron, which gets scattered around as it travels through the detector, so its Cherenkov cone is somewhat blurry. A muon neutrino produces a muon (2000 times heavier than an electron) that punches through the detector in a straight line, and hence produces a nice, clean Cherenkov cone.

The instrument was constructed to help solve one of the fundamental mysteries of astrophysics — why does the Sun appear to produce far fewer neutrinos than current theory suggests? One possible solution is that solar neutrinos change types as they travel from the Sun to the detector. Before SNO, neutrino detectors were unable to observe neutrinos in all their forms, just the type emitted initially from the Sun. To shed light on the puzzle, researchers will have to observe many more events of the type described here.



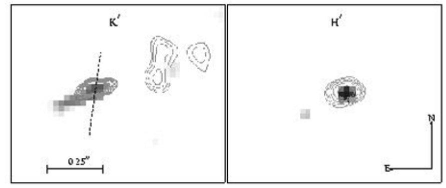
SOPHISTICATED DATA ANALYSIS FINDS NEUTRON STAR IN STRANGE LOCALE

Phil Gregory of the University of British Columbia, working with Marta Peracaula and Russ Taylor of the University of Calgary, has found a stellar odd couple in the form of a neutron star orbiting an unusual Be star. The latter is a massive star with a strong stellar wind, with emission lines in its spectrum arising from the fluorescence of the gas in the wind. The system, catalogued as X-ray source LS I+61°303, was initially detected in the Galactic Radio Patrol search for transient sources at radio wavelengths, but is now known to emit energy from the radio to the X-ray regions of the spectrum, and possibly as high-energy gamma rays as well. At all of these wavelengths, the energy output of this strange object varies, with radio outbursts on a 26.5-day period.

More recently, the object has been monitored with the U.S. National Radio Astronomy Observatory's Green Bank Interferometer, so that over 21 years of data are now available for analysis. Based on statistical techniques known as Bayesian analysis, the team's results, recently submitted to the *Astrophysical Journal*, suggest that the radio outbursts have a secondary pattern of variation with a time scale of 1584 days. While the 26.5-day period appears to represent that of a neutron star orbiting in the wind of the Be star, the secondary period appears to be associated with variations in the Be star wind itself. Such a periodic wind has not previously been observed for a Be star, thus underlining that this unusual stellar system provides a natural probe of the Be star wind by having a neutron star move through it.

DUST FORMATION IN A HOSTILE ENVIRONMENT

Interstellar space contains not only very thin gas but also dust, as one can readily see by looking carefully at the dark regions of the summer Milky Way. Researchers at the Université de Montréal have recently detected the formation of dust in an unexpected place. Rather than forming in the atmosphere of a cool star, as is suspected to be the case for most dust, this dust is found in a binary system composed of stars of the hottest known types.



The images of HD 192641 (WR 137) above are maximum entropy-restored, and subsampled by a factor of three. The different scales of gray correspond to different logarithmically-scaled intensities in the infrared *H′* and *K′* bands as observed in 1998, while the contours depict the infrared *H′* and *K′* images as obtained in 1997. The dashed line indicates the probable orientation of the projected axis of symmetry of the flattened wind of the Wolf-Rayet star, according to spectropolarimetry of the star.

Tony Moffat, Sergey Marchenko, and Yves Grosdidier used the Near Infrared Camera and Multi-Object Spectrograph (NICMOS) of the *Hubble Space Telescope* to discover a dust cloud surrounding the hot binary star HD 192641. The components are a blue O-type star and a yet-hotter Wolf-Rayet star rich in carbon. Both stars have strong stellar winds, and when they collide with a relative speed of about 4000 km s^{-1}, the resulting compression appears to allow dust to form. Earlier work by Moffat's group had suggested that such dust formation is possible if the colliding winds are already inhomogeneous or "lumpy," and that appears to be verified by the recent observations, which will appear soon in the *Astrophysical Journal*.

TO FIND PLANETS, FIND BLINKING STARS IN CLUSTERS

Gene Milone, a professor in the Physics and Astronomy Department of the University of Calgary, and University of Victoria professor Don VandenBerg, are Canadian scientists on an international team that will be searching for evidence of new planets with the help of the *Hubble Space Telescope*. The team has been awarded eight days (120 orbits) of time this summer to study the rich, luminous, globular cluster 47 Tucanae, which contains perhaps a million or more stars. By examining the myriad of stars in each image taken, the team hopes to detect possible decreases in luminosity arising from transits of planets across the disks of the stars.

Globular clusters in general contain ancient stars, with few of the elements heavier than helium that characterize younger stars like the Sun. Their stars might therefore be expected to have less likelihood of harbouring planets than do stars in the spiral arms of the Milky Way. Among globular clusters, however, 47 Tucanae is particularly rich in metals. The reduced probability of planet formation is also compensated for partially by the ability to image stars very efficiently in the rich environment of a globular cluster. Preliminary estimates suggest that an HST image at the core of the cluster will contain 40,000 stars bright enough to show transits by planets as small as Saturn.

Milone comments that a rich trove of eclipsing variables and pulsating stars is also expected from the study, with a possibility that cataclysmic variables ("dwarf novae") may also be found. The observing team is being led by Ronald Gilliland of the U.S.-based Space Telescope Science Institute. Other team members include Michel Mayor and Didier Queloz, who discovered the planet around the star 51 Pegasi in October 1995 — thereby beginning the modern age of extrasolar planetary discoveries — and veteran extrasolar planet discoverer Geoff Marcy.

CFI SUPPORTS MONT MÉGANTIC

The Mont Mégantic Observatory, jointly operated by the Université de Montreal and Université Laval, will receive nearly 4.8 million dollars from the Canada Foundation for Innovation (CFI) for improvements and innovations in observing techniques. According to Robert Lamontagne of the Observatory, the aims of the upgrade project are many. There will be improvements to dome air flow to reduce turbulence and to improve the "seeing," mechanical and electrical improvements to the telescope, and the construction of an adaptive optics system to further improve "seeing" in the infrared part of the spectrum. New instruments will include a large-field infrared imager and a low-noise Fabry-Perot spectrographic device. A fibre optic communications system will assist in transferring the large amounts of digital data generated by the upgraded telescope and new instruments. Work should begin in a few months, and the project will last three years. The Mont Mégantic Observatory is located in the Eastern Townships of Quebec, southeast of Montreal.

Feature Articles
Articles de Fond

A Build-It-Yourself Dew Preventer

by Dave McCarter, London Centre
mccarterd@claven.fanshawec.on.ca

Any observer knows that dew can quickly put an end to a promising evening, or at least force an intermission as hair dryers are used to dry off fogged optics. In addition, dew may also carry harmful airborne chemicals that attack optical coatings. While the Kendrick Dew Remover system is very popular, many home-brew astronomers and amateur telescope makers may wish to make their own dew preventer.

You do not have to remove dew if you prevent its formation by slightly warming the lens or corrector plate above the dew point. The heater elements, small resistors or a length of resistance wire to which electrical power is applied, are housed inside a fabric shell and held around the lens or eyepiece by Velcro tape. Power can be supplied from either a line-operated transformer-isolated power supply or a 12-V rechargeable battery.

Only a few watts of heat are required to warm a lens barrel or eyepiece adequately. A heater control box is used to regulate the amount of electrical current delivered to several plug-in heater elements. Such a high-speed switching circuit, which does not waste excess power, extends the useful battery life and allows control over the heat delivered, thus preventing overheated optics.

The Control Circuit

My dew zapper is very easy to assemble if one enjoys experimenting with one's

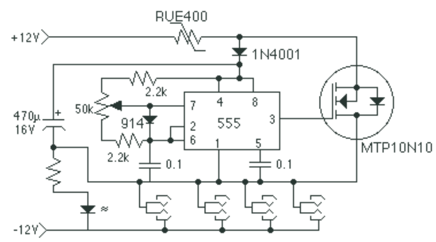


Fig. 1

telescope accessories and is not intimidated by soldering small parts. Table 1 lists the parts needed. The circuit (see Figure 1), based on the 555 timer integrated circuit (IC), produces a variable duty cycle to switch the heater current for controllable lengths of time. The longer the current is on, the more heating power is delivered to the lens. Circuit timing is controlled by the 50-kΩ variable resistor and the timing capacitor, which are connected to IC pins two and six, while the pair of 2.2-kΩ resistors set minimum and maximum switching periods. The 1N914 diode ensures that the switching duty cycle is symmetrical. The 555 IC has limited current switching capability, so it drives a high-power field effect transistor that switches the current with little loss. It can easily supply up to fifty watts.

A self-resetting plastic fuse, an RUE400, provides protection from shorted heaters or other calamities, while a red LED indicates that the unit is on and also provides a rough estimate of the level of heating being provided.

The circuit goes together quickly on my homemade printed circuit board (see Figures 2 and 3), but you could use perf board or "dead bug" construction. The completed board, control pad, and connectors all fit into a small Hammond-type 1591A or 1591L plastic case.

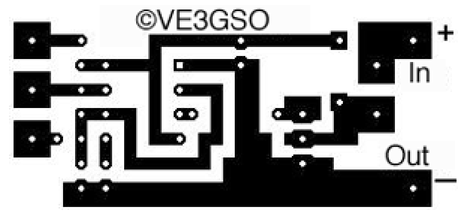


Fig. 2

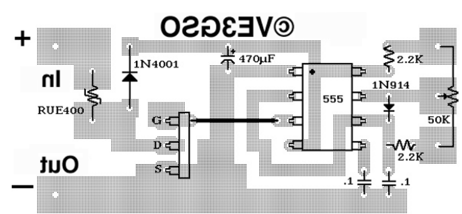


Fig. 3
The PC board component-side layout, where each part fits into pre-drilled holes. Note that orientation is critical for some of the items, as shown in the parts list. The potentiometer, LED, heater connectors, and power line mount into holes drilled into the case. The PC board is cut so that it will slide into the special ridges on each side of the case. Try the parts for fit before you decide exactly where to cut the holes to ensure that everything will fit properly.

Heaters

When the controller is complete, the next task is to build some heaters. The local surplus electronics store should have a stock of 330-Ω or 470-Ω 0.25-watt resistors, hopefully at an inexpensive price, as quite a few are needed. When a 330-watt resistor is supplied with twelve volts, the resistor will dissipate 0.44-watt and get very hot, which is usually not a problem on a chilly winter night. The 470-Ω resistor will operate closer to the 0.25-watt safety margin, but will not warm the lens as much when the mercury dips low. Of course, if you only need a small amount of heat, you can turn down the controller.

To build a heater, you solder, in parallel, as many of the resistors as are required to provide the desired level of heat around the lens (see Figure 4). I use a strip of copper foil to connect the resistors together and to transfer heat to the lens, but a length of stranded or braided copper wire works well too.

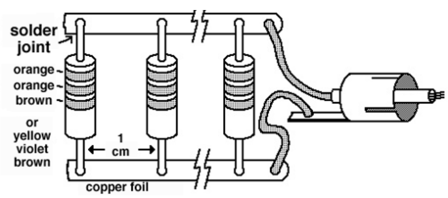


Fig. 4

For a small finder or eyepiece, two to three watts will be plenty, but for an eight-inch corrector plate a little more power is needed, perhaps as much as twelve watts on a very cold night. Experiment to determine what works best for you. The heater resistors should be evenly spaced around the lens cell. I typically place a resistor for every centimetre of circumference on finder and eyepiece heaters, and space them a little further apart for Schmidt-Cassegrain corrector plates.

The heaters can be permanently installed or packaged in a removable casing. My finder objective and its eyepiece were always becoming fogged from either dew or my breath, so I wrapped resistors directly onto the plastic lens housings and held them in place with electrical tape. The resistors must be electrically insulated from a metal lens cell, and a few layers of vinyl electrical tape will work. A short pair of wires, 20-AWG speaker wire, for example, connects the heater element to the RCA phono jack, which plugs into the heater control box.

Some form of insulation should be placed over the heaters to prevent cold winter breezes from stealing the heat they supply. A piece of closed cell foam used for camp ground rolls can be formed into a tube large enough to wrap around the front of the telescope. If made long enough, the foam tube can also act as a lens hood to shield the corrector lens from stray light.

Eyepieces

Eyepieces need to be warmed too, but it is often impractical to install heaters on each eyepiece. Flexible cloth heater casings are easy to make. Finally, you will have a use for that orphaned black, wool sock whose twin was lost to the clothes dryer!

To prepare the sock, cut off the foot at the ankle and retain the elastic leg portion. Make a heater element long enough to encircle your eyepiece and attach the lead wire, but do not solder the connection just yet. Thread the lead wire through the sock, from the outside to the inside, at the same distance from the cut as the heater is wide (see Figure 5). Fold the cut end over the heater, fold the finished end over the cut end, and sew the two folds together. Now two layers of cloth insulate the heater, while one layer will be between the heater and the eyepiece. Easy!

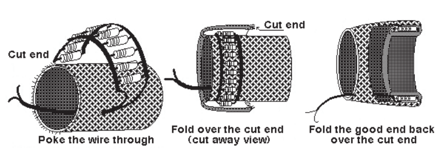


Fig. 5

The short end of sock, the finished and elasticized end, goes onto the eyepiece first, to hold the heater securely. The fluffy warm end of the contraption forms a comfortable eyecup that also keeps out stray light and even keeps your eye from watering from cold night breezes. To cozy up to a slightly warm eyepiece is a true pleasure. You will never do without it after you have tried it once. I have observed for several years with such a heater system, and on the many occasions when the telescope tube was covered with a layer of dew or ice, all of the glass surfaces were clean and dry.

Printed circuit boards, which greatly ease construction, are available at minimal cost. You can reach me via e-mail or the RASClist for guidance in your construction effort. Clear skies and warm observing!

Dave McCarter became interested in astronomy at the age of seven, when a chance encounter with Saturn, viewed through a six-inch scope, left him speechless, a rare condition indeed! When he is not observing, polishing mirrors, building Dobsonian mounts, and nagging David Lane to add meteor streams to ECU, *Dave enjoys hearing exclamations of joy and wonder from first-time observers. Astronomy occasionally makes way for teaching electronics at Fanshawe College in London, Ontario.*

Table 1

Dew Controller Parts List

Quantity	Item
1	555 timer IC* (may be marked MC1455P, NE555N, UA555P, *etc.*)
1	MTP10N10* or similar N-channel power MOSFET, 50 V at 10 A or better
1	470 μF 16 V electrolytic capacitor*
1	1N4001 silicon diode*
1	1N914 or 1N4148 silicon diode*
1	Red LED*
1	50 kΩ linear potentiometer* *e.g.* PEC type V6U5031
3	2.2 kΩ 0.25 W resistors
2	0.1 μF 50 V monolithic capacitors
1	RUE400 Raychem polyswitch fuse
1	1591A or 1591L Hammond plastic case
1	Plastic knob (*e.g.* Augat PKES-60B-1/4)
4 or 5	chassis phono jacks (*e.g.* Switchcraft 3501FR)
4 or 5	phono plugs (*e.g.* Switchcraft 3507)
1	18G white two-wire "zip" cord*, long enough to go from the heater control to the power control (*e.g.* car battery, gel pack)

* The orientation of the parts on the board is very important. For example, the power supply must be connected properly or the unit may be destroyed.

Another Side of Relativity

Uncle Ernie blows his first Perseid all-nighter

Nailing the Equinox Sunrise

by Michael Attas & Jude McMurry, Atomic Energy of Canada Limited, Whiteshell Laboratories, Pinawa, Manitoba (attasm@aecl.ca)

The vast, flat, prairie landscape has many features that make it wonderful for celestial observations. The sky is big, the air is clear, the nights are dark, and the roads are straight. (A pessimist would add that the wind is high, the mosquitoes are fierce, the summer nights are short, and the winter nights are cryogenic.) In fact, most of the straight country roads are laid out in a regular grid oriented exactly east-west and north-south, with intersections spaced one mile apart. That makes for dull driving, but allows our thoughts to wander without harm.

One of us (McMurry) spends several hours a day on such roads, commuting from Winnipeg to a research laboratory near Pinawa, 100 km to the northeast. The car pool noticed last summer that not only did the Sun rise later every day, but it rose from different points on the horizon. Explaining that phenomenon became one of many scientific topics of conversation at our lunch table in the lab cafeteria. One of us (Attas) surmised that on the equinox, the Sun should rise due east and shine straight down the road into the driver's eyes. Demonstrating and documenting the event proved to be a difficult task, but the accompanying photos show it was accomplished in the end.

The first difficulty was scheduling. Some car pool members felt that no delays in arriving at work could be tolerated; others insisted that high-quality photography required a tripod set up on the centre line of the highway. Even a compromise plan requiring the driver to aim the vehicle just left of centre on the two-lane blacktop, so that the front passenger could snap photos from the exact centre, was not accepted. At least traffic was light at 7:15 a.m. and there was no need to justify the erratic driving to the RCMP patrol.

Weather conditions played a commanding role, of course. The plan called for daily photos throughout the week, before and after the equinox. By definition, therefore, clouds obscured the horizon every morning during this period except for two days, 1998 September 21 and 23, the latter being the first sunrise after the actual equinox (which was at 00:34, Central Daylight Time, on September 23).

Sunrise along Highway 44, Agassiz Forest, Manitoba, two days before the autumn equinox (top) and on equinox morning (bottom).
Photos by J. McMurry.

More arguments: where to take the pictures? Is the road horizontal? Should the Sun's disk be touching the road or just above? What's a good exposure? Will the photos be blurred? In the end, the photographer snapped (!), and several weeks later the prints arrived. The lunch table was highly critical of the photographer's efforts, but the authors are convinced that the experiment was a success, *i.e.* that the photos demonstrate the exact alignment between the sunrise point and the road on the fall equinox. Improvements to the experiment are left as an exercise for the reader.

Michael Attas is a radioanalytical chemist with Atomic Energy of Canada Limited at AECL's Whiteshell Laboratories in Pinawa, Manitoba. He has done research in many areas, including archaeological ceramics, cold fusion, nuclear safeguards, and ultraviolet digital imaging. These days his stargazing activities use the Astronomy Picture of the Day Web site more often than his backyard Newtonian telescope.

Jude McMurry is a geochemist in the radioactive waste management program with Atomic Energy of Canada Limited at AECL's Whiteshell Laboratories in Pinawa, Manitoba. She received a Ph.D. in igneous petrology from Texas Tech University, where she studied the geochronology and chemical evolution of felsic plutons in northeastern Brazil. Her current research interests involve low-temperature mineral and water interactions in fracture zones, but she occasionally looks up from the stones for a glimpse of the horizon.

Messier Memories

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

Charles Messier (1730–1817), comet hunter and compiler of the Messier Catalogue of deep-sky objects.

In the April 1999 issue of the *Journal*, Peter Broughton recounted the history of the RASC Messier Certificate, starting with the birth of the "Messier Club" concept in the Montreal Centre in the 1940s. The systematic observation of Charles Messier's catalogue of 110 deep-sky objects (star clusters, nebulae, and galaxies) was reborn in the Edmonton Centre in the late 1970s, leading to the introduction of the RASC Messier Certificate in 1980. By awarding Messier Certificates, the RASC formally recognizes members for the significant achievement of having located and observed all 110 M-objects without assistance. The trigger for Peter's article was the award of the 150th Messier Certificate in 1998. Peter invited discussion, and I was able to fill in some of the gaps in the RASC history on the subject, which I will now share with everyone, at Peter's urging.

Reading Peter's article transported me back in space-time to the 1968 meetings of the Observers' Group of the RASC Ottawa Centre. The meetings were held independently of the regular meetings, and the Observers' Group was a young, dynamic gang of enthusiastic observers who were willing and able to take on meteor observing, grazing occultations, solar observing, and so on. Each specialty had its co-ordinator, and the recently-appointed Deep Sky Co-ordinator was Ken Hewitt-White, perhaps better known today as one of the hosts of the television show *Cosmic Highway* on the Discovery Channel and as a *SkyNews* columnist. (Ken kindly provided some of his own musings and memories for this article.) I was a 14-year-old new student member at the time, although I had already been a solitary amateur astronomer for about four years (not including those years of stargazing with the unaided eye).

KHW — as we called him — was a natural leader, and he lost no time in rallying the troops. In February he began a deep-sky column for the average observer in *AstroNotes*, the Ottawa Centre newsletter, and by March he had announced the formation of a "Messier Club" for members interested in observing the entire Messier Catalogue. There was a mild competitive edge to the club, as some of us had already started chalking up objects and Ken deemed it necessary to reset our counters. My observing log for 1968 has the following entry: "KHW says start from zero as of 3 February 1968." After that, my own memory is fuzzy, except that I always appeared last in the monthly tallies and I only managed to get about halfway finished, on that first attempt. Messier Club members also included Les MacDonald, Rick Lavery, Dan Brunton, and John Conville, among others. (Back issues of *AstroNotes* might shed more light on such activities.)

Les MacDonald was the first to finish, through a combination of persistence, dedication, and the tactical use of a 60-mm Unitron refractor, a Norton's star atlas, … and a car. The latter element was crucial, and I will let Ken pick up the thread of the story:

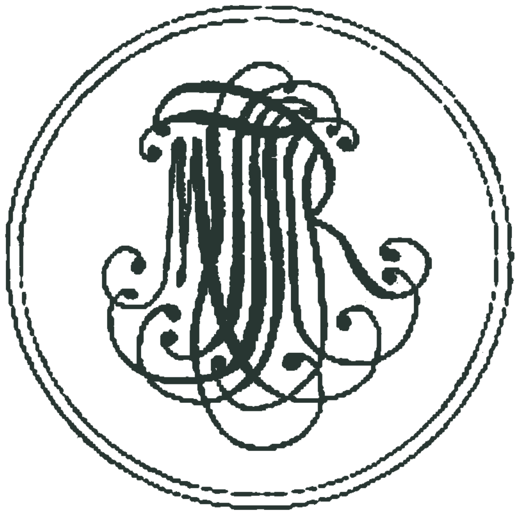
"The key to Les's victory was his sneaky manoeuvre of motoring out to the Quiet Site one wind-swept evening in late winter 1968 and tracking down M77 in Cetus on surely the last possible occasion before it disappeared for the season. The rest of us thought M77 *was* gone for the season. The May *AstroNotes* recorded Dan Brunton way out in front with 82 Messiers. I was second with 67. Rick Lavery had 60 and Les had only 59. But none of the top three observers had M77 in the bag. Les did! So Les finished first later that year, before M77 even returned to the evening sky. I think that was the only occasion that Les did not invite me for a QS observing run!" (The Quiet Site was an unmanned field station maintained by the Defence Research Telecommunications Establishment and made available to us for dark-sky observing. We also had "coffins" there for meteor observing, but that is another story.)

By the time Les had completed his list in the summer of 1968, there were about 30 Ottawa Centre members in the Messier Club. Ken personally kept individual sheets for each observer, on which he recorded each observer's progress at the monthly Observers' Group meetings. I never finished; in fact, I soon "dropped out" from organized amateur astronomy altogether for about 15 years.

Fast forward to Halifax in the early 1980s. My interest in astronomy was rekindled by a colleague at work, and the first recorded M-object in my second attempt to complete the list was M11, observed on 1983–07–31; the last was M75 observed on 1985–09–08. Most of them were bagged with Pentax 7×50 binoculars and a Celestron C90 Maksutov telescope; for a few, I borrowed any telescope handy, usually Gordon Hawkins' 6-inch f/8 Newtonian reflector. In 1984, Gordon and I — now an RASC member again — initiated a "Messier Hunt" project in the Halifax Centre modelled after the Ottawa Centre's activity 16 years earlier, or what I could remember of it. We may have also been influenced by the Edmonton Centre activities and the announcement of the RASC Messier Certificate. We produced a form for observers to complete as they progressed through the list. (The form is still in use.) The first to finish was Bill Thurlow, who made all his observations in Jan–May 1985 from his home in Digby. I was the next to finish in September of the same year. We both received certificates from the Halifax Centre, and later we also received RASC Messier Certificates, thanks to the efforts of Alan Dyer and the Edmonton Centre in setting up that programme. According to Peter, today there are 14 Halifax Centre members holding Messier Certificates.

Observing the entire Messier Catalogue is a satisfying personal achievement, a "sky-learning" experience that sharpens one's observing skills and explores the capabilities and deficiencies of one's optical instruments, however, there are further challenges for those who will accept them. It is strange that some of the sky's finest deep sky objects are not on the list (Double Cluster, Coathanger, Cat's Eye, etc.). That could be a by-product of Messier's original aim, which was to produce a practical list of non-cometary objects that might confuse comet hunters. Perhaps he found some deep-sky objects to be "obviously" not comets and excluded them, but even such an explanation does not stand up to scrutiny. Whatever the reason, one shortcoming of Messier-based observing activities is that they skip over some fine objects just because they do not have an "M" label.

A more comprehensive and modern catalogue of deep-sky objects is Dreyer's *New General Catalogue*, published in 1888, supplemented by two subsequent *Index Catalogues*. All together, the NGC and IC catalogues contain descriptions of 13,226 galaxies, nebulae, and star clusters. Alan Dyer's list, "The 110 Finest NGC Objects" appears on page 259 of the 1999 *Observer's Handbook*, a companion observing list to the Messier Catalogue appearing a few pages earlier on page 255. (Has anyone else noticed that "Dyer" = "Dreyer" divided by "re"?) Several RASC members have observed all the objects in Dyer's advanced deep-sky list, and no doubt Peter Broughton will be reporting on our collective progress on this project in some future issue of the *Journal*!



Messier's colophon, which he inscribed on his own copy of his catalogue.

Another observing challenge that has emerged in recent years is the Messier Marathon. The goal of the marathon is to observe all the M-objects in a single night! I understand that this is only feasible on a dark night near the Spring Equinox, beginning in evening twilight and ending in morning twilight. David Levy, in his book *The Sky: A User's Guide* (Cambridge University Press, Cambridge, 1991) describes one such marathon. The Internet web site `www.reflector.org/MESSIER.HTM` is one of several devoted to the subject. The Messier Marathon is indeed a challenge for advanced observers, but I must confess that attempting the feat does not appeal to me in the least.

Having established a couple of certificates of observing achievement for its intermediate and advanced observers, the RASC might consider designing some less ambitious observing programmes for beginning deep-sky observers. A scaled-down list containing a smaller number of relatively easy objects would be challenge enough for the beginner, perhaps using binoculars or a small telescope under the urban light dome. With a standard list, some simple rules, and a corresponding certificate, the RASC Centre Observing Chairs (or whoever) would have the resources to motivate newcomers by initiating and leading simple observing programs with achievable goals.

I hope you have enjoyed hearing a little "modern" RASC history in this column, a slight departure from the vintage astronomical history I usually peddle from my armchair, resting comfortably on my laurels.

(For those interested in some real history, the book *The Messier Album*, by John Mallas and Evered Kreimer (Sky Publishing Corporation, Cambridge, Massachusetts, 1978) includes an excellent history of the Messier Catalogue by Owen Gingerich.)

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

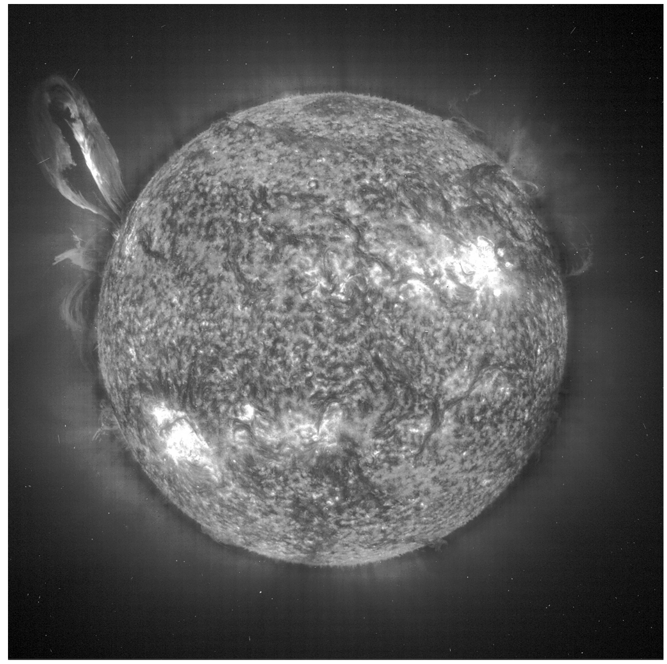
Remarkable Increase in the Sun's Magnetic Field

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

Global warming is on people's minds these days, particularly in summer, when it seems that every year — at least for the last few years — has seen record-setting heat in North America. As the source of the Earth's energy, our Sun plays a large role in determining average global temperatures, but it is now generally accepted that humans are affecting the global climate as well. What remains unknown is the relative importance of the different effects. Mike Lockwood and his colleagues at the Rutherford Appleton Labs in England have added a new variable to the equation. They find that the general magnetic field ejected by the Sun with the solar wind has more than doubled in strength over the last century (see 3 June issue of *Nature*). While they deliberately avoid speculating on how such an increase might affect our climate, it seems likely that there will be an effect.

Consider this. The Sun's luminosity changes over the 22-year sunspot cycle, with the Sun being brightest at sunspot maximum. Naively, one might expect that with the surface of the Sun covered by cool, dark sunspots, the luminosity would decrease, but in fact the effect is in the opposite direction. The origin of the increase is controversial, but the measurements are clear — the Sun is on average about 0.15% more luminous at sunspot maximum. Sunspots are magnetic phenomena, so it may not be too surprising that the ejected magnetic field increases in step with sunspot numbe, however, connecting that to climate change will be difficult because of the many variables that affect the Earth's atmosphere.

The general magnetic field surrounding the Sun plays a role in affecting the total cloud cover on the Earth. The average amount of cloud cover is related to the flux of cosmic rays (high-energy nuclei and electrons). Cosmic rays come from many sources, including the Sun, neutron stars, and active galactic nuclei. As cosmic rays pass through the Earth's atmosphere, they ionize the molecules along their paths. The ions in turn provide sites for the growth of clouds. So, the more cosmic rays, the more clouds on average. Cosmic rays — because they are charged particles — are affected by magnetic fields. So, the greater the magnetic field in the solar system, the more shielding that is provided. Therefore, fewer cosmic rays will hit the Earth, thus reducing the total cloud cover. Quantitative estimates of the size of the effect are very difficult, however, because clouds also are affected by temperature, wind speed and direction, water vapour content, *etc.*, all of which vary in complicated (*i.e.* non-linear and chaotic) ways to different inputs.



Changes in the Sun's magnetic field may be contributing to the Earth's climate change.

Lockwood and his colleagues have used direct (spacecraft) measurements of the change in the interplanetary magnetic field since 1964 to establish that there is a correlation between the magnetic field strength in near-Earth space and data from Earth-based magnetometers. Once the correlation was established, they showed that the magnetometer data indicate that the magnetic field strength has increased by a factor of 2.4 since the turn of the century. The average number of sunspots has increased by about the same amount over the same period of time.

This century has seen an increase in global temperatures, yet that has occurred against the background of an unquestioned increased in the global production of carbon dioxide and methane, both of which are effective "greenhouse gases." That means that they are transparent to the visible and ultraviolet radiation arriving from the Sun, but not to the longer-wavelength infrared photons emitted by the warm Earth. The net result of such a trapping of infrared photons is a general increase in the average temperature. Which is responsible for the majority of the global warming, then? An increase in the Sun's luminosity and expelled magnetic field, or an increase in atmospheric greenhouse gases? Right now, there is no quantitative answer to that question.

It is well known that an extended absence of sunspots between 1645 and

1715 was correlated with a "mini ice age" in Europe, and surrogate measurements indicate that a general increase in global temperatures during the twelfth century was correlated with a period of anomalously high sunspot activity. During both periods, the Sun's luminosity changed by about 0.5%. Records of climate obtained from deep ice cores show periods of abrupt changes in average temperature over the last 10^5 years, sometimes with a precipitous drop in atmospheric carbon dioxide.

Most of the Earth's carbon dioxide (CO_2) is dissolved in the oceans, where some of it is locked up in corals and rocks. The rate at which the oceans remove CO_2 from the air depends on the surface temperature of seawater. Just as warm soda pop quickly loses its "fizz," warmer oceans give up their CO_2 more easily. If the Sun is brighter and there are fewer clouds, it will tend to warm the oceans, perhaps accelerating the greenhouse-gas problem.

What Lockwood's discovery tells us about our future climate, is for now, a mystery, but an intriguing one. The changes in the magnetic field strength probably are not closely related in origin to the changes in the sunspot number, so the fact that they track each other is curious. Also, some solar physicists believe that such changes may be chaotic, and hence inherently unpredictable, which means that long-term forecasts of climate change become, to a certain extent, an exercise in numerical speculation. Perhaps, if we understood the Sun better, the prospects for prediction would be better: the variations we see seem chaotic only because we do not understand the underlying physics. Right now, the problem is too complex, with too many variables, for us to make much headway in connecting the changing magnetic field with our simple models of climate change, but a factor of 2.4 change in the Sun's field cannot be ignored.

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.*

FROM THE PAST — AU FIL DES ANS

THE SUN AND OUR RECENT WINTER

At a recent meeting at Washington, Dr. C. G. Abbot, our great authority on the measurement of solar radiation, made the statement that in recent months the output of heat from the Sun had shown a diminution of four or five per cent. Now in various parts of the United States and Canada the general impression is that the past winter was one of exceptional severity. In Toronto there was more snow than usual, and several periods of decidedly cold weather led many of the citizens to believe that the winter as a whole was distinctly colder than the average. At once there comes the suggestion that the Sun's diminution would produce just such a state of affairs. But reports state that in England the winter was mild, and that at some places in our north-west provinces it was not so cold as usual. Further, letters from Australia bring the information that there was no lack of heat down there. And then, to add to all this, one of our newspapers published an article by Sir Frederic Stupart, the director of the Meteorological Service of Canada, in which it is declared that the recent winter was not abnormally cold after all.

by C. A. Chant,
from *Journal,* Vol. 17, p. 167, May, 1923.

EXPLORING THE FRONTIERS OF THE UNIVERSE WITH NEW EYES[1]

by David Crampton

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(Received May 13, 1999)

Abstract. The technique of sharpening images using adaptive optics now permits ground-based telescopes to achieve diffraction-limited performance. Canada has been involved in building one of the best such instruments in the world for use on the Canada-France-Hawaii Telescope: the Adaptive Optics Bonnette or "PUEO." A brief description of the instrument and its spectacular performance are given in this review, followed by examples of the wide variety of scientific problems that it is being used to address.

Résumé. La technique utilisée pour rendre les images plus nettes en se servant d'optiques adaptives permet maintenant aux télescopes terrestres d'atteindre une performance à la limite de diffraction. Le Canada a participé à la construction d'un des meilleurs de ces instruments au monde, nommé l'Adaptive Optics Bonnette ou "PUEO" et utilisé avec le télescope Canada-France-Hawaii. Une courte description de l'instrument et de sa performance spectaculaire est donnée dans ce rapport, suivi d'examples d'une grande variété de problèmes scientifiques, lesquels cet instrument sert à étudier. SEM

1. Introductory Remarks to the Lecture

It is a great pleasure for me to be invited to give a lecture commemorating Helen Sawyer Hogg. I was fortunate in having Dr. Hogg as a professor when I was a student at the University of Toronto, and I was continually impressed by her combination of scholarship and graciousness. Her professional reputation is well known, but as an example of the latter, when my first daughter was born, a present arrived in the mail containing some very unique knee-length "booties" with a label "from the knitting needles of Helen Sawyer Hogg." They are still among my prized possessions. Helen Hogg also has a connection with Victoria. I particularly like the anecdote told by Joe Pearce (Pearce 1968) of one memorable night when he was entertaining the Astronomer Royal:

> "I vividly recall Dyson's first visit to our dome to see the largest telescope in the British Empire in action. It was a splendid night and direct photography at the Newtonian focus was in progress. Plaskett, Dyson, and I climbed the steep stairs, and paused at the top in the completely darkened dome. All was silent, save for the drowsy hum of the motor generator and the constant click-click as the unseen observer guided the great reflector. Suddenly there was a loud insistent cry of a baby in discomfort and distress, which startled the Astronomer Royal, and immediately a pleasing voice from the skies above called out, 'Frankie, change Sally, give her a bottle, and send up two more plates.' Before Plaskett could speak, there was an answering response, 'All right Helen, the plates are coming up.' Dyson exploded, 'Good Lord — what the Devil!' Laughingly, Plaskett explained that Dr. Helen Hogg had a baby last month, and though it was actually Frank's night for spectrographic work, Helen was taking advantage of a good night for her cluster variable work, since the clusters were rapidly going west."

I am also very pleased to be back here at Pearson College and, indeed, in this theatre, because I enjoyed several productions by the students here when my daughter attended the college several years ago.

I am sure that Dr. Hogg would be amazed and very excited about the "new eyes" that we can now use to explore the universe. Most of you are familiar with the extraordinary images brought to us by the *Hubble Space Telescope* (HST), and most of you understand that the basic reason those pictures are so sharp is that the HST is above the atmosphere of the Earth. Now, however, with recent advances in adaptive optics, ground-based telescopes can also deliver comparable images. Arguably the most successful adaptive optics instrument has been built by a team of engineers and scientists here in Victoria together with teams in France and Hawaii for the Canada-France-Hawaii Telescope (CFHT). I was privileged to be one of the project scientists of that instrument, and hence participated in many observations during the initial commissioning phases. I would like to share with you some of the resulting pictures and scientific results. I will confess that it was amazing and very exciting for me to watch HST-quality images come out of the instrument at the mere touch of a button.

[1] The 1998 Helen Sawyer Hogg Public Lecture, delivered at Lester B. Pearson College of the Pacific in Victoria on June 20, 1998, during the RASC General Assembly.

2. The Adaptive Optics Bonnette

a. The Instrument

When the shape of a mirror or some other optical element is altered in such a way that it compensates for the instantaneous distortions introduced into the wavefront of a light beam by the atmosphere and any other optics in the light path, the process is referred to as compensation by adaptive optics. The instrument that enables such real-time compensation for the CFHT is known as the Adaptive Optics Bonnette (AOB) — the latter word being a French term for a camera back that was adopted because we could not think of a simple translation. Hence, it is often called the "AOB" even though it has a more official name of "PUEO," which is Hawaiian for sharp-eyed owl.

A simplified diagram of how PUEO works is shown in figure 1. Light from the telescope is initially collimated by a mirror, passes through an atmospheric dispersion compensator, and then an image of the telescope pupil is formed on the deformable mirror. The mirror is a "bimorph" type containing 19 sub-elements that can be actuated at kiloHertz rates to correct the incoming wavefront. The light then proceeds to a mirror that refocuses the light at a focal ratio of f/20 and also corrects for large image motions, including those caused by

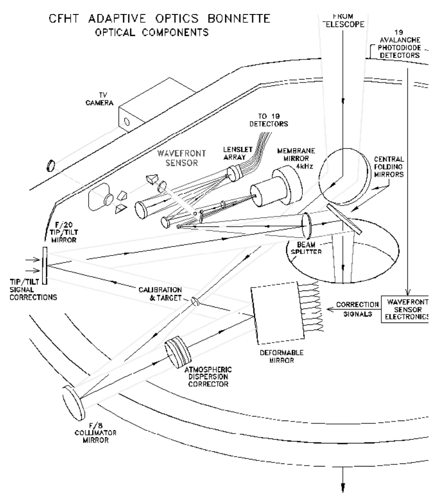

Fig. 1. — The path of light through the AOB. Light from the telescope enters from the top, is deflected to a collimating mirror, a deformable mirror, and a tip-tilt mirror, and then to a beam-splitter. At this point, some wavelength segment or fraction of the light is deflected to the wavefront sensor, while the remainder, which has now been corrected, passes through to the science instrument.

poor tracking or wind shaking the telescope. En route to the detector or instrument, a portion of the light is directed into the wavefront sensor by an interchangeable beam-splitter. As indicated by the diagram, the wavefront sensor consists of a rather complicated optical system that forms slightly out-of-focus images of a reference star onto an array of 19 lenslets at 4 kHz — images that are alternately made just before and just after the focus. As Roddier *et al.* (1991) explain, such a method, referred to as "curvature wavefront sensing," has many advantages over other methods. The before and after focus images are transferred through optical fibres to 19 avalanche photodiodes — photon-counting detectors — and the signals are processed by a high-speed digital computer to produce the necessary signals for the tip/tilt mirror and the deformable mirror. Of course, speed is of the essence since the distortion that was sensed by the system must be corrected before it has changed. Hence, the system is normally run at 1000 cycles per second (1 kHz).

Since atmospheric perturbations are slower and of smaller amplitude at longer wavelengths, adaptive optics systems work best in the infrared spectral region. Consequently, the beam splitter most commonly used is one that passes an infrared "science image" to the detector while directing the visible light to the wavefront sensor. Other beam splitters that direct different proportions or colours of the visible light to the science instrument and wavefront sensor can also be inserted. A picture of the nearly completed instrument during final testing at the Dominion Astrophysical Observatory is shown in figure 2.

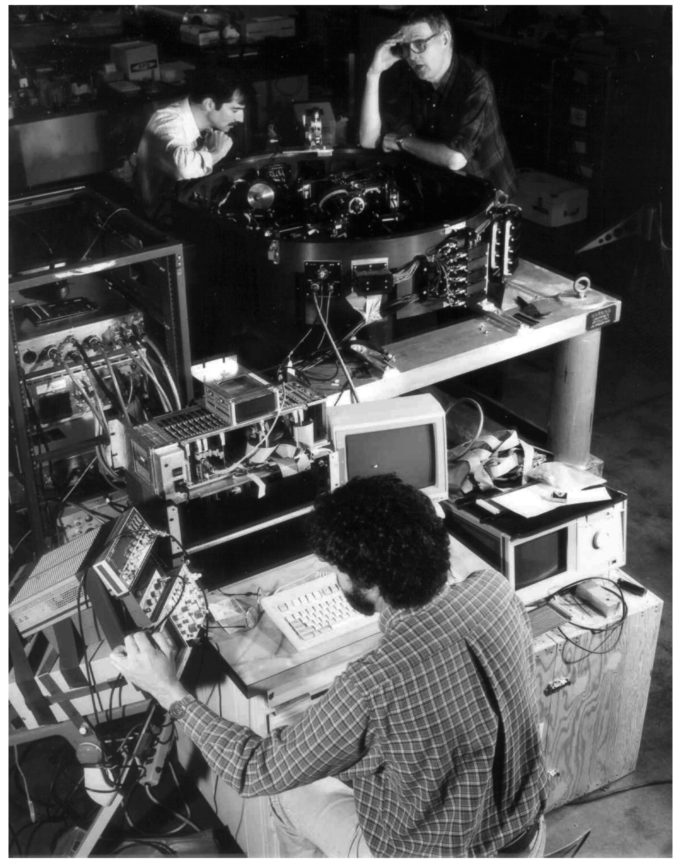

Fig. 2 — Final tests of the AOB in Victoria. Some of the high-speed electronics used to detect and interpret the signals from the wavefront sensor are shown in the foreground. Jim Stilburn is shown operating the electronics, Murray Fletcher is leaning on the AOB casting at the back right, and Brian Leckie is on the left.

The Adaptive Optics Bonnette was designed and built to fit on the Cassegrain focus of the CFHT in such a way that light can either pass directly through the AOB without compensation to reach an instrument (camera or spectrograph) below it, or the light can be corrected by the AOB and end up at the same instrument. In order to determine how to correct the wavefront, the AOB must have adequate light from a nearby reference star or the science object itself. In practice, that is the most severe limitation on what targets are accessible. As a rule of thumb, the AOB requires a reference source (which must be reasonably point-like as seen by the wavefront sensor) brighter than a magnitude of about $R = 14$ and lying within about 30 arcseconds of the target for diffraction-limited performance in the near-infrared, but guide stars as faint as $R = 17$ can be used with good results in the best seeing conditions. The delivered image quality depends on the wavelength, seeing, and distance and brightness of the guide star; to gain an appreciation of what can be expected for a given target, try the "AOB performance estimator" at `cfht.hawaii.edu/Instruments/Imaging/AOB/psf.html`. More complete descriptions of the AOB are given by Arsenault *et al.* (1994), Richardson (1994), Thomas *et al.* (1997), and Rigaut *et al.* (1998), and further details can be obtained from `cfht.hia.nrc.ca/Instruments/Imaging/AOB/description.html`.

b. Typical Performance

The AOB was installed on the CFHT for commissioning early in 1996, after extensive testing (including at −10° C, the coldest temperatures expected on Mauna Kea) in Victoria and Paris. It produced diffraction-limited images within hours of installation, and has performed nearly flawlessly ever since. Although it was expected that the AOB would deliver much better images than one gets from the CFHT itself, it is fair to say that everyone was delighted and amazed by how much better they were, and how easy it was to operate the instrument. A fax from the team at the summit a few hours after dusk on the first night to those of us anxiously waiting in Victoria displayed a diffraction-limited image and the simple phrase "worked straight out of the box"! When one considers the complexity of the instrument, its journey halfway around the world, and the rough ride it got on the way to the summit, its immediate success was a tremendous tribute to the engineers and technicians who were involved in its design and construction.

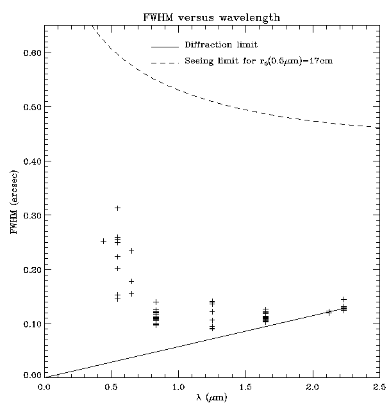

Fig. 3 — A graph demonstrating the enormous improvements in image quality realized with the AOB, based on all observations recorded during 16 nights while commissioning the instrument. The upper dashed curve indicates what the image quality would have been with the regular imager during median conditions at the CFHT. The line at the bottom shows the best image quality that a 3.6-m telescope can deliver (the diffraction limit). The observations demonstrate that the AOB images are as good as physically possible in the near infrared, and are much improved in the visible region.

Approximately 15 nights were scheduled in 1996 for engineering tests and establishing the performance of the AOB for different types of objects and conditions. Fortunately, most of the nights were clear and a lot of data was collected, mostly with MONICA (the Montreal Infrared Camera), an infrared camera adapted and provided by l'Université de Montréal (Nadeau *et al.* 1994). Figure 3, adapted from an internal CFHT report by Rigaut *et al.* (1998), demonstrates the tremendous gain in image quality delivered by the AOB at various wavelengths, as compared to normal images from the CFHT (dashed curve). During median seeing conditions the AOB delivers stellar images with a full width at half maximum (FWHM) of ~0.12 arcsecond at red and near-infrared wavelengths from the *I* to *K* wavelength bands, and substantially improves images at blue and visible wavelengths. The best image recorded so far was obtained in the *I* band and had FWHM = 0.068 arcsecond.

In addition to improving image quality, the AOB has proven to be remarkably efficient in terms of operation. Once the telescope is pointed at a bright star close to the target, or on the target itself if bright enough, then the AOB immediately focuses and guides on the image. In fact, the overhead is less than with a standard imager. During a project that involved observing a sample of relatively bright stars to look for close companions, we were able to stop the automatic compensation on one star, slew the telescope, and resume observations on the next within about 30 seconds. The AOB is able to accomplish that through use of very clever software that analyzes the signals from the wavefront sensor and continuously adjusts the correction loop to achieve optimum results. Such automatic control is essential, since the seeing varies a lot with time — one of the optional displays from the wavefront sensor shows the variation as a function of time, and it is surprisingly variable. In addition, the user interface to the AOB was deliberately made very simple and robust so that even inexperienced observers could operate it with minimal instruction. In practice that feature also works extremely well.

To summarize, if one has a sufficiently bright point-like target or nearby reference star, then the AOB will deliver images at red to near-infrared wavelengths that are comparable to those obtained by the HST. Some examples will be briefly described in the following sections.

3. Images from the Adaptive Optics Bonnette

In order to sample adequately the best images expected from the AOB, the optics of the MONICA camera were exchanged for some that gave a pixel scale of 0.034 arcsecond per pixel. While that allowed us to examine images of point sources in detail and to understand better what the AOB was doing, it also meant that the field of the 256×256-pixel detector was only 8.8 arcseconds square. Such small fields were certainly a new experience for me, as I am sure they would be for most RASC members who have ever taken astronomical images! To form a complete picture of almost any object other than a point source, several frames had to be mosaiced together. One result of such a procedure is that the edges of the resulting images displayed below often have less exposure than the central section. Most of the images presented in this article are from MONICA, although a few are from a CCD or the newer "KIR" detector (K = 1000 pixels, IR = infrared), which has a 36-arcsecond field.

a. Stars

Ironically, the full power of adaptive optics is demonstrated best using images of bright stars or point sources. That is ironic because, apart from showing the tremendous improvement in image quality (including diffraction rings, the signature that the resolution limit of the telescope has been achieved), a point source is still a point source and so no structure can be revealed. However, the detection and measurement of companion stars, for example, is of interest for a number of studies, including investigations of the formation of young stars. A typical example from a program by J. Bouvier (see Bouvier *et al.* 1997) is shown in figure 4 — note the diffraction rings. A much more difficult problem is to detect significantly fainter companions, *e.g.* planets. Gordon Walker of the University of British Columbia and René Racine of l'Université de Montréal have already attempted to use the AOB for such a "holy grail." So far they have not been successful, largely because of the tremendous difference in relative brightness between star and planet, which means that many planets could remain undetected in the scattered light of the parent star. One of the next steps will be to use a coronagraphic mask to block some of the starlight and so improve the contrast of stellar images.

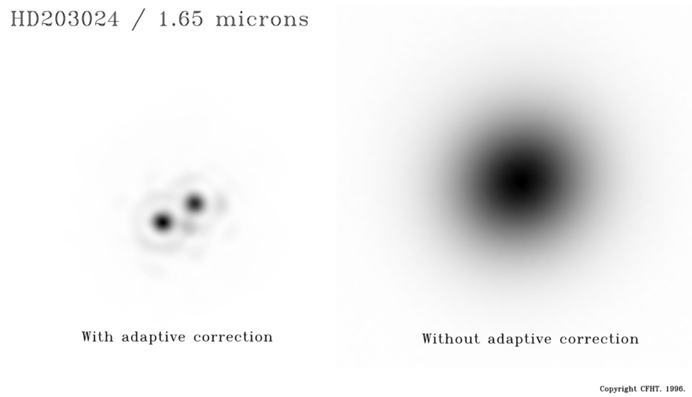

Fig. 4 — An example of *H*-band (1.65 μ) observations (with "normal" seeing) of an apparently single star (right), that is in fact a double system (left). The separation between the two components is only 0.2 arcsecond. Note the diffraction rings in the AOB image on the left.

b. Star Clusters

The cores of globular clusters and similar dense star fields benefit substantially from the improved image quality delivered by the AOB. As well as reducing the crowding, the AOB achieves a significant gain in depth because it produces sharper images in comparison with the sky background, especially in the near-infrared. Figure 5 depicts a field in the core of the cluster M71. The image, taken in the *I*-band with a CCD for which each pixel corresponded to 0.02 arcsecond of sky, begins to show the effects of isoplanatism. That is the degradation of the effectiveness of the image compensation as the distance away from the guide star increases (attributable to the fact that the properties of the atmosphere through which the light passes are different as one proceeds away from the guide star). In figure 5 the FWHM of the images increases from 0.12 arcsecond at the position of the reference star in the centre to 0.16 arcsecond at the corners of the field 30 arcseconds away. The size of the "isoplanatic patch," or region of good compensation, depends on the seeing conditions, and also decreases with decreasing wavelength.

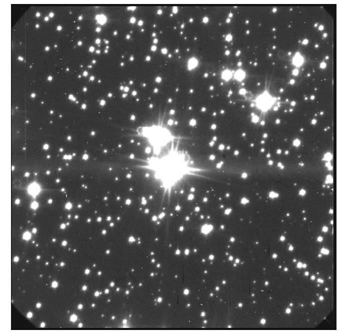

Fig. 5 — An *I*-band image of the central region of the globular cluster M71. The bright star in the centre was used as the reference star for the wavefront sensor. In this case, only half of the light was transmitted to the science (CCD) detector, while the other half went to the wavefront sensor. The FWHM of the image increases from 0.12 arcsecond at the centre to 0.16 arcsecond at the corners as a result of the effects of isoplanatism(see text).

c. The Galactic Centre

Fortunately, there is a sufficiently bright guide star close to the direction of the centre of our Galaxy that good images of the very core of our Milky Way can be obtained with the AOB. Because of the tremendous amount of absorbing material in front of the nucleus, such observations are best taken in the near-infrared. Figure 6 displays an image of the Galactic Centre region taken with the AOB in the *K*-band compared to one taken with the normal imager. Diffraction rings around most stars are a bit distracting in the display, but notice how many more faint stars are visible in the AOB image. The centre of our Milky Way Galaxy is near the clustering of faint stars towards the centre of the image (there is nothing visible at the location of the radio emission that is believed to signify the precise centre). The sharpness of the images allows the positions of the stars to be measured very accurately

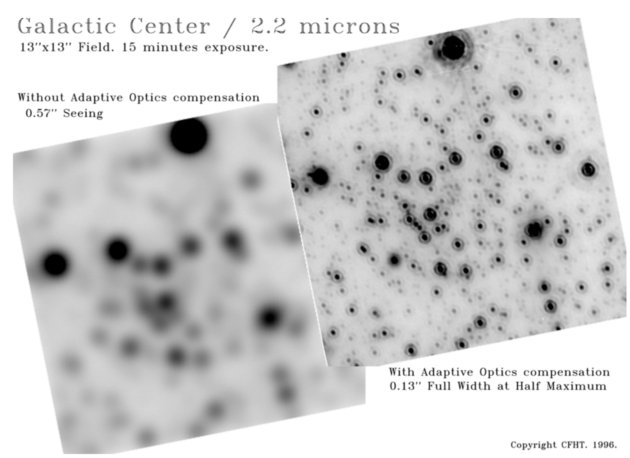

Fig. 6 — *K*-band images of the centre of our Galaxy, obtained both with and without the use of adaptive optics. Radio observations reveal that the Galactic centre is near the group of faint stars towards the centre of the image. The motions of some of the stars indicate that they must be in orbit about a black hole.

relative to each other, and, when compared with similar measurements taken a year apart, can be used to derive their relative motions. It turns out that some of the stars are moving across the line of sight at more than 1000 km s^{-1}. This means that there must be a very strong gravitational field at that location. In fact, our data and those from similar studies (*e.g.* Genzel *et al.* 1997; Ghez *et al.* 1998) demonstrate that the stars must be moving around an object whose density is so high (10^{12} solar masses per cubic parsec) that it must be a black hole. Such results currently provide some of the best evidence for the existence of these enigmatic objects.

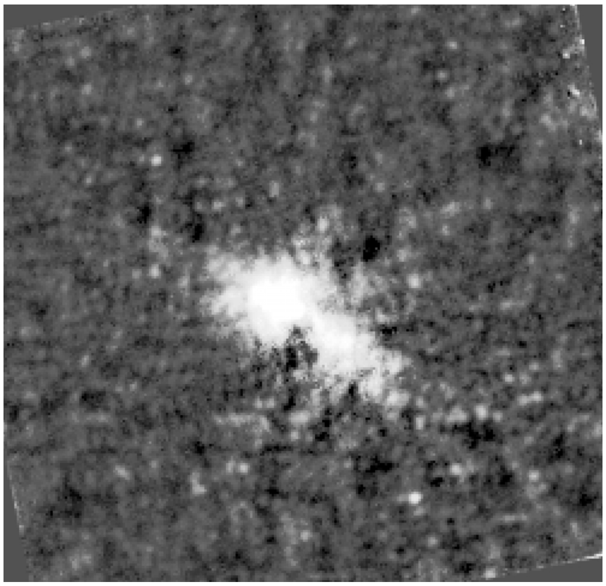

Fig. 7 — The overall background light of the bulge of M31 has been subtracted from the remainder of this *K*-band image taken with the AOB. The dynamical centre of the galaxy is near the fainter of the two blobs (which are separated by 0.5 arcsecond) of stars that together form the bright nucleus of M31 in previous ground-based images. The exact nature of the groups of stars and their relationship with the black hole that has been demonstrated to be located at the centre is still a mystery.

d. Nearby Galaxies

Extended objects such as the nuclei of nearby galaxies, Seyfert galaxies and bright quasars can usually be used as the reference or guide star for the wavefront sensor provided they are sufficiently bright. The nucleus of M31 is one such example. It has been known since the early Stratoscope balloon flights that the nucleus of M31 is unexpectedly double (Light *et al.* 1974). Later studies showed that the centre of rotation of the galaxy is located at the fainter of the two fuzzy patches rather than the brighter. No convincing explanation of the nature of the brighter "nucleus" has yet emerged. Near-infrared observations with AOB (figure 7) show that the brighter nucleus appears to be resolved into a massive star cluster of some sort, perhaps supporting the hypothesis put forth by Tremaine (1995) that it is due to a disk of stars orbiting around the nucleus. Analyses of the colours of the stars in the larger central region observed by AOB demonstrate that they are similar to those in the centre of our Milky Way (Davidge *et al.* 1997). What are sorely lacking are spectroscopic observations using AOB so that motions can be derived. A new spectrograph, OASIS, has been built by the Observatoire de Lyon to do precisely

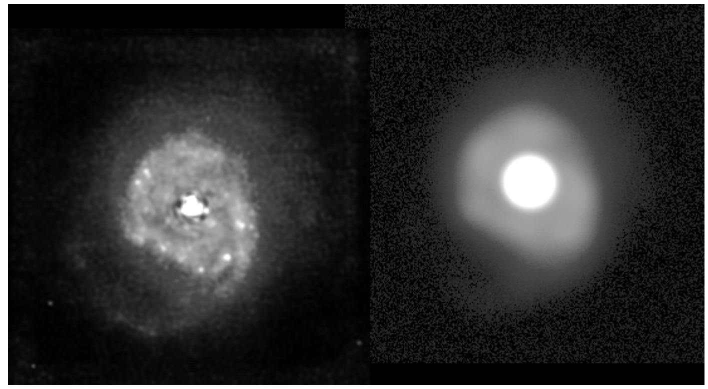

Fig. 8 — *K*-band images of the Seyfert galaxy NGC 7469, obtained with and without image compensation. The bright point-like nucleus was used as the guide object.

such observations. Unfortunately, bad weather and a telescope breakdown have so far prevented this. The very fact that we are able to resolve, from the ground, not only the nucleus of M31 into its components but also into its individual stars is very impressive to me.

e. Active Galactic Nuclei

Galaxies with sharp bright cores, presumably resulting from the infall of material onto massive black holes, are ideal for studies with adaptive optics. In the past, it was difficult to study features in the surrounding galaxies because of the presence of the very bright central source. An indication of the tremendous improvement offered by the AOB is shown in figure 8. Many of the features detectable in this near-infrared image are also present in HST images taken in visible light, so there can be no doubt that the resolution is comparable (a direct comparison with HST and false colour images of many other AOB images are illustrated at `www.hia.nrc.ca/science/instrumentation/optical/pueo2/pueo2.html`.

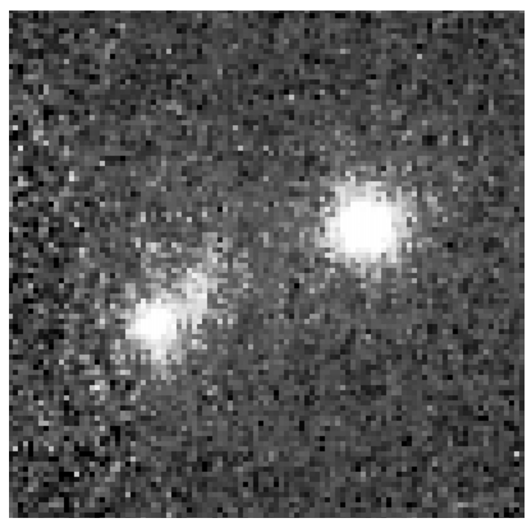

Fig. 9 — An *H*-band image of the gravitational lens SBS 1520+530. Detailed observations of the two brighter objects in the picture indicate that they are images of the same quasar at a redshift of $z = 1.8$. The gravitational field of the faint galaxy to the upper right of the object on the left is producing the double images, which are separated by only 1.6 arcsecond. A 12th magnitude star, fortuitously located 13 arcseconds to the east, was used as the AOB guide star.

f. Objects in the Distant Universe

My own personal research interests have led me to attempt to use the AOB to explore the very distant universe. In general, distant galaxies, although quite small, are still fuzzy, and so the improvements brought about through the use of adaptive optics are not as dramatic as those for nearby objects. One counterexample involves the study of gravitational lenses. Figure 9 illustrates an example of such a phenomenon. The light of a quasar at a redshift of $z = 1.8$ has been split into two images by a foreground galaxy (probably near a redshift of $z = 0.8$). Observations by Chavushyan *et al.* (1997) show that the colours and spectra of the two brightest objects are identical and must be from the same source. The foreground galaxy is clearly visible in the AOB image, even though it is only 0.4 arcsecond from the much brighter quasar. Observations like these enable geometric parameters of the lensing system to be determined. They in turn can be used to derive such diverse information as constraints on the curvature of space and the properties of the galaxy which is acting as a lens, *e.g.* how much dark matter it contains. Although information from just one lens cannot give values with any certainty, studies of dozens of such lensing systems over several years hold great promise — both for estimating cosmological quantities and for the study of the all-pervasive dark matter.

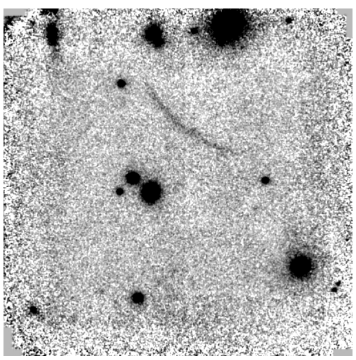

Fig. 10 — A *K*-band image of Abell 2390, a cluster of galaxies at a redshift of $z = 0.23$. The long arc is an image of a background galaxy at a redshift of $z = 0.91$ that has been magnified by the lensing action of the gravitational potential produced by the foreground cluster.

Gravitational lenses can also serve as "telescopes" — both to enlarge the images of background galaxies and to make them appear brighter. Recently, Simon Lilly and I attempted to make use of that feature with the AOB by trying to image exceedingly high redshift galaxies lensed by foreground clusters of galaxies. The so-called "arcs" formed in such fashion have been known for several years, and indeed such an arc is apparent in figure 10. The latter arc is a magnified image of a galaxy at a redshift of $z = 0.9$ (Pelló *et al.* 1991), but we were trying to detect small point-like galaxies or clusters in the process of formation at much higher redshifts. Unfortunately, the weather did not co-operate and we only obtained less than a quarter of the required exposure with worse than average seeing. But we did succeed in getting a nice image of the foreground cluster. Once again, the technique of using foreground lenses to explore the distant universe shows great promise for the future.

4. Observing with an Adaptive Optics System

As the above examples indicate, the technology of adaptive optics can produce tremendous gains for ground-based telescopes. There are several restrictions, however, and factors that beg for innovative scheduling methods to enhance the efficiency and effectiveness of such observations. The main restriction, of course, is that a bright reference source must be located in the field (at least until laser guide star technology matures). Several other factors degrade the performance of an adaptive optics system, however, including cirrus and bright moonlight (both of which make the guide star appear fainter to the wavefront sensor), as well as poor seeing (which degrades the compensation performance). Ideally, observations made using adaptive optics should be queue scheduled so that such factors can be taken into account. It is bad enough to be clouded out entirely, but it is equally distressing to try to observe a target with a guide star that is only just bright enough for near-perfect conditions on a night with a small amount of cirrus and/or bright moonlight. On a clear night with typical CFHT seeing conditions, however, observing with the AOB is an incredible experience. No longer do observers complain about poor seeing when it goes above 1 arcsecond; now the goalposts are closer to 0.1 arcsecond! A more detailed description of some of my observations with the AOB is given in an article by Crampton (1998).

5. Summary

My experience with the AOB demonstrates that it is robust, reliable, efficient, and user-friendly. It routinely delivers 0.1 arcsecond images at red and near-infrared wavelengths that are comparable to those produced with the HST. It also improves images substantially in the blue and visible regions, especially when the site seeing is good. The new 8-m telescopes are being designed to exploit adaptive optics and, indeed, an adaptive optics system for the Gemini North telescope is currently under construction at Victoria. It is interesting to see how far we have come since Dr. Hogg was taking her pictures of globular clusters with the 1.8-m telescope in Victoria.

Acknowledgements

The Adaptive Optics Bonnette owes its success to a large number of scientists, engineers, and technicians working for the Canada-France-Hawaii Telescope Corporation, the Observatoire de Meudon, Laserdot, the University of Hawaii, and the Dominion Astrophysical Observatory. I am grateful to the commissioning team and especially to Robin Arsenault, Jérome Bouvier, François Rigaut, and Daniel Rouan for permission to reproduce some of the images.

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DAVID CRAMPTON is a research scientist at the Dominion Astrophysical Observatory (DAO) in Victoria, where he has been since 1967. Since 1985 he has been the leader of the DAO Instrument Development Group, the team that designed and developed the spectacularly successful Adaptive Optics Bonnette described in this paper. His university education was completed at the University of Toronto, where he earned a B.Sc. in Mathematics and Physics in 1963 and a Ph.D. in Astronomy in 1967, the latter in the area of galactic structure. The author of more than 270 articles in astronomy, David has broadened his interests in recent years to include observational cosmology, quasars, gravitational lenses, and X-ray binaries, as well as astronomical instrumentation. He is a member of several professional societies, and in 1983 was honored by being awarded the Gold Medal of the Science Council of British Columbia.

ABSTRACTS OF PAPERS PRESENTED AT THE 1999 CASCA ANNUAL MEETING HELD AT SAINT MARY'S UNIVERSITY IN HALIFAX, JUNE 27–30, 1999

R. M. Petrie Prize Lecture/Présentation R. M. Petrie

The Local Group of Galaxies, Sidney van den Bergh, Herzberg Institute of Astrophysics, National Research Council of Canada.

Hubble's 1936 view that the Local Group (LG) is "a typical, small group of nebulae which is isolated in the general field" is confirmed by modern data. The total number of certain and probable group members presently stands at 35, falling within a half-mass radius of $R_h \approx 350$ kpc. The zero-velocity surface that separates the Local Group from the field expanding with the Hubble flow has a radius $R_0 = 1.18 \pm 0.15$ Mpc, and its total mass is $M_{LG} = (2.3 \pm 0.6) \times 10^{12} M_\odot$, with most of the mass concentrated in the Andromeda and Milky Way subgroups. The total luminosity represented by the light from Local Group galaxies is $M_V \approx -22.0$, which corresponds to a mass-to-light ratio (in solar units) of $M/L_V = 44 \pm 12$. The solar motion relative to the Local Group is 306 ±18 km s^{-1}, directed towards $l = 99° \pm 5°$ and $b = -4° \pm 4°$. The velocity dispersion within the Local Group is $\sigma_r = 61 \pm 8$ km s^{-1}, and the galaxies NGC 3109, Antlia, Sextans A, and Sextans B appear to form a distinct grouping at $v_r = +114 \pm 12$ km s^{-1}. They are located beyond the group's zero-velocity surface at a distance of 1.7 Mpc from its centroid. The luminosity function for group members has a slope $\alpha = -1.1 \pm 0.1$, a value significantly less negative than what is found for rich clusters of galaxies. The luminosity distribution of member dwarf spheroidal galaxies is steeper than that for dwarf irregulars, and they are strongly concentrated within the Andromeda and Milky Way subclusters of the Local Group. Most dwarf irregulars, by contrast, appear to be free-floating members of the Local Group considered as a whole. With the possible exception of Leo I and Leo A, most group members appear to have begun forming stars simultaneously ~15 Gyr ago. Many of the galaxies for which evolutionary data are available appear to have shrunk with time. Such a result is unexpected since *Hubble Space Telescope* observations appear to show that galaxies at redshifts of $z = 3$ are smaller than those at $z = 0$. The rate of star cluster formation in the Large Magellanic Cloud was low for a period that extended from ~12 Gyr to ~4 Gyr ago. The rate may have increased more rapidly than the rate of star formation 3–5 Gyr ago, but the reason for the sudden burst ~4 Gyr ago remains obscure. None of the dwarf galaxies in the Local Group appear to have experienced a starburst strong enough to have produced a "boojum."

J. S. Plaskett Medal/La médaille J. S. Plaskett

The Potential of Asteroseismology for Subdwarf B Stars, Stéphane Charpinet, Canada-France-Hawaii Telescope Corporation.

The pulsating subdwarf B stars — also referred to as the EC 14026 stars — were theoretically predicted (Charpinet *et al.* 1996) and independently discovered (Kilkenny *et al.* 1997) almost at the same time, a situation that triggered very prolific theoretical and observational efforts during the past three years in a brand new field of research. Reviewed here are recent developments from the very first results that led to the theoretical prediction of such objects, to the latest numerical calculations that can now be compared to the growing amount of data available for the new class of pulsating stars. Also discussed, relative to the results of that theoretical survey, is the very promising potential of applying asteroseismology tools to the objects in order to probe their internal structure.

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Helen Sawyer Hogg Public Lecture/La conférence publique Helen Sawyer Hogg

The Impact Threat and Public Perception, Paul Chodas, Jet Propulsion Laboratory.

Recent popular movies have raised public consciousness of the very real possibility of a comet or asteroid collision with the Earth, and a news report last year implying that asteroid 1997 XF_{11} had a distinct chance of hitting the Earth in the year 2028 further caught the public's eye. The report of possible impact was withdrawn the very next day, and the public perceived either that astronomers had made mistaken calculations, or that the pre-discovery observations found that day had been responsible for the revised prediction. In fact, the original report of the possibility of impact in 2028 was simply a premature assessment. The XF_{11} affair has demonstrated the need for clarity and precision in public communications dealing with the possibility of Earth impact, as well as the importance of peer review before results are released to the press. This year, another potentially hazardous asteroid, 1999 AN_{10}, has made the news, and this time there is indeed a remote chance of collision. Although impact is not possible during the asteroid's primary close approach in 2027, the uncertainties allow for a remarkably close passage, and embedded within the encounter's uncertainty region are many narrow "keyholes" that could bring the asteroid back for a close approach in a later year. Three keyholes have been identified that could perturb the asteroid onto trajectories that collide with the Earth in the years 2044, 2046, or 2039. At the time of writing, the estimated impact probability for 1999 AN_{10} is on the order of 1 in 500,000, larger than for any other known object, but still significantly less than the probability of an undiscovered asteroid of equivalent size striking the Earth before 2044. Additional astrometric measurements of 1999 AN_{10} will likely drive its impact probability to nearly zero, but that may not happen for years, testing the public's reaction to a lingering remote possibility of impact. A side effect of the increasing discovery rate for Near Earth Objects will be a growing number of cases like 1999 AN_{10}.

Invited Lectures/Présentations spéciales

The Age and Fate of the Universe, John P. Huchra, Harvard Smithsonian Center for Astrophysics.

New cosmological observations are closing in quickly on a model for the universe that is of surprise and perhaps delight to both theorists and observers. This is the result of a combination of long-term programs to determine the cosmic expansion rate, the masses of large structures and the ages of its oldest constituents, and startling new observations of the universe's global geometry using high-redshift supernovae and steadily improving constraints from Cosmic Microwave Background observations. The debate about the cosmological mass density now strongly favours a low value, about $^1/_4$ to $^1/_3$ of that needed to close the universe, made up of a mix of baryons, neutrinos, and some as yet to be determined cold dark matter. Evidence for a cosmological constant is improving, and it appears as if the debate on the total value of Ω is being resolved in favour of the favoured theoretical value of unity, with $\Omega_{\rm matter} \sim 0.3$ and $\Omega_\Lambda \sim 0.7$. With numerous determinations of the distances to nearby galaxies with the *Hubble Space Telescope*, most notably the work of the H_0 Key Project team, the determination of the Hubble Constant has converged to a value in the range of 55–75 km s^{-1} Mpc^{-1}. Taken together, these parameters yield a universe with an age of around 15 Gyr, fully consistent with the latest age determinations of the oldest stars. If the values hold up, the universe will continue to expand forever. But there is still a lot of work to do!

What Do We Really Know About Neutrinos?, Malcolm Butler, Saint Mary's University.

The Sudbury Neutrino Observatory is now on line, and there is an expectation that we will see definitive evidence of neutrino oscillations in the solar neutrino flux. Summarized here is the current status of the theory of solar neutrino oscillations, and speculation on surprises that may await us. There are other experiments that seem to suggest the existence of neutrino oscillations (Liquid Scintillator Neutrino Detector and SuperKamiokande observations of atmospheric neutrinos), and there are certain issues/worries that arise if one assumes they are all correct.

The Leonids: 1998 Results and Implications for the Future, R. Hawkes, Mount Allison University, M. Connors, Athabasca College, A. R. Hildebrand, University of Calgary, K. J. Ellis, Communications Research Centre, S. Molau and J. Rendtel, International Meteor Organization, T. Baayraa, D. Batmunkh, and B. Bekhtur, Mongolian Academy of Sciences, A. LeBlanc and I. Murray, Mount Allison University, Maj. R. Sponder, National Defence Headquarters, M. Beech, University of Regina, P. Gural, Science Applications International Corporation, Maj. J. Thorne, U.S. Air Force Space and Missile Systems Center, Lt. Col. M. Bedard, Maj. R. Correll, Lt. Col. D. Jewell, Lt. T. Montague, Maj. B. Tilton, and Col. S. P. Worden, U.S. Air Force, P. Brown, M. Campbell, J. Jones, and A. R. Webster, University of Western Ontario, D. Babcock and R. Worsfold, York University, Peter Jenniskens, SETI Institute and NASA Ames Research Center, G. Garradd and R. H. McNaught, no affiliation.

We present results of observations of the 1998 Leonid meteor shower from sites in Mongolia and Australia using image intensified CCD and multi-frequency radar techniques, as well as some results from the Canadian experiment on the 1998 NASA Airborne Leonid Mission. The flux profile of the shower in different mass regimes is presented and discussed in terms of models of the meteor stream. In 1998 the Earth encountered the peak in the larger masses significantly prior to the peak in smaller meteoroids. Distributions of beginning heights, light curve irregularities, light curve skew, and overall trail length can be used to infer the physical nature of the meteoroids. One interpretation of the data is that even the smallest meteoroids are clusters of much smaller grains bonded by a second component. Such a physical structure has astrophysical significance regarding models of cometary and solar system formation, and also practical importance in assessing the interaction between meteoroids and spacecraft, and the risk posed by the Leonid and other potential meteor storms.

Oral Papers/Les présentations orales

On Non-Gaussianity of the COBE-DMR Map, Robert Crittenden, J. Richard Bond, and Ue-Li Pen, Canadian Institute for Theoretical Astrophysics.

In the past year, two papers have reported positive evidence of non-Gaussian features in the COBE-DMR four-year maps, both in the measured bi-spectrum and in correlations between wavelet amplitudes. Recently, Bromley & Tegmark suggested that the observations might be attributed to local effects, from patches smaller than the COBE beam. Here we review the evidence for non-Gaussianity and introduce a test designed to locate local signs of non-Gaussianity. We apply it to the COBE data and discuss some preliminary results.

Photometric Properties of Low Redshift Galaxy Clusters, W. A. Barkhouse and H. K. C. Yee, University of Toronto, and O. López-Cruz, Instituto Nacional de Astrofísica, Óptica y Electrónica.

We present preliminary results of a photometric study of low redshift galaxy clusters ($0.02 \leq z \leq 0.04$). The survey was conducted using the 8k CCD mosaic camera on the Kitt Peak National Observatory 0.9-m telescope. Luminosity functions (for the whole cluster as well as a function of clustercentric radius) are presented for several galaxy clusters. The data will allow us to test the cD formation scenario based on the disruption of dwarf galaxies (López-Cruz *et al*. 1997).

Reference

López-Cruz, O., Yee, H. K. C., Brown, J. P., Jones, C. & Forman, W. 1997 ApJ, 475, L97

The Virgo Cluster in 3-D, Michael J. West, Saint Mary's University, and John P. Blakeslee, California Institute of Technology.

One of the most striking features of the large-scale distribution of galaxies is its filamentary appearance, with long, quasi-linear arrangements of galaxies extending over tens and perhaps even hundreds of megaparsecs. Here we present the first evidence of a *bona fide* three-dimensional filament that passes through the heart of the nearby Virgo cluster of galaxies. Based on distances to individual Virgo galaxies obtained using the method of surface brightness fluctuations, we show that the Virgo cluster's principal axis can be resolved as a genuine three-dimensional linear structure that is inclined to the line of sight, with a systematic trend of decreasing galaxy distance as one moves along the filament in the easterly direction. The major axis orientations of Virgo's brightest elliptical galaxies, as well as M87's jet, also appear to be aligned with the filament. We show that the filament can also be traced to even larger distances, where it eventually intersects with the rich cluster Abell 1367 some 50 Mpc away. Abell 1367 itself forms one node of a well-known supercluster with the Coma cluster, which raises the intriguing possibility that the Virgo, Abell 1367, and Coma clusters may all be members of a enormous filamentary network.

The Evolution of Interstellar Dust Out to z = 0.001, Geoffrey C. Clayton, Louisiana State University.

The recent discovery that the ultraviolet dust extinction in starburst galaxies is similar to that found in the Small Magellanic Cloud (SMC) motivated us to re-investigate the ultraviolet extinction found in Local Group galaxies, where we can study the dust environment in detail. Recent work in M31 and M33 with the *Hubble Space Telescope* seem to show ultraviolet extinction more similar to the Galaxy than that seen in the Magellanic clouds. The extinction properties in the Large Magellanic Cloud (LMC) lie within the range of properties in the Galaxy, but do not follow the relation of Cardelli, Clayton & Mathis. The SMC extinction properties are more extreme than anything seen in the Galaxy. Thus, the behaviour of the dust extinction in the Magellanic Clouds supports a dependence of dust properties on star formation activity. However, other environmental factors (such as galactic metallicity) must also be important. Dust in the LMC, where much more active star formation is present, does not share the extreme extinction properties seen in SMC dust. We are using maximum entropy methods and the discrete dipole approximation to model individual dust grains along these lines of sight. The knowledge gained from studies of interstellar dust in nearby galaxies is being used in radiative transfer models of more distant galaxies that include dust in a more realistic way.

The Growth of Black Holes During Self-Similar Virialization, R. N. Henriksen, Queen's University.

The presence of large (non-stellar) "black holes" in the nuclei of galaxies now seems virtually inescapable. That raises the still very uncertain question of their origin and growth. Since the early work by Peebles and Young, and the subsequent confirmation and extention by Quinlan, Hernquist, and Sigurdsson, the adiabatic growth of black holes in already formed galaxies has been understood and known to produce density cusps comprised of stars bound to the black hole. Recently, Stiavelli has calculated the density cusps induced by central black holes under the assumption of degenerate Fermi-Dirac type stellar statistics. He finds that the cusps agree with the adiabatic cusps for appropriate values of the "chemical potential." Also, recently Henriksen and Widrow discovered a kind of "self-similar virialized" phase during the formation of Dark Matter halos. It is therefore of interest to note how a pre-existing black hole at the centre of the Dark Matter grows during this phase of galaxy growth, and is of interest to calculate the density profiles induced by the black hole in regions bound to it and in regions of the halo perturbed by it. Such results are presented here.

The Canadian Galactic Plane Survey, A. R. Taylor, University of Calgary.

Since April 1995 the Dominion Radio Astrophysical Observatory has been engaged in a project to image the radio emission from a 70° section of the Galactic plane as part of the Canadian Galactic Plane Survey (CGPS). The DRAO observations provide simultaneous radio continuum images at two wavelengths, 74 cm and 21 cm, and spectral line images of the 21-cm line of neutral atomic hydrogen. In the radio continuum at 21 cm, dual polarization receivers provide images in all four Stokes parameters. The observations form part of an international collaboration to create a database of arcminute scale resolution, high spatial dynamic range images of all known major components of the Galactic interstellar medium (ISM). The survey observations are scheduled for completion in April 2000, and data products will soon begin to enter the public domain through the Canadian Astronomy Data Centre. Described here are the CGPS data products and some of the Canadian scientific highlights, including the detection of unusual atomic hydrogen structures related to the vertical transfer of matter and radiation between the disk and halo, the use of Faraday rotation to study the magnetic field and diffuse ionized component in the plane of the Galaxy, the identification of bubbles and superbubbles in the ISM created by multiple generations of massive star formation, and the characterization of a cold atomic phase of the neutral medium that may provide a link between global shock phenomena in the Galaxy and the formation of molecular clouds.

The Binding Energies of Galactic Globular Clusters, Dean E. McLaughlin, University of California Berkeley.

Binding energies are calculated from the observed core radii and velocity dispersions of Galactic globular clusters, under the assumption that the clusters' internal spatial and dynamical structures are described by standard, isotropic King models. A tight correlation is found between binding energy and cluster mass, with E_b proportional to $M^{1.8}$ or so. The correlation is better than any other monovariate correlation between the properties of Galactic globulars. It is comparable in statistical significance to the best bivariate correlations, *i.e.* the so-called "fundamental plane" for globular cluster cores. The connection between the fundamental plane and the mass–binding energy relation is discussed, as are some possible implications for questions of globular cluster formation.

Revealing the Galactic Magnetic Field in the Plane of the Galaxy, J. C. Brown and A. R. Taylor, University of Calgary.

The Canadian Galactic Plane Survey (CGPS) is an international collaboration to map a section of our Galaxy about its mid-plane with high spatial dynamic range. Continuum images of the polarized emission at 1.42 GHz are created from four closely spaced frequency bands. Using the data from the individual bands, we are deriving rotation measure maps of the survey region. Rotation measures of polarized extragalactic sources with polarized intensity greater than 3 mJy allow us to extract information about the magnetic field along the line of sight across the plane of the Galaxy. While global, broad-scale, rotation measure mappings of the Galaxy have been performed previously at high galactic latitudes (Han *et al*. 1997), only a few sources have been measured in the plane of the Galaxy. The CGPS observations are providing an average source density for rotation measure determinations of approximately one source per square degree. As a result, much more detail of the magnetic field can be obtained. We present rotation measure maps of some initial CGPS images and our analysis of the magnetic field in the region.

Reference

Han, J. L., Manchester, R. N., Berkhuijsen, E. M. & Beck, R., 1997, A&A, 322, 98

Blowing Bubbles??, J. English, Space Telescope Science Institute.

Neutral hydrogen "worms," which stream vertically from the mid-plane to high latitudes, may transport material and energy from the Galactic disk into the halo. Using the Dominion Radio Astrophysical Observatory's (DRAO) Synthesis Telescope, as part of the Canadian Galactic Plane Survey, we have resolved (1 arcmin and 0.82 km s^{-1}) an H I worm candidate. Although the mushroom-shaped cloud extends only a few hundred parsecs *south* of the mid-plane, the cap appears to be fragmenting. Therefore, components of the cloud, including any existing hot gas or ultraviolet photons, could escape to higher galactic latitudes. Simulations have previously made general predictions that implied worms could be superbubbles. However, our data, which constrain for the first time detailed numerical models of the dynamical processes generating worms, suggest alternative scenarios. For example, for an observed minimum estimate of the H I mass of $1.3 \times 10^5 M_\odot$, both our preliminary thin-shell and fluid dynamical models indicate that the observed cloud is consistent with a single off-plane explosion. The energy input equivalent to a supernova would generate a buoyant fireball that produces a mushroom-like feature interior to an expanding outer blast wave.

Searching for Wind-Blown H I structures in the Canadian Galactic Plane Survey, Lewis B. G. Knee and Brad J. Wallace, Herzberg Institute of Astrophysics, National Research Council of Canada.

Using high-resolution wide-field H I mosaics from the Canadian Galactic Plane Survey (CGPS), we are searching for evidence of anisotropic flows of atomic gas presumably driven by massive young stars. We have found a number of unusual streamer-type H I structures, some of which appear associated with massive star-forming regions: some show evidence for very large (several tens of km s^{-1}) velocity shifts between the atomic gas and the presumably associated molecular clouds. If the association is real, it appears that in some flows the atomic gas has been accelerated up to velocities comparable with the dissociative shock velocity. The most striking examples of candidate streamer-type atomic flows we have found are all at relatively high Galactic latitudes in the CGPS. This suggests that confusion in the H I may be preventing the detection of similar objects closer to the Galactic plane. Anisotropic flows of dissociated molecular gas may be a common occurrence in the destruction of molecular clouds in which stars of high mass have formed.

Consequences of Feedback from Early Supernovae for the Milky Way Disk, Priyamvada Natarajan, Canadian Institute for Theoretical Astrophysics.

We examine the role of the first supernovae in proto-galaxies, their role in feedback, and the consequences for disk assembly. Extending the picture proposed by Dekel & Silk (1986), we argue that energetic supernovae winds can expel baryons from all proto-galaxies with varying degrees of efficiency. The fraction of baryons retained, and hence available to assemble into the baryonic disk, is therefore a function of the central velocity dispersion of the halo. Such a coupling of the baryonic component to the dark halo leads to the following interesting consequence, a prediction for a weak scaling of the zero-point of the Tully-Fisher relation or, alternatively, the mass-to-light ratio with the central velocity dispersion of the halo. Upon application to the case of the Milky Way halo, such a feedback mechanism implies: (i) that the Milky Way halo lost ~10% of its original gas content, and the gas mass lost is roughly what is estimated for the mass in our X-ray halo consistent with the X-ray background in the soft band; (ii) a range in the inferred redshift of formation z_f and the local baryon fraction f_b for the Milky Way that depends on the initial spin parameter λ_h of the halo. In a range of viable cold-dark matter cosmological models, we find that for a low spin halo ($\lambda_h \sim 0.02$) with $z_f < 1, f_b \sim 2\%$, for a median spin halo ($\lambda_h \sim 0.05$) with $z_f \sim 1–2.5, f_b \sim 5\%$, and for a high spin halo ($\lambda_h \sim 0.2$) with $z_f \sim 4–8, f_b \sim 20\%$. The observationally determined ages for the oldest disk stars in the Milky Way seem to rule out a low value for the spin parameter. Given the shape of the spin distribution of halos obtained in *N*-body simulations, we find that, while a high value for the spin parameter is not very probable, it is interesting to note that if it is indeed the case for the Milky Way halo, then feedback processes can cause the local baryon fraction to differ significantly from the universal value.

Putative Planets, William D. Heacox, University of Hawaii.

The planetary identification of recently discovered low-mass objects orbiting main-sequence stars is based entirely upon mass. But the mass distinction between planets and brown dwarfs is unclear: the only meaningful distinction between them appears to be one of formation mechanism, for only in such terms can the presence of Earth-like planets be inferred from the discovery of Jupiter-mass objects. To resolve this matter, the overall statistical properties of putative planets are compared with those of stellar-mass secondaries to stars of similar spectral types. The results are striking: in all orbital characteristics the properties of the reported planetary systems are statistically indistinguishable from those of binary systems, while differing markedly from those expected of planetary systems, and in both the binary and putative planetary systems secondary mass is uncorrelated with all orbital properties, in contrast to what is observed in our solar system. Such comparisons argue for a common formation mechanism for the reported planetary systems and for binary star systems: what is probably being discovered is largely a population of binary star systems with brown dwarf secondaries. Planetary systems similar to ours apparently have yet to be found elsewhere in the universe.

Canadian Participation in the Atacama Large Millimetre Array, L. W. Avery, Herzberg Institute of Astrophysics, National Research Council of Canada, and C. D. Wilson, McMaster University.

The concept of building a large array of antennas to operate at millimetre and submillimetre wavelengths has been under discussion in various astronomical communities since 1983. Although initially somewhat disparate, these visions have evolved and grown together over the years until, today, there is a single, virtually worldwide focus on the construction of a facility recently dubbed the Atacama Large Millimetre Array, or ALMA. ALMA will provide a quantum leap ahead in our ability to understand virtually all aspects of the thermal universe. The new array is to consist of more than 60 antennas operating within all the atmospheric windows from 30 GHz (1 cm wavelength) to 900 GHz (330 microns). It will be built high in the Andes Mountains of Chile at one of the very best submillimetre sites on Earth. The combination of large collecting area, broad wavelength coverage, and an outstanding site will yield unprecedented sensitivity and resolution for studying a wide range of fundamental scientific questions concerning such things as asteroids, comets and planets in our solar system, star and planet formation elsewhere in the Galaxy, galaxy formation at distances corresponding to redshifts z as high as 30, and small-scale cosmic background fluctuations from the era $z \sim 1000$. The Long Range Planning Panel, based on wide-spread, multi-disciplinary support for the project, has strongly recommended that Canada participate in ALMA. Work has already begun within the Canadian community to ensure that the recommendation will be realized.

Preparing for the Gemini First Call for Proposals, Stephanie Coté and Tim Davidge, Herzberg Institute of Astrophysics, National Research Council of Canada.

The first call for proposals for shared-risk use of Gemini North is rapidly approaching. Described here is the complete application process, from proposal preparation to the completion of Phase 2. Particular emphasis is placed on the support infrastructure provided by the Canadian Gemini Office and the Gemini Observatory to assist Canadian astronomers. The first images with the northern Gemini telescope were recorded in December 1998 and since then considerable effort has been devoted to making the facility operational.

Data Mining in Astronomy?, Daniel Durand, David Schade, and Pat Dowler, Herzberg Institute of Astrophysics, National Research Council of Canada, Randy Zingle, University of Victoria, and Sévérin Gaudet, National Research Council of Canada.

During the past decade a wide variety of astronomical data sets, ranging from the *Hubble Space Telescope* (HST) archive of optical data to NASA's High Energy Astrophysical Archive Center, have become available. The Canadian Astronomy Data Centre (CADC) archives and distributes data from the Canada-France-Hawaii Telescope and James Clerk Maxwell Telescope, and provides a unique re-calibration pipeline for the HST that provides users with data that are superior to the products provided by the U.S. archive site. Contained within them and other international archives is a virtual mountain of data, whose full scientific potential has barely been touched because we lack effective tools to access and analyze them. Furthermore, a virtual avalanche of data from new survey programs is beginning to flow in support of the international investment in large new telescopes on the ground and in space. To partly solve the problem, the CADC have started the development of archive tools that are intelligent and could effectively locate and retrieve data anywhere in the world that are of interest to a specified science question, and operate seamlessly across archive boundaries. Once the tools locate and return relevant data, we need analysis tools that extract meaning from them. Collectively, the tools constitute what we mean by "data mining." Presented here is the very first implementation of such a tool, using the CNOC I data set as the first example.

High Energy Gamma-Ray Astronomy with STACEE, D. S. Hanna, K. Ragan and C. G. Théoret, McGill University, M. C. Chantell, Z. Conner, C. E. Covault, M. Dragovan, R. Ong, S. Oser, and R. Scalzo, University of Chicago, D. Bhattacharya, J. A. Zweerink, and T. O. Tumer, University of California Riverside, L. Boone and D. A. Williams, University of California Santa Cruz, D. T. Gregorich, California State University Los Angeles and California Institute of Technology, and R. Mukherjee, Barnard College and Columbia University.

The Solar Tower Atmopheric Cherenkov Effect Experiment (STACEE) is a new instrument for observing astrophysical sources of gamma rays in the energy range from 50 to 250 GeV. This energy range corresponds to an "unopened window," inaccessible to previous ground and space-based experiments. STACEE is located at the National Solar Thermal Test Facility at Sandia Laboratories in Albuquerque, New Mexico. STACEE uses large heliostat mirrors at night to collect Cherenkov light from gamma-ray air showers. The first phase of STACEE, using 32 heliostats, was completed in the fall of 1998. We describe the performance of STACEE during the 1998-1999 winter observing season. We also describe analysis in progress of several preliminary observations, including the Crab nebula and pulsar, supernova remnants, and extragalactic sources such as blazars. Construction to expand STACEE is continuing, and we expect the next phase using 64 heliostat mirrors to be completed by the end of 1999.

JCMT/SCUBA Sub-Millimetre Wavelength Imaging of Star Formation in the Orion A Molecular Cloud, Doug Johnstone, Canadian Institute for Theoretical Astrophysics, and John Bally, University of Colorado. We present the first high dynamic range and high sensitivity images of the sub-millimetre wavelength continuum emission at 450 and 850 microns of the "Integral Shaped Filament" in the northern portion of the Orion A Molecular cloud. The images trace the morphology and spectral index of optically thin emission from interstellar dust, and constrain the grain temperature and emissivity. The images reveal a remarkable chain of compact sources embedded in a narrow (< 1 arcminute = 0.14 pc) high column density filament that extends over the 50 arcminute (7 pc) length of the map with faint extended structure surrounding it. The equilibrium of the filament is inconsistent with an isothermal ridge, requiring magnetic fields for stability. While many compact sources contain extremely young protostars, others may be pre-collapse phase cloud cores. Analysis of the clump distribution reveals a mass function similar to the observed stellar initial mass function and inconsistent with the standard molecular cloud mass function. The spectral index is uniform between 450 and 850 microns, except for the ridge sources, the photo-heated H II region edges including the Orion Bar, and the location of molecular hydrogen shocks. Analysis of the spectral index is essential for understanding the changes to dust in dense star-forming environments.

Infrared-Dark Clouds: Part 1. Cold, Filamentary Dust Clouds, P. A. Feldman and R. O. Redman, Herzberg Institute of Astrophysics, National Research Council of Canada, S. J. Carey, Boston College, and M. P. Egan, Air Force Research Laboratory.

In April 1999 we used the Sub-millimetre Common User Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope to observe a selection of Infrared-Dark Clouds (IRDCs) discovered by Egan *et al.* (1998) with the Midcourse Space Experiment (MSX). Many of the dust clouds revealed in the SCUBA images have filamentary structures. Bright spots, often unresolved, appear along the filaments. In all cases but one, the bright sources do not appear in the IRAS or MSX point source catalogs. At their kinematic distances, the filaments extend over 20 pc in some cases and contain thousands to hundreds of thousands of solar masses. The structures resemble the large-scale dust clouds mapped in Orion by Johnstone & Bally (1999). The temperature of the dust in the filaments is typically less than 15 K. The filamentary structures with bright spots along them bring to mind early theoretical star-formation models involving collapse along magnetic field lines (Mestel 1977).

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Infrared-Dark Clouds: Part 2. Sites of Very Early Star Formation, R. O. Redman and P. A. Feldman, Herzberg Institute of Astrophysics, National Research Council of Canada, S. J. Carey, Boston College, and M. P. Egan, Air Force Research Laboratory.

In April 1999 we used receiver A3 on the James Clerk Maxwell Telescope (JCMT) to observe key points within our selection of Infrared-Dark Clouds (IRDCs). Observations of such tracers of dense gas as CS (5–4), $C^{34}S$ (5–4), and HCO^+ (3–2) were made of the brighter continuum sources discovered in the Sub-millimetre Common User Bolometer Array (SCUBA) images (Feldman *et al.* 1999). The bright, point-like sources almost always showed line profiles indicative of outflow/infall. Several sources exhibited strong blue/red asymmetries, usually characteristic of infall (Zhou *et al.* 1993). The lines are weaker and narrower away from the bright sources, suggestive of dense but quiescent gas. The gas in the IRDCs is dense and cold, with temperatures less than 15 K, H_2 number densities > 10^6 cm^{-3}, and H_2 column densities ranging up to 10^{23} cm^{-2}. At their kinematic distances, the individual clumps contain 10^2–10^4 $M_\odot$. It is tempting to speculate that the IRDCs may be the long-sought centres of massive star formation in the Galaxy.

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Time Dependence of Jets from Protostars/Gamma-Ray Bursters, M. Aburihan and R. N. Henriksen, Queen's University.

Recently Fiege & Henriksen and Lery, Henriksen and Fiege have demonstrated that the self-similar quadrupolar circulation models are quite promising as a description of at least the exterior (super-Alfvénic) regions of bipolar outflows. However, those are steady state models and so do not include the sudden collapse phase that may be associated with the first moments of star formation according to works by Henriksen, André and Bontemps and by Shantanu Basu. This paper seeks to correct this by finding time dependent generalizations of such models. In the process we have found that the new models can actually describe the sudden, early development of highly beamed high velocity outflows from post super(or hyper)-nova-implosion conditions such as are now considered a likely part of gamma-ray burst models. We describe the present results and future possibilities.

Modeling Magnetic Fields in Stars: The Input[1], Stephen Shorlin and John D. Landstreet, University of Western Ontario, Gregg A. Wade, University of Toronto, and Jean-François Donati, Observatoire Midi-Pyrénées.

The multi-line technique Least-Squares Deconvolution (LSD) has recently been developed and used to extract information about stellar magnetic fields from stellar spectra. LSD may be used to find average polarization signatures for stellar absorption lines under the influence of the Zeeman effect, which may then be used to constrain magnetic field amplitudes and topologies in magnetic stars. The largest approximation in the LSD process is that all lines are split and polarized in the same way by the Zeeman effect, which is not true. This approximation is made in order to use as many lines as possible in the average, thus reducing the signal-to-noise ratio. Tests of the approximation are presented here, and the implications for polarization signatures as the input for magnetic field modeling are discussed.

The White Dwarf Population of Globular Clusters, Brad Hansen, Canadian Institute for Theoretical Astrophysics.

The white dwarf population in globular clusters represents the fossil record of stellar evolution in these coeval systems. Current and future

[1]Selected as the best student oral paper at the 1999 meeting.

technologies promise soon to allow us to study the population in detail and in full. Described here are known and predicted theoretical properties of the white dwarf sequence and what we can learn from them. In particular, we focus on the use of the faint end of the white dwarf sequence as an age estimator and the use of the bright end of the sequence as a constraint on dynamical evolution processes in cluster cores.

The Magic of Betelgeuse, David F. Gray, University of Western Ontario.

The M-type supergiant star Betelgeuse has been known as a variable star for many years. More recently, *Hubble Space Telescope* observations and interferometer observations have shown a bright spot on the star's surface. High spectral resolution observations taken at Western show the spectral lines to be variable in depth, and this is the key to understanding what is going on. This paper explains how all of the observations can be interpreted, and how the bright spot is not a giant convection cell, as proposed by others. New evidence is presented for giant convection cells.

The Evolution of Rotating Stellar Collision Products, Alison Sills, Ohio State University, and Jamie Lombardi, Jr., Vassar College.

Blue stragglers in dense globular clusters are believed to have been created through the direct collision of two normal cluster stars. In previous work (Sills *et al.* 1997) we have used the results of smoothed particle hydrodynamics (SPH) simulations of stellar collisions as initial models for stellar evolution calculations of stellar collision products. In that work we investigated the results of head-on collisions. However, the majority of collisions will be grazing collisions. SPH simulations of non-head-on collisions show that the collision products can be rotating rapidly, which has strong effects on the future evolutionary state of such stars. We present evolutionary tracks for the collision products of non-head-on collisions, and discuss their implications for studies of blue straggler populations in globular clusters.

Poster Papers/Les présentations affichages

Discovery of 200 Carbon Stars in the Irregular Galaxy IC 1613, Loic Albert (S) and Serge Demers, Université de Montréal, and William Kunkel, Carnegie Institute.

We have discovered more than 200 carbon stars in the Local Group Galaxy IC 1613 by employing a photometric approach developed by Brewer *et al*. (1995). The four-band observations were acquired in December 1998 with Weymann's new wide-field camera mounted on the DuPont 2.5-m telescope at Las Campanas, Chile. Our objective was to discover carbon stars as far out from the centre of IC 1613 as possible; hence, we covered the galaxy in two 25 arcminute diameter fields — east and west. Carbon stars were found as distant as 14 arcminutes from the centre of the galaxy. A distance modulus of $m{-}M = 24.3$ (Freedman 1988) for IC 1613 yields a carbon star luminosity peak at $R = -3.2 \pm 0.6$ and $I = -4.3 \pm 0.6$, 0.4 magnitude fainter than carbon stars in M31 (Brewer *et al*. 1995).

Reference

Brewer, J. P., Richer, H. B. & Crabtree, D. R. 1995, AJ, 109, 2480

H I in the Field of the dIrr/dSph Galaxy Phoenix, Claude Carignan and Julie St-Germain, Université de Montréal.

New results are presented for a mosaic mapping of the H I in the field of the Local Group dwarf galaxy Phoenix. The observations, obtained with the Australia Telescope Compact Array, cover an area of 120×120 arcminutes. Four velocity components are identified, at heliocentric velocities of −23, +7, +59, and +140 km s^{-1}. While the gas at +7 km s^{-1} is of Galactic origin and the gas at +140 km s^{-1} is most likely associated with the Magellanic Stream, the situation for the two other components is uncertain. We suggest, however, that the component at −23 km s^{-1} is probably associated with Phoenix because: (i) it has a compact structure and is only slightly offset from the optical, (ii) its H I mass of 10^5 $M_\odot$ is what is expected from such a system, and (iii) it has a definite velocity gradient. Because of the large mass implied for the component at +59 km s^{-1} if it lies at the distance of Phoenix (> 10^6 $M_\odot$), we tend to exclude it as being associated with the galaxy. Optical velocities are needed to confirm or negate the possible associations.

Dynamics, Distribution, and Amount of Molecular Gas in Galaxies with NIR Isophote Twists: NGC 5728 and NGC 2273[2], Glen Petitpas, McMaster University, and Christine Wilson, McMaster University and California Institute of Technology.

Recent near infrared observations of the stellar components of barred galaxies have revealed evidence for isophotal twists interior to the nuclear ring of star forming regions. These twists are thought to be the signature of a "bar within a bar," which may be a method of fueling active galactic nuclei. There are competing models explaining such isophote twists, all of which rely on the molecular gas quantity and distribution. In this paper we present high resolution CO $J = 1{-}0$ maps of NGC 5728 and NGC 2273 taken at Owens Valley Radio Observatory Millimeter Array. We compare our maps with the gas conditions required by the models to produce the observed near infrared morphology.

Initial Results from the VSOP Survey Program, W. K. Scott and A. R. Taylor, University of Calgary.

In February 1997 the first Space VLBI satellite was launched from Kagoshima Space Center in Japan. In addition to general observing, approximately 25% of the mission time has been devoted to the VSOP Survey Program of ultra-compact cores. Global VLBI observations using only ground-based radio telescopes cannot exceed a brightness temperature detection limit of 10^{12} K. This value is in agreement with the theoretical upper limit for an incoherent synchrotron source. Nevertheless, variability studies of compact Active Galactic Nuclei (AGN), and an early space-based VLBI experiment, have suggested that brightness temperatures in excess of that limit exist. The VSOP mission allows, for the first time, a systematic investigation of the brightness temperature properties of a statistical sample of ultra-

[2]Selected as the best student poster paper at the 1999 meeting.

compact AGN. The VSOP Survey Program is a collaboration of teams from Japan, Canada, the United States, and Australia. We present here initial results and images obtained at the University of Calgary, including the detection of brightness temperatures greater than 10^{13} K.

A New Superbubble in the Perseus Arm, P. E. Dewdney, B. J. Wallace, and T. L. Landecker, Herzberg Institute of Astrophysics, National Research Council of Canada.

A superbubble in the Perseus Arm has been discovered in the data from the Canadian Galactic Plane Survey. The superbubble is about $5^\circ \times 8^\circ$ in size (physical size 200×300 pc). The shell that defines the boundary of the bubble can be seen clearly in arcminute-resolution H I, ^{12}CO, and HiRes-processed IRAS data from the Survey. The quantities of atomic and molecular gas in the shell are $3 \times 10^5\ M_\odot$ and $10^5\ M_\odot$, respectively. We find evidence of numerous young stellar objects in the shell, and suggest that formation of the supershell has led in turn to the formation of molecular gas and to the formation of new stars. The structure of the H I shell is irregular, implying that it is being disrupted by stellar winds and supernovae arising from new, massive stars formed at its periphery.

Molecular Clouds Shocked by Supernova Remnants, Andreea Font and George F. Mitchell, Saint Mary's University, Jean-Pierre Maillard, Institut d'Astrophysique de Paris, and Dale Frail, National Radio Astronomy Observatory.

We investigate three supernova remnants, 3C391, W28 and W44, which are known to be interacting with their environmental molecular clouds. An important goal in studying such interactions is to determine whether compression by supernova shocks triggers star formation or whether, on the contrary, the shock destroys the clouds. In this study, we are using as tracers CO and other high density molecules, as well as high resolution (~15 km s^{-1}) $v = 1\text{–}0$ S(1) molecular hydrogen emission. The spatial coincidence of molecular peaks near the location of (1720 MHz) OH masers has been reported previously. Here, we investigate in detail the morphology of the gas near the shock front and analyze the gravitational stability of the clumps as a possible clue for the shock's history. Also, the resolved lines of H_2 emission provide additional information about the local speed of the shocks and their possible physical nature.

A Radio Study of Three Galactic Objects in Cygnus, Tyler Foster and David Routledge, University of Alberta.

Data from the Canadian Galactic Plane Survey (CGPS) are used to investigate the supernova remnant (SNR) 3C434.1 (G94.0+1.0) and the H II region NRAO 655 (G93.4+1.8). We find the radio spectra to be non-thermal and thermal, respectively. Combining CGPS 408 MHz and 1420 MHz continuum data with 151 MHz and 2695 MHz data, we present images of spectral index variation across the objects. A cavity in the 21-cm H I distribution is seen near –73 km s^{-1} that matches the position and size of 3C434.1. The –72 km s^{-1} image shows H I morphology resembling that of the SNR. A second cavity in the H I is seen near –70 km s^{-1} that matches the position and size of NRAO 655. An expanding shell of H I with centroidal velocity near –70 km s^{-1} is seen within the cavity. The kinematic distances of the SNR and H II region are therefore both about 8.7 We present physical models for both objects. A third diffuse object is visible between the SNR and the H II region in 408 MHz, 1420 MHz, and 2695 MHz continuum images. It is also faintly visible in $H\alpha$ light, and appears as a well-defined local minimum in the CGPS 1420 MHz polarization intensity image. The object, which we designate G93.6+1.3, has a thermal radio spectrum. We find a cavity in the CGPS H I data at –47 km s^{-1} that matches the 25 arcmin-diameter radio source in size and position, and suggest that it is a foreground object at a distance of 6.1 kpc.

The Canadian Galactic Plane Survey — Phase 2, T. L. Landecker, L. B. G. Knee, C. Brunt, P. E. Dewdney, S. M. Dougherty, J. A. Galt, A. D. Gray, L. A. Higgs, R. Kothes, C. R. Purton, R. S. Roger, K. Tapping, B. J. Wallace, and A. G. Willis, Herzberg Institute of Astrophysics, National Research Council of Canada, J. C. Brown, S. J. Gibson, D. A. Leahy, M. Peracaula, A. R. Taylor, and S. Wilder, University of Calgary, T. Foster, D. Routledge, and J. F. Vaneldik, University of Alberta, W. H. McCutcheon, University of British Columbia, S. Basu, D. I. Johnstone, C. Kerton, and P. G. Martin, Canadian Institute for Theoretical Astrophysics, F. Cazzolato, E. Gagnon, S. Germain, N. Ghazzali, S. Godbout, G. Joncas, S. Y. Maschenko, M.-A. Miville-Deschènes, and S. Pineault, Université Laval, C. Carignan and N. St.-Louis, Université de Montreál, R. A. Christie, Okanagan University College, J. A. Irwin, Queen's University, R. Brar and M. Fich, University of Waterloo, X.-Z. Zhang, Beijing Astronomical Observatory, C. E. Heiles and M. Normandeau, University of California, S. Tereby, Extrasolar Research Corporation, M. H. Heyer, Five Colleges Radio Astronomy Observatory, H. J. Wendker, Hamburger Sternwarte, C. A. Beichman, Infrared Analysis and Processing Center, G. H. Moriarty-Schieven, Joint Astronomy Centre, D. A. Green, Cambridge University, N. Duric, University of New Mexico, and J. English, Space Telescope Science Institute.

The Canadian Galactic Plane Survey (CGPS) is a major initiative to improve our understanding of physical states and interactions in the interstellar medium (ISM) in our Galaxy. In 1995 we set out to create arcminute-resolution images of the major constituents of the ISM. We have (i) captured in action the flow of material and energy from the disk to the halo of the Galaxy, (ii) revealed detailed coupling of stellar winds to the ISM, (iii) laid the groundwork for statistical studies of the turbulent morphology of the ISM, (iv) shown that polarimetry provides a new window on the magneto-ionic medium in the Galaxy, and (v) discovered the first stages of star formation, where the Galactic spiral shock is driving formation of molecular gas from atomic clouds. Based on the results of the first five years, the CGPS Consortium proposes a Phase 2, designed to probe new questions. Over the period 2000 to 2005 the Consortium will tackle three major goals: (i) an extensive investigation of the disk-halo interaction, (ii) completion of the study of the local spiral arm, where many astrophysical processes can be observed in great detail, and (iii) the first detailed mapping of atomic gas in a major star-forming region, the nearby Cepheus complex, which is forming stars over a wide range of masses.

Large SCUBA Images of the Rho Ophiuchi and Orion B Molecular Clouds, George Mitchell, Saint Mary's University, Lorne Avery, Lewis

Knee, Henry Matthews, and Gerald Moriarty-Schieven, Herzberg Institute of Astrophysics, National Research Council, Shantanu Basu, Jason Fiege, Brenda Matthews, Ralph Pudritz, and Christine Wilson, McMaster University, Michel Fich, University of Waterloo, Douglas Johnstone, Canadian Institute for Theoretical Astrophysics, and Gilles Joncas, Université Laval.

We are using the Sub-millimetre Common User Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope to map extended regions of the Ophiuchus, Orion B, and Taurus molecular clouds. Star formation in these clouds spans a range of efficiencies, mass functions, and environmental conditions. The observational goals are: (1) to obtain 850 μm and 450 μm continuum maps of large (1 degree^2) areas, (2) to obtain smaller maps of ^{13}CO and C^{18}O emission from the denser cores, and (3) to obtain maps of polarized continuum emission from some of the denser cores. To date, we have continuum maps of a 25×45 arcminute region of Orion B, a 40×30 arcminute region of ρ Ophiuchi, and a 10×35 arcminute region of TMC-1. In addition, we have smaller maps in ^{13}CO 2–1 and C^{18}O 2–1. Finally, we have maps of polarized emission from three Orion B cores. An initial analysis of a small part of the ρ Oph map shows extended linear features, arcs of emission, and a new pre-protostellar core (Wilson *et al.* 1999). We present here the ρ Oph and Orion B maps, along with preliminary analysis.

Generating a Hierarchical Structure Tree Using Wavelets and Segmentation Analysis, Michael Seymour and Larry Widrow, Queen's University.

Numerous authors have used merger history trees as a tool to study the formation of dark matter halos. In this paper we take a complementary approach of using a snapshot of a dark matter halo in an *N*-body simulation and constructing a hierarchical structure tree. Two techniques used are the discrete wavelet transform and segmentation analysis. By comparing our results to the merger histories of these halos, we can investigate the survival of substructure in collisionless systems. Although the techniques are being developed for *N*-body simulations, they may also find applications in observational work.

Molecular Gas in an Unbiased Sample of S0 Galaxies, Gary Welch, Saint Mary's University, and Leslie Sage, University of Maryland.

This is the first progress report from a program aimed at assessing the mass and distribution of gas within all identified S0 galaxies inside 20 Mpc, north of declination −10 degrees, and which are neither members of the Virgo Cluster nor obviously interacting. Our first goal is to measure or set a very low upper limit on the total gas mass in each galaxy. The limits correspond to a small fraction of the gas expected to be returned to the interstellar medium by evolving stars. We report here on the results of our survey of molecular gas in the sample.

Canadian Astronomy Data Centre Services, David Bohlender, Daniel Durand, David Schade, and Sévérin Gaudet, Herzberg Institute of Astrophysics, National Research Council of Canada.

Since its establishment in 1986, the Canadian Astronomy Data Centre (CADC) has provided a wealth of services to the Canadian astronomical community. In this paper we present a summary of our most popular facilities, a description of CADC activities of the last year, and a discussion of new tools we hope to provide to our users in the near future.

The VSOP Space-VLBI mission: the Canadian Component, Sean M. Dougherty, University of Calgary and National Research Council of Canada, P. E. Dewdney and B. R. Carlson, Herzberg Institute of Astrophysics, National Research Council of Canada, W. H. Cannon, CRESTech, W. T. Petrachenko, National Research Council of Canada, A. R. Taylor and W. K. Scott, University of Calgary, and D. Del Rizzo, University of Calgary and National Research Council of Canada.

Canada has made a significant technical contribution to the Japanese-led VSOP Space-VLBI mission, largely based around the S2-format recording and correlation system. This low-cost, highly reliable VLBI system was developed and is operated with funding from the Canadian Space Agency (CSA). The VLBI S2 record/playback system was designed and built by the Space Geodynamics Laboratory of CRESTech. Each system consists of an array of eight video-cassette VHS transports that sustain a data rate of 128 Mbits s^{-1}. The recorders have been placed by the CSA at four spacecraft tracking stations (TSs), and five Ground Radio Telescopes (GRTs). In addition, S2 recorders have been placed by observatories at seven other GRTs and one other TS, all of which participate in the VSOP mission. The S2 Space-VLBI correlator is a unique system, designed and built at the National Research Council of Canada. It is based on a modular system architecture that allows replication of a small number of modules to construct a wide range of system sizes and configurations. It presently has ten-station capability, though is currently populated with six playback systems. This lag-based correlator is designed specifically to handle the delays, velocities and accelerations associated with Space VLBI. The correlator has a number of specialized signal-processing features unique among Space-VLBI correlators: fast dumping and spectral-line zoom mode. The fast-dump modes provide correlator co-efficients at a rate up to 1 kHz. Used in conjunction with a multiple gating facility, they are especially useful for studying structure, dispersion, and spectra of pulsar signals. The zoom mode feature provides a high frequency resolution spectral line processing capability, where wide-bandwidth low spectral resolution data ($\Delta\nu$ ~15.6 kHz) can be re-processed to a spectral resolution of 488 Hz, a 32× increase in spectral resolution. This is most useful for line observations obtained with the wide bandwidth receivers, as used in the VSOP mission. The recording and correlation systems are used in the VSOP mission for both the VSOP Survey observations, and for General Observing Time observations. To date, these systems have participated in nearly 200 experiments during the first two years of the four-year VSOP mission.

The MOST Space Mission: A 15-cm Telescope in the 8-m-Class Era, Jaymie Matthews, Rainer Kuschnig, Gordon Walker, Ron Johnson, Kristy Skaret, Evgenya Shkolnik, Trevor Lanting, and John Paul Morgan, University of British Columbia, John Pazder, Optical Consultant, Peter Sinclair, John Harron, and Don Sturgeon, Centre for Research in Earth and Space Technology.

MOST is Canada's first space science microsatellite and its first optical space telescope project, aiming for launch in late 2001. MOST is designed to measure (as its acronym implies) Microvariability & Oscillations of STars in broadband light with a precision of a few micromagnitudes over time scales from minutes to days. The resulting eigenfrequency data will be used primarily for stellar seismology, to probe the structure and ages of Sun-like stars, magnetic stars, Wolf-Rayet stars, and halo subdwarfs. The subdwarfs are expected to yield age estimates that would place a meaningful lower limit on the age of the universe. MOST should also be capable of confirming the presence of giant extrasolar planets identified in Doppler surveys. How will a 15-cm telescope on board a 50-kg microsat whose total budget is of order Can$10M accomplish all this? The MOST project has just completed its Preliminary Design phase, and we provide a status report on the mission, the instrument design, and its modes of operation. In addition, three companion papers are being presented at CASCA'99 to describe specific aspects of the mission: scientific targets (Shkolnik *et al.*), radiation effects (Skaret & Matthews), and numerical simulations of the MOST photometric performance (Matthews, Kuschnig, *et al.*).

Ultraprecise Photometry from Space: Simulations of the MOST Space Telescope Performance, Jaymie Matthews, Rainer Kuschnig, Trevor Lanting, and Gordon Walker, University of British Columbia.

Achieving micro-magnitude photometric precision from a small space telescope in low-Earth orbit is a challenge of the first magnitude. The MOST instrument is designed to project extended pupil images illuminated by target stars on a CCD detector through an array of Fabry microlenses each about 1.2 mm across. To guide the design of the instrument and realistically estimate its photometric error budget, we have developed a numerical simulation of the data collection that includes:

- intrinsic stellar oscillations and Poisson noise
- CCD dark current and readout noise (with temperature variations)
- analogue-to-digital conversion (ADC) noise
- ADC nonlinearities
- flat fielding errors (including sub-pixel sensitivity gradients)
- exposure timing jitter
- telescope wander due to the MOST Attitude Control System
- stray light from the Earth, Moon and other sources
- the contribution of faint background stars and galaxies wandering in and out of the field stop
- dust particle obscuration on optical surfaces near the focal plane
- cosmic rays
- duty cycle caused by radiation-induced interruptions
- intrinsic slow stellar variability due to chromospheric activity and sunspots

The results of simulations to date demonstrate that MOST should be able to detect solar-type oscillations (amplitudes ~ 4-8 micromagnitudes) easily in stars brighter than V ~ 4 within 10 days, and in stars brighter than V ~ 6 within 30 days.

Oldest Stars, Newest Worlds: Targets for the MOST Space Mission, Evgenya Shkolnik and Jaymie Matthews, University of British Columbia, and David B. Guenther, Saint Mary's University.

The primary science goals of the MOST project are: (i) to carry out *p*-mode seismology of solar-type stars, metal-poor subdwarfs, rapidly oscillating Ap (roAp) stars, and Wolf-Rayet (W-R) stars, and (ii) to quantify the turbulence of W-R stellar winds. A secondary objective is to confirm the Doppler detections of giant planets orbiting close to nearby solar-type stars. The metal-poor subdwarfs are particularly interesting targets since such stars are believed to be very old. They therefore play a key role in the calibration of globular cluster isochrones. Analysis of rich *p*-mode eigenfrequency spectra in such stars can lead to independent estimates of their ages, possibly setting a meaningful limit on the age of the Galaxy and the universe. We discuss what is currently known about the two most attractive subdwarf targets for MOST: HD 76932 and HD 224930 (85 Peg). A preliminary grid of pulsation models demonstrates how eigenfrequency spacings and splittings are sensitive to mass and main-sequence age. MOST will have a photometric precision of a few micromagnitudes. That makes it sensitive to the light variations arising from the cycle of illumination phases of a giant planet orbiting close to its parent star. MOST can observe extrasolar planet candidates around stars that lie within the Continuous Viewing Zone (CVZ) of its orbit and whose periods are short enough to be monitored for three or more cycles in a few weeks. The phasing of the light and velocity curves would confirm the orbital nature of the variations (or suggest other mechanisms intrinsic to the star). If such planets do exist, then the amplitudes of the light curves will put constraints on their radii and albedos, and hence their surface compositions. We identify suitable MOST targets and discuss model light curves for these systems.

Ultraprecise Photometry from Space: Radiation Effects on the MOST CCD and Duty Cycle, Kristy Skaret and Jaymie Matthews, University of British Columbia.

The goal of Canada's first microsatellite project, MOST, is to obtain rapid photometry of stars with micromagnitude precision in order to do asteroseismology as a probe of stellar structure and evolution. To attain the required photometric sensitivity and frequency resolution, MOST will monitor each target with a CCD detector from a polar Sun-synchronous orbit that allows the star to be in view for weeks without interruption. The low-altitude (~800 km) orbit has been chosen in part to minimize the radiation flux. However, the MOST spacecraft will be exposed to charged particles, especially when it passes through the South Atlantic Anomaly (SAA), a region where the Van Allen belts extend to lower altitudes. The radiation effects on MOST will be threefold: (1) photometric noise increase caused by cosmic ray strikes, (2) reduction of the observing duty cycle when particle flux levels associated with the SAA are too high to permit precise photometry, and (3) damage to the CCD and electronics [including degraded charge transfer efficiency (CTE) and localized "hot" regions of permanently damaged pixels]. The MOST radiation environment has been modeled using the RADMODLS program in conjunction with SHIELDOSE in order to estimate the amount of Al shielding needed to sustain a long duration mission, as well as to predict the duty cycle. Our results show that, even with a cropped duty cycle resulting from the regular influx of trapped magnetospheric partices in the SAA, and with no more than 5 mm of aluminum shielding around the CCD, MOST should be able to satisfy its primary science goals.

Formation d'étoiles massives en régime sous-critique, Mario Lelièvre and Jean-René Roy, Université Laval, and Pierre Martin, Canada-France-Hawaii Telescope Corporation.

La formation stellaire en milieu de forte activité (starbursts) est étudiée depuis déjà plusieurs années. Cependant, les étoiles massives se forment également de façon moins spectaculaire au sein d'environnements qualifiés de sous-critique. Ce régime manifeste de multiples différences par rapport au régime starburst. Entre autres, les régions H II qu'on y retrouve sont généralement plus petites, moins lumineuses et davantage isolées. En plus d'être présent dans les portions externes des disques de galaxies spirales, le régime sous-critique se retrouve au sein des galaxies naines en phase latente, dans les galaxies à faible brillance de surface et probablement dans les systèmes absorbants Lyman alpha. Malgré les connaissances acquises à ce jour, le régime sous-critique demeure bien mal connu et soulève des questions fondamentales sur les mécanismes de formation stellaire dans les galaxies. Nous proposons de caractériser la formation stellaire en régime sous-critique. Pour ce faire, un vaste programme d'imagerie profonde $H\alpha$ est présentement entrepris sur un grand échantillon de galaxies (spirales, naines, galaxies à faible brillance de surface). Ce programme sera complété par la spectroscopie de plusieurs régions H II situées en milieu sous-critique dans le but de décrire la métallicité et l'évolution chimique dans ce régime.

Numerical Simulations of Protostellar Jets with Multi-Pressure Components from Keplerian Disks, Juan Ramon Sanchez Velar, David A. Clarke, and Rachid Ouyed, Saint Mary's University.

In an extension to the work of Ouyed & Pudritz (1997a,b), we are using ZEUS-3D (two-fluid MHD solver) in its 2-D mode to launch protostellar jets from Keplerian disks in spherical polar co-ordinates. In particular, we now include the energy equation for an adiabatic fluid, as opposed to specifying the pressure as $P = \rho^{\gamma}$ directly in the momentum equation as done by Ouyed & Pudritz (1997a,b). This approach allows the study of shocks and contact discontinuities on episodic flows. Additionally, we implement a new fluid variable, Alfvén pressure, to evaluate the dynamical impact of Alfvénic turbulent waves, modeled as a polytropic gas (index 1/2) and an adiabatic gas (index 3/2), as discussed in McKee & Zweibel (1995).

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Superpolarized Dark Dusty Simple Bok Globules [Boks], Jacques P. Vallée, Herzberg Institute of Astrophysics, National Research Council of Canada, Pierre Bastien, Université de Montréal, and Jane S. Greaves, Joint Astronomy Center.

The earliest stages of star formation may harbour well-collimated magnetic field structures. A good test of that is to make polarimetric observations of small isolated dark clouds such as Bok globules, at a wavelength corresponding to optically-thin dust emission (extreme infrared/submillimetre regime). In August 1998 we investigated Bok globule CB068, visible in *absorption* on the Palomar Observatory Sky Survey 0.6-micron red print with a total size of 7×7 arcminutes. We report results on the core of CB068, seen in *emission* with the James Clerk Maxwell Telescope at 860 microns with a core size of 3×3 arcminutes. CB068's dust emission has a linear polarization exceeding 10%, with a magnetic field oriented along the minor axis of the Bok globule (with the position angle of linear polarization along the major axis). Such a high percentage is very remarkable, suggesting a coherent magnetic field structure with little turbulence in the gas, too cold and too young to have a bipolar CO outflow (hence a pre-Class 0 Young Stellar Object). Nearby Boks may well be fantastic laboratories in which to further test star formation theories.

Binary Stars in the Old Open Cluster M67 and Praesepe, Melvin Blake, York University.

The ages of the globular cluster population of the Galaxy help trace the processes that formed the halo of the Galaxy. In a similar manner, old open clusters can be used to trace the star formation history of the Galactic disk. We have obtained photometry and spectroscopy of two contact binaries in the old open clusters M67 and Praesepe, which can be used to obtain independent distance estimates for the clusters. We present preliminary results of work to evaluate the method of obtaining distances to star clusters in such fashion.

Radiative Accelerations in Stellar Atmospheres, Francis LeBlanc and Serge Émile LeBlanc, Université de Moncton.

The main cause of abundance anomalies observed in certain stars is believed to be atomic diffusion induced by momentum transfer to atoms via photoabsorption. The radiative flux selectively pushes the atomic species, which compete for the photons, outward, and thus counteracts gravitational settling. The radiative diffusion of the elements can modify the structure and the evolution of stars and can also lead to stellar pulsation. Precise radiative forces are therefore needed in order to include atomic diffusion in stellar modeling. Several recent studies have concentrated on the radiative forces in stellar interiors. In order to obtain radiative accelerations in stellar atmospheres, the radiative transfer equation has to be solved to a precision, in wavelength, sufficient for accurate integration of the radiative acceleration equation. The physical processes involved and recent improvements in the calculation methods of radiative accelerations are reviewed here. A frequency grid on which precise radiative forces can be obtained in stellar atmospheres via the sampling method are also illustrated.

A Survey for Pulsating Hot B Subdwarfs (EC 14026 stars): A Progress Report and the Case of KPD1930+2752, Billeres Malvina, Gilles Fontaine, and Pierre Brassard, Université de Montréal.

In 1996, on the basis of the theoretical predictions of Charpinet *et al.* (1996), we initiated a survey in the northern hemisphere for luminosity variations in subdwarf B stars. We focussed our research on a sample of stars for which atmospheric parameters have been obtained on the basis of model atmosphere fits to optical spectra and for which such parameters indicated a possible association with the expected instability strip. To date we have observed more than 70 objects, and we have discovered 4 pulsating sdB stars. The principal characteristics of the known pulsating sdB stars are: effective temperatures around 35,000 K, surface gravities between log g = 5.2 and log g = 6.1, and observed periods from 80 to 601 seconds (the latter indicating the presence of p-mode pulsations). We present here a brief progress report of our observational survey and details for a particularly interesting pulsator: KPD1930+2752. It is a unique object in that it shows, along with the usual short-period p-mode pulsations seen in EC14026 stars, a long-period variation (~8200 seconds) bearing the signature of the variation associated with an ellipsoidal binary system. The system likely consists of a sdB star and a white dwarf, a rare combination seen, so far, in only five or six binary stars. KPD1930+2752 is unique, however, in that the sdB component is a p-mode pulsator.

Reference

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DDO Radial Velocity Program: Short-Period Binaries, Slavek Rucinski and Wenxian Lu, David Dunlap Observatory, University of Toronto.

Bright, nearby, short-period binary systems, mostly from the *HIPPARCOS* list, are systematically observed at the David Dunlap Observatory with the 1.88-m telescope and the Cassegrain spectrograph. The preliminary goal is to obtain mean radial velocities and mass-ratios, while the future goal is to perform complete light and radial-velocity synthesis-model solutions that would give distances accurate at better than the 5% level. Comparison with *HIPPARCOS* distances will allow us to check for and calibrate out any imperfections of the models. The program has been initiated with contact binaries, but is planned to be expanded into related (short-period EB) systems. Contact binaries of the W UMa-type have been shown recently — the basis of the micro-lensing OGLE survey (Rucinski 1998) — to be very numerous in space, with the spatial frequency of about 1/80 of all FGK dwarfs. Through observations with large telescopes and from averaging results for hundreds or even thousands of such systems, there exists a potential for determining distances to nearby galaxies at the level of 1% in a purely geometrical way, without any complications related to differences in chemical abundances. We present a collection of radial velocity curves for the first ten systems (Lu & Rucinski 1999: GZ And, V417 Aql, LS Del, EF Dra, V829 Her, FG Hya, AP Leo, UV Lyn, BB Peg, AQ Psc); the results for the second ten (Rucinski & Lu 1999: AH Aur, CK Boo, DK Cyg, UZ Leo, XZ Leo, V839 Oph, GR Vir, NN Vir) are ready for submission. The data for the third ten are currently being analyzed.

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Rucinski, S. M. & Lu, W. 1999, in preparation

Studies of Changing Patterns of Solar Activity Using the DRAO Synthesis Radio Telescope, K. Tapping, Herzberg Instiute of Astrophysics, National Research Council of Canada, I. Burke, MacDonald Dettwiller, H. Cameron, Acadia University, K. Harvey, National Solar Observatory, Kitt Peak, and C. Zwaan, Utrecht.

Every summer since 1992, with the exception of 1997, the Dominion Radio Astrophysical Observatory Synthesis Radio Telescope has been used to make several maps of the solar disc at 21-cm wavelength, following the declining phase of Solar Activity Cycle 22 and the rise of Cycle 23. In each case the positions and intensities of emission peaks were measured, and all contributions to the total flux density from the solar disc budgeted. The distribution of activity and the characteristics of the active regions hosting sources were established from Ca II K and $H\alpha$ images from Big Bear Observatory, and the National Solar Observatories at Kitt Peak and Sacramento Peak. Full-disc magnetograms were provided by NSO-Kitt Peak. The brightness of the 21-cm sources is strongly dependent upon where the host region is in its evolution, peaking when young regions are growing rapidly to their maximum size, and that there is strong tendency for the brightest sources to be in the most magnetically complex regions. These relationships vary with the position of the Sun in its activity cycle, suggesting substantial, cycle-related differences in the coronal distribution of plasma and magnetic flux, even though the photospheric manifestations may appear similar.

The Open Cluster(s) Containing P Cygni, David Turner, Gary Welch, Andrew Horsford, Michael Seymour, Marianne Graham, and David Fairweather, Saint Mary's University, and Walter Feibelman, Goddard Space Flight Center.

P Cygni is the name object for stars whose spectra exhibit the diagnostic signature of outward-flowing matter through emission lines with characteristic absorption features on their short wavelength wings. The star is also one of a handful of hypergiant stars in the Galaxy, extremely luminous, high-mass, early-type stars that are also light variable. In the case of P Cyg, its B2 Oe spectral type denotes a very young post main-sequence star whose future evolutionary stages are uncertain. Yet a great deal of information on the star is readily available by studying the cluster(s) to which it belongs. The anonymous cluster in which P Cyg is directly located is one source of information, and the spatially adjacent cluster IC 4996 is another. We have collected photometric and spectroscopic observations for both clusters, which appear to constitute a paired system in which both clusters are of similar age ($8 \pm 1 \times 10^6$ years) and distance (2.31 ±0.03 kpc). Our photometry is a mix of photoelectric, CCD, and photographic data; owing to the brightness of P Cyg, background contamination is a serious problem for all but the former. It is shown that the inferred distance, reddening (E_{B-V} = 0.53 ±0.02), and age of P Cyg as a member of the binary cluster system — where cluster membership is argued by a coincidence in radial velocity with cluster stars — are not entirely what one expects according to published estimates for the star's parameters. Although the high luminosity (M_V = −8.46 ±0.03) and early spectral type of P Cyg are confirmed by its cluster membership, the most luminous terminal main-sequence companions to the object are estimated to have masses of order ~20 $M_\odot$. The implied mass for P Cyg itself is therefore of order 22–25 $M_\odot$, which differs from the larger masses that have been adopted previously in the literature.

Since the star's derived luminosity ($M_{bol} = -9.19 \pm 0.12$) is close to the upper limit for single star evolution for an age of 8×10^6 years, it may be necessary to invoke a binary star scenario to explain the current parameters for P Cyg.

Education/La pédagogie

Excellence in Teaching, Douglas Duncan, University of Chicago.

1. Introduction

Introductions and expectations for the session.

2. Bad Teaching and Good

True or False? "Good teachers are born, not made."
The best and worst teachers you ever had.
Five components of effective instruction.
Thinking about your own teaching: strengths and weaknesses.
Organization: goals, plans, and testing.
Six common ways to discourage learning.

3. Good Teaching and Great

Different learning styles.
What do you expect your students to know by freshman year?
What does research show they actually know?
"A Private Universe" videotape and discussion of learning and constructivism.

What can be better that a good, clear lecture?

Facilitating conceptual understanding:
- Student motivation
- Critical thinking
- Peer instruction

Examples of such activities:
- Mine
- Eric Mazur's
- Yours! (Participants develop activity based on light, colour, and spectra)

(If time permits) The "flow" experience
- What is the most fun you have ever had either teaching or learning?

Education Poster Paper/Une présentation pédagogique affichage

Delta Cephei as a Target Star for Student Observations, David Turner, Saint Mary's University.

In introductory courses in astronomy, it is sometimes desirable to assign a variety of simple observing projects as a means of familiarizing students with astronomical objects that they can locate in the night sky. As noted by the American Association of Variable Star Observers (AAVSO), the study of one or more variable stars can be an interesting educational exercise. For Canadian universities, perhaps the most easily observed variable star is Delta Cephei, the name object for classical Cepheid variables. The star is circumpolar from Canadian sites, and is well placed for observation near the zenith during the period October to March, the "core" interval for the Canadian university year. It is bright enough that it can be observed in skies suffering from modest light pollution, and does not require the eyes to be fully dark-adapted for one to make magnitude estimates, even near light minimum. Its period of about 5.37 days is also short enough that its light variations are evident from one night to another, a feature that helps to sustain interest among novice observers. Changes can even be detected hourly near light maximum. Older charts for Delta Cephei circulated by the AAVSO contain only two primary reference stars near the variable, but there are three other reference stars well placed in both magnitude and distance from the star that can be used to establish a more extensive chart more suited to student observers. Observations of Delta Cephei made with the unaided eye by the author are used to demonstrate the accuracy that can be obtained from simple eye estimates, as well as the temporal drift in the variable's period that allows one to use such observations to update the star's ephemeris.

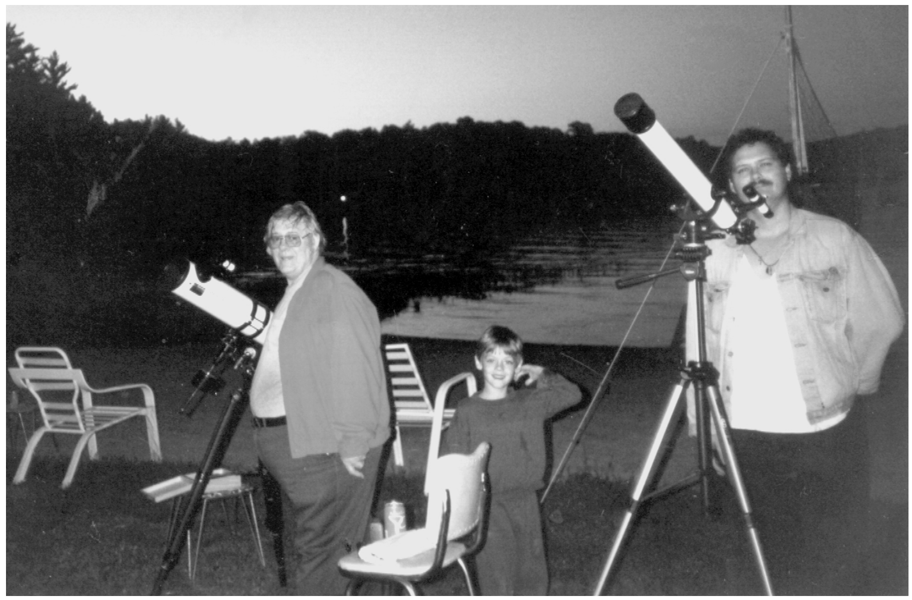
from the cheap seats

by Robert Sears, Hamilton Centre

I have been a member of the Hamilton Centre for about three years now. My son and I live in what you could call "central" Burlington. Consequently, there are few dark sites nearby; indeed, they could almost be said not to exist. Much of the time we end up on the sidewalk in front of our apartment building. While it is rather light polluted, we can still make out the planets and the Moon quite clearly, perhaps a few globular clusters here and there, *etc*.

It never ceases to amaze me how many people will stop by that have never looked through a telescope, or are unaware of the composition of the solar system (and one of them was an elementary school teacher!). Any time a person walks by, if they do not ask me what I am looking at, I will go out of my way to engage them in conversation. Some of the good folks that I have talked to said that they had wanted to ask me what the heck I was looking at, but did not do so because either they did not want to appear foolish or they did not know if I was approachable. I always tell them that the vast majority of amateur astronomers are very approachable indeed, and are quite anxious to share their love and fascination with the night sky with others. I also tell them a little about the Hamilton Centre, our free trial membership, and the observatory, and invite them to attend a monthly meeting. I hope all of our members take the time to do that when they can.

I occasionally assist in public education at our observatory in Flamborough, and do a little sidewalk astronomy in front of my apartment building in Burlington, when the state of my health permits it. Most of the time, though, because of my different ailments,



A family observing session at the cottage we rent each summer. It is about 30 km north of Bracebridge, Ontario. From left to right: my father, Clyde; my son, Justin; the author.

I am restricted to my second-floor south-facing balcony. I am restricted by a number of physical ailments, which require the constant use of a cane, and I cannot carry any significant amount of weight anymore. My scope, a 4.5-inch Newtonian, weighs about 30 pounds, so I cannot just pick it up and go like others can.

There are a few tricks I would like to share with other people with physical infirmities. In the past, if I wanted to observe out on the sidewalk, I would have to take out my telescope in two trips. Recently, though, I have been using a different means of transporting it. I use a metal cart on wheels, of the type that many seniors use when grocery shopping. The only thing that puzzles me is why I had not thought of it before.

Here is another tip for any person who is physically challenged. If you are anything like me, you cannot stand for any more than a couple of minutes. I have found a type of chair that is very well suited to astronomy. The only thing it lacks is a backrest. It is called a "drummer's throne" chair, and it is much more adjustable than many commercially available chairs that I have seen. The seat can be adjusted in height from about 50 cm to one metre. It is rather heavy, but it is very solid, stable, and well balanced. The three legs take up very little space, so I am not continually tripping over them.

I have had a lot of people from the Centre and elsewhere offer to assist me in moving my equipment when I am at the observatory or when I observe from the sidewalk. I truly appreciate it, but I feel rather bad about it, as their kindness must be cutting into their observing time. Generally, I can move the scope myself, though I cringe at the thought of what my cardiologist and family doctor would say if they saw me lifting all that heavy gear. They would likely tear into me for sure… but no pain, no gain, right? I am fortunate enough to have access to another telescope, a 60-mm refractor belonging to my son, Justin, which I use occasionally when I am unable to move my 4.5-inch Newtonian.

Another difficulty I have had in the past is using a finder scope. The one on my 4.5-inch Celestron is a 6×30 LER (long eye relief) finder scope. I would heartily recommend that type of finder to anyone who has bending or balance problems, as I do. It certainly makes life a lot simpler. I think a Telrad might be an even better choice.

This may seem minor, but I have discovered that medication can affect your dark adaptation. One drug in particular, codeine, constricts the pupils of the eyes. I take Tylenol 3 for pain, which contains codeine, and after taking the medication I have found a noticeable reduction in the detail that I can see as well as in the brightness of dim objects. If you take that or any other opiate-related pain reliever, you may want to consider not taking any for a while before you go out observing. I have found that about six hours is adequate to get it out of my system.

One last word. I have a suggestion; this does not apply only to the physically challenged, but to any community-minded amateur astronomer who does most of their observing from their homes or without travelling to an isolated dark site. We, as a group, live the life of vampires in a sense, being outside observing until the wee hours of the morning. Might I suggest that you consider getting involved in a Neighbourhood Watch program? I am always on the lookout when observing, and I will be checking into the Neighbourhood Watch program here in Burlington. Surely keeping our eyes open and making a few extracurricular observations would not be too much of a hardship. After all, who is better than we are at observation? We are in a unique position to assist the law enforcement community in a little covert reconnaissance. I am not advocating vigilantism, just being aware of what is going on. Let us make our neighbourhoods a little safer for our loved ones and ourselves.

Astronomy has given me a great sense of personal fulfilment and a feeling that I am contributing to society in some, albeit small, way. I just love teaching kids (and adults) about the sky, and all the treasures to be found within. The sense of wonderment or awe that many such folks experience is very gratifying. When you show a child Jupiter or Saturn through a telescope, that planet ceases to be a picture in a book or an image on television: it becomes a *real place*. The imagination soars, the mind opens; in flows knowledge, awe, and wonderment. I would like to make it my mission in life to continue to share my love of the universe with others, sharing the rapture of a starry night or the Milky Way — a bejewelled ribbon across the firmament.

Robert A. Sears has been a member of the Hamilton Centre for about three years, and his father, Clyde, is also a member. His seven-year-old son Justin will be joining on his eighth birthday. He is primarily a lunar and planetary observer, and assists in public education at the Centre's observatory in Flamborough. He also enjoys teaching people, especially the young, about the wonders of the night sky.

Astrocryptic

by Curt Nason, Halifax Centre

HERE ARE THE ANSWERS TO LAST ISSUE'S ASTROCRYPTIC PUZZLE

1 J	■	2 F	L	3 A	M	4 S	T	5 E	E	6 D	■	7 H
A	■	L	■	I	■	O	■	T	■	A	■	E
8 C	H	A	I	R	■	9 L	O	C	K	Y	E	R
K	■	R	■	Y	■	A	■	H	■	S	■	S
■	10 D	E	N	D	E	R	A	■	11 O	T	I	C
12 P	■	■	■	I	■	T	■	13 A	■	A	■	H
14 A	T	15 L	A	S	■	R	■	16 V	E	R	S	E
R	■	A	■	K	■	A	■	O	■	■	■	L
17 F	I	N	E	■	18 E	N	D	G	A	19 M	E	■
O	■	D	■	20 C	■	S	■	A	■	E	■	21 L
22 C	A	S	S	I	N	I	■	23 D	R	A	K	E
A	■	A	■	E	■	T	■	R	■	D	■	N
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Leslie C. Peltier

by Barbara Silverman, Montreal Centre

Many of the most important discoveries in astronomy have been made by amateurs who work full time in other professions. Foregoing that wonderful thing called sleep, they study the skies while others slumber. Leslie C. Peltier was one such person — a "common Joe" who led a quiet, unspectacular life but who exemplified the dedicated amateur astronomer.

Peltier was born on January 2, 1900, on a farm four miles west of Delphos, Ohio. Farming had been his family's way of life since 1849. He had an older brother, Kenneth, and a sister, Dorothy. His mother, Resa, was a former schoolteacher, and, with her husband, still taught Sunday school. She was a life member of the Woman's Christian Temperance Union and a leader of the Woman's Foreign Mission Society. She was a woman of unfailing optimism, well versed in history and American literature.

His father, Stanly W. (nicknamed Deacon by his wife), farmed fifty acres, did oil paintings in his free time and, as an expert carpenter, built the house young Peltier grew up in. The elder Peltier was also the Master of the Masonic Hall Lodge and the local Grange. He was a dedicated farmer who never missed a Farmer's Institute, and was the first in his neighbourhood to try soybean as a new crop. Both parents were churchgoers who believed in regular attendance, not the winter revival meetings so common in that period.

Young Peltier's childhood was spent in solid family surroundings with his black terrier Buster roaming over pasture land, fishing in the nearby creek, helping tend the cows, and performing other farm chores. He grew up in the time of Mary Pickford, Francis X. Bushman, and Tom Mix, under an American flag displaying forty-eight states. He had a decent education in a one-room schoolhouse that, typical of those days, housed all grades together. Also typical was the fact that he walked back and forth to school, good weather and bad.

He lived in a six-room, two-story house in which, for the first three years of his life, the upstairs rooms were reached by means of a ladder. There was no electricity until 1925, and no indoor plumbing. The food, which the family raised themselves, was simple but in large supply. They bought in town only what was absolutely necessary.

> **"Many of the most important discoveries in astronomy have been made by amateurs who work full time in other professions."**

All members of his family were avid readers, and often in the evenings his mother would read to them aloud. Peltier was fortunate to belong to a family that owned a large and varied collection of books. Their bookcase housed *The Encyclopaedia Britannica*, the works of Charles Darwin, *The Three Musketeers, Hans Brinker, Uncle Tom's Cabin,* and, to Peltier's delight, *Webster's Unabridged Dictionary*. The last gave him hours and hours of pleasure, since the back of the book contained pages of coloured pictures displaying world and state flags, birds, mammals, sailing ships, and a great many other interesting things.

One of his most prized possessions was his mother's 1913 Christmas gift of *Rolf in the Woods* by artist-naturalist Ernest Thompson Seton. That book helped to instill in young Peltier a love and true appreciation of nature. Peltier had three years of high school, during which his favourite subjects were biology, botany, and English literature. Then, in 1914, his brother left for the war overseas, and Peltier had to leave school to help on the farm. Even with his brother's safe return at war's end, he decided not to return to school but to remain on the farm.

In November 1933 he married his girlfriend, Dottie, the daughter of nearby farmer Homer Hihiser. By coincidence Dottie was born in May 1910, just as the Earth was passing through the tail of Halley's Comet. They spent their honeymoon camping in the southwest, enjoying their favourite pastimes of rock and mineral collecting, and exploring the prehistoric caves of the Rio Grande. Returning to Delphos, they settled down. Here Dottie would eventually spend her time raising their two sons, Stanley and Gordon. In 1934 Peltier went to work full-time designing juvenile furniture for the Delphos Bending Company. He worked by day with his hands and a pencil and by night with his eyes and a telescope.

Peltier had first become interested

in the stars in 1905, when at age five something in the sky caught his eye through the east kitchen window of the family home. His mother identified the object of his interest as the Pleiades. At age seven, Peltier was returning from the barn one night carrying a lantern when his father pointed out another lantern in the sky — the planet Jupiter.

In 1909 and 1910 events began to unfold that would have an everlasting effect on young Peltier's life. Back then airplanes were very new, and in 1909 he had an opportunity to see Bud Mars's small Curtis biplane. Mars, who died tragically during a later flight, only flew four or five kilometres at a height of 100 metres, but it was enough to instill in young Peltier a desire to become an aviator and to sail the skies. Though he never did fulfill his goal in the manner he imagined, he did accomplish his dream in a totally different way.

In January 1910 he observed his first comet, 1910a, at the age of ten with his unaided eye. The comet had been discovered on January 16 at Lick Observatory. It was of first magnitude, and presented young Peltier with an enticing view of its feathery tail stretching upward to the east and south. Then, on May 18, Halley's Comet made an appearance.

For the next five years Peltier would occasionally glance upwards, but it was not until five years later, at age fifteen, that he asked himself, "Why do I not know any of those stars?" He obtained from the local library a copy of Martha Evans Martin's book *The Friendly Skies*, which he used for the next two years. With its help he located the star Vega, which would become a lifelong friend. Over the next few weeks he became acquainted with five of the fifteen first-magnitude stars that could be seen from his location. It took about a year for him to become comfortable with the stars and constellations with the help of the book, but in time they became "his stars," and he greeted each by name as it made its evening and morning appearances.

At about that time he happened to see an advertisement for a telescope that was on sale for $18.00. With no funds on hand, a determined Peltier went into the strawberry fields and worked for almost a month from 9:00 A.M. to 3:00 P.M., during which he picked almost 4,000 litres of strawberries and for which he was paid the necessary $18.00. Berry picking is, at the best of times, a backbreaking chore, and in those days the strawberries were "Warfields," slightly larger than a good-sized cherry.

The $18.00 telescope purchased by Peltier was a 2-inch refractor with a focal length of 36 inches. Actually it was a spyglass that sea captains used, and it contained four draw tubes and two eyepieces providing magnifications of 35× and 60×. The telescope was French-made of heavy brass encased in black-pebbled leather, and was designed for terrestrial viewing with the erecting lens permanently mounted so that objects were seen right-side up.

"To Peltier a telescope was not just a piece of property, but a gift given in trust with himself as administrator."

If his telescope was not perfect, it made little difference to the teenaged Peltier. He intended to use it, and use it he did, but first his telescope needed a mount. So he built one. With that telescope, he viewed the planets Uranus and Neptune, the Great Nebula in Andromeda, the Dumbbell Nebula, and countless others celestial wonders for the first time.

In 1917 Leslie Peltier's mother gave him the book *The Field Book of Stars* by William Tyler Olcott. Olcott was the founder of the AAVSO — The American Association of Variable Star Observers. In the book Peltier found an appeal for interested stargazers to aid in the study of variable stars. Peltier was soon accepted into the AAVSO, and received his first issue of *Popular Astronomy* as well as a variable star chart. Once he learned how many of the stars on the chart he could view with his telescope, he was on his way. To aid himself further, he purchased *Upton's Star Atlas,* which he used for the next thirty years until it wore out. With the spotting of R Leonis, his first variable, on March 1, 1918, he began what would become an unbroken string of 500 reports to the AAVSO, made over the next forty-five years.

The year 1918 was an important year for young Peltier. Variable stars were not the only objects to capture his attention. On June 8, 1918, he was able to observe a 75% total solar eclipse during the day, then observed his first nova that evening. It was Nova Aquilae, of magnitude 1.4. During 1918-19 he began to combine his hobby of photography with his love for astronomy, and it was during that period, because of heavy sunspot activity, that he saw magnificent displays of the northern lights.

By the time he retired the 2-inch telescope in 1919, he had made over 190 observations of variable stars. In November of that year the AAVSO loaned him a Mogey 4-inch refractor with a 60-inch focal length. It was designed for observations of comets, and came with an equatorial bearing designed for permanent placement. Once again Peltier designed an inventive pier to mount his new scope. It was while using it, on March 13, 1920, that he observed a comet split into two pieces that continued to orbit the Sun side by side.

In 1921 Peltier and his father built a small observatory. Although located in a cow pasture, it was more than just a post in the ground. It consisted of a wooden shed, measuring three metres by four metres, with a three-metre diameter dome. A solid cubic metre of concrete was set in the ground to anchor an upright 15-cm steel pipe for mounting the telescope.

In 1922, Henry Norris Russell, director of Princeton University, arranged for Peltier to have a 6-inch refractor, also designed for observing comets. The telescope had a focal ratio of f/8, and was capable of observing stars as faint as fourteenth magnitude. The telescope also had an alt-azimuth mounting. It was with that telescope that Zaccheus Daniel had discovered two comets in 1907 and 1909.

While Peltier was delighted with his new observatory, he found he had also lost something with its construction. No longer was he in direct touch with the denizens of the night: meteors streaking across the night sky, fireflies, nocturnal bird calls, and crickets, all of which had kept him company on so many long nights.

In 1925 electricity was introduced to the farm, and in November of that year he discovered his first comet. The comet that bears his name — Comet Peltier — was discovered on Friday the thirteenth. Although his parents owned a car by that time, it was unavailable when he made his discovery, so Peltier jumped on his faithful bicycle, and raced into town to dash off a telegram to Harvard College Observatory.

After the discovery Peltier began to gain fame. Dr. van Biesbroeck suggested to him that he should send collect telegrams to Yerkes Observatory to allow faster confirmation of any future discoveries. In the years between 1929 and 1933 he was to discover three more new comets.

In 1938-39 he and his father built another observatory, which he nicknamed "the merry-go-round." It was of simple construction, consisting of a room about two metres square and a metre and a half high, revolving on four rubber-tired steel wheels sitting on a circular wooden track. He mounted a single upholstered auto seat onto an old piano stool screw, producing an excellent adjustable chair. An auto steering wheel turned the building, while another small wheel raised and lowered the instrument in altitude from horizon to zenith. For an added bit of comfort, Peltier installed an electric hot plate into the floor to warm his feet during the long, cold observing nights.

With the construction of the new merry-go-round observatory, the old one could now be torn down. It had been in use since 1921, and had allowed Peltier to make countless observations of variable stars and to discover seven comets.

In 1934 Dr. Harlow Shapley called Peltier "the world's greatest non-professional astronomer." Even on camping trips Peltier was never without his telescope. In December of the same year, while visiting Hot Springs National Park in Arkansas, he discovered a nova, now called DQ Herculis, which lies in the void between Vega and the head of Draco. Unfortunately for Peltier, the nova had been spotted ten days earlier when it was at third magnitude.

In July 1959, Miami University gave Peltier a gift of not only a 12-inch Clark refractor, but also an entire observatory, complete with a transit room. The telescope, 16 feet long, had been manufactured in 1868.

Moving the donated telescope and observatory from Miami to his home near Delphos was a major undertaking for Peltier, but that did not deter him. Louie Justus, the president of the Delphos Bending Company, arranged for the transport, and by September all of the various components were in Peltier's field awaiting re-assembly.

Reconstruction was finished by May 1960, but not without the combined efforts of many friends. The dome was almost seven metres in diameter and three metres in depth. It weighed several tons, and required two cranes to lift it into place. Once the new observatory was complete, Peltier could observe to slightly fainter than sixteenth magnitude, which allowed him to view many of the variables occurring in the magnitude range fourteen to sixteen.

Peltier's procedure for making variable star estimates was quite simple. Once he had identified the variable, he would then choose two nearby stars, one brighter and one fainter than the variable. Then, using a special star chart, he would determine the magnitudes of the two reference stars. Once he had that information, he could estimate the magnitude of the variable.

Over the years Peltier, and especially his father, had the pleasure of showing off the old observatories not only to the public but also to many well known in the field of astronomy. In 1935 Peltier was paid a visit by Clyde Fisher from the Department of Astronomy, American Museum of Natural History, and the curator of the Hayden Planetarium. In later years he was visited by George van Biesbroeck of Yerkes Observatory, Donald Menzel from Harvard College Observatory, and John S. Hall from the Lowell Observatory. On more than one occasion, Peltier's father gave impromptu astronomy lessons to sightseers who, out of curiosity, stopped to inquire about the strange buildings standing in the middle of a cow pasture.

Both Peltier and his wife Dottie loved open space and quiet solitude. In 1948 they purchased the Moening Place, at the edge of town. Altogether they obtained twelve acres of land, and it was here that the 12-inch Clark refractor found a permanent home. The Peltiers allowed their love of nature to flourish. They built a natural sanctuary for birds, wild flowers, and trees. Of trees alone there were over forty species, and one white oak was at least 250 years old with a trunk diameter of four feet.

His observing years encompassed the only period in recorded history during which four novae visible to the unaided eye occurred in an eighteen-year interval. The first was found on the eve of a solar eclipse in 1918, and the last was discovered on the eve of another eclipse in 1936: Nova Aquilae 1918, Nova Cygni 1920, DQ Herculis 1934, and Nova Lacertae (CP Lacertae) 1936.

A simple man, born and raised on a farm, Peltier died late in 1979, having lived his entire life either in Delphos or in the surrounding countryside. He left behind a proud legacy. In August 1965 the Ford Observatory on Mount Peltier, California was dedicated to him, *i.e.* both observatory and mountain were renamed in his honour. Peltier discovered twelve comets during his lifetime, ten of which carry his name, the last being discovered in 1954. He reported to the AAVSO for over sixty years, and made over 132,000 variable star observations.

One day, around 1960, a librarian gave him a copy of his beloved book *The Friendly Stars* by Martha E. Martin. It was beautifully bound in a dark cloth binding with the title lettered in gold, looking almost brand new. Upon closer examination, Peltier discovered that it was the exact book he had used in 1915, complete with finger markings and the outline of an unfortunate moth that had become trapped between its pages.

To Peltier a telescope was not just a piece of property, but a gift given in trust with himself as administrator. When one thinks of Leslie Peltier, an image comes to mind of a man, a book tucked under his arm, striding across a cow pasture to a telescope pointing up to the stars, shining in welcome.

Barbara Silverman recently retired from a career as a junior accountant. She has had a life-long fascination with astronomy, but is relatively new to the RASC. Having joined the Montreal Centre only a few years ago, she is already a member of the Centre's Board of Directors. Her main interest in astronomy is its history, including archeoastronomy. Her other main hobby is science fiction, and she is currently working on a novel in that genre.

At the Eyepiece

The All Splendors, No Fuzzies Observing List (Part 1 of 4)

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

Most of us work from observing lists. Let me share my "must-see-in-my-lifetime" list with you here. This modern observing list attempts to include all of the finest splendours in the entire sky, chosen as objectively as possible and hopefully without any northern hemisphere bias. The 144 sights are the best that there are — no predetermined target number was aimed at; there are no featureless fuzzies. Because many observers will eventually travel to lower latitudes or to the other hemisphere to see those marvels that never rise at home, the list covers wonders from celestial pole to celestial pole.

Surprisingly, no other single list has that focus. The Messier list, for example, includes everything that Messier knew of, so while about 60 Messiers are very fine sights, a significant minority are quite ordinary. Few observing lists cover the whole sky, and most offer a mixture of splendours, fuzzies, and challenge objects. Hunting faint fuzzies and challenge objects is great fun at a star party, but an observer who has an opportunity to travel briefly to foreign lands primarily wants to know what new splendours can be seen from there in a portable telescope or set of binoculars. At least 33 of the 144 wonders listed here are visible without optical aid. Except for the few close double stars, all objects on the list can be seen with a portable 100-mm (4-inch) telescope under excellent skies. The descriptions, however, reflect the larger apertures used by today's amateurs and the advent of nebula filters. I have not yet seen ten of the 144 sights — they are identified at the beginning of the list for each season.

Many experienced observers will wonder why one of their personal favourites was not included. My thinking can probably best be illustrated by giving examples of the last ones that I cut from the final list. The open clusters NGC 4755 (Herschel's Jewel Box) and M36 were relegated to the Remarks section of the table because they are badly overshadowed by NGC 3532 and M37 respectively. Some bright but coarse clusters that are visible with the unaided eye, such as NGC 752 and M48, have also been left off the list. The most common aperture, an 8-inch, does not resolve enough stars in the globular clusters M19 and M53 to make them true splendours. While M87 and M100 are major galaxies, they look like hundreds of others in the eyepiece. The wonderful Crescent Nebula, NGC 6888, was the object that I wavered over the longest, but many observers who do not have access to pristine skies cannot find it.

Many showpieces in the sky have popular names, such as Blue Snowball (NGC 7662). I expect that in most cases that started out as some author's description, for example "Like a blue snowball." If any reader knows of any originator for the popular name of one of the objects included in *The All Splendours, No Fuzzies Observing List*, please let me know so that proper attribution can be made in the final list.

The seasonal lists will continue in my upcoming October, February, and June columns. If I have missed an object that you feel is superior to others of the class that are on the list, or if I have included one that you feel is not deserving of inclusion, please contact me via E-mail.

FALL (28 objects)

ID	Con	Type	RA(2000)	Dec(2000)	Mag.	Size	Remarks
NGC 7009	Aqr	PN	21:04.2	−11:22	8.3	0′.5	Lord Rosse's Saturn Nebula; greenish; 24-in: ansae
61 Cyg	Cyg	Dbl	21:06.9	+38:45	5.2,6.1	28″	Orange dwarfs
M15	Peg	GC	21:30.0	+12:10	6.4	12′	Core peaks like Mt. Fuji; CC IV
M2	Aqr	GC	21:33.5	−00:49	6.5	13′	Brightest CC II
Zeta	Aqr	Dbl	22:28.8	−00:01	4.4,4.6	1″.9	Both white
NGC 7293	Aqr	PN	22:29.6	−20:48	6.5	13′	7×50s show Helix Nebula; annular
NGC 7662	And	PN	23:25.9	+42:33	9.2	0′.3	Blue Snowball; 10-in: annular
NGC 7789	Cas	OC	23:57.0	+56:44	6.7	16′	Ri, 300 faint st
NGC 55	Scl	G-Sc	0:14.9	−39:11	8p	25′×3′	4-in: diffuse splinter
NGC 104	Tuc	GC	0:24.1	−72:05	4.0	31′	NE; 47 Tuc: second best GC; CC III
Beta	Tuc	Dbl	0:31.5	−62:57	4.4,4.5	27″	Both blue-white
M31	And	G-Sb	0:42.7	+41:16	3.5	160′×40′	NE; 8-in: 2 dl, st cloud, GC G1
M32	And	G-E2	0:42.7	40:52	8.2	3′	M31 group; also M110, NGC 147, NGC 185
NGC 253	Scl	G-Sc	0:47.6	−25:17	7.1	22′×6′	Elongated, mottled; GC 288 adj
SMC	Tuc	G-Im	0:52.6	−72:48	2.8p	216′	NE; Cl and EN inv
NGC 281	Cas	EN	0:52.8	+56:37	7p	35′	Use nebula filter; DN inv
NGC 362	Tuc	GC	1:03.2	−70:51	6.6	13′	Milky Way GC beside SMC; CC III
NGC 457	Cas	OC	1:19.1	+58:20	6.4	13′	Polakis's Kachina Doll Cluster: Splendid
M33	Tri	G-Sc	1:33.9	+30:39	5.7	60′×40′	Difficult NE; 8-in: spiral arms; 16-in: 6 EN inv; 24-in: four arms
NGC 663	Cas	OC	1:46.0	+61:15	7.1	16′	80 st; 4 OC within 2 deg
Gamma	Ari	Dbl	1:53.5	+19:18	4.8,4.8	7″.5	Both white
Gamma	And	Mlt	2:03.9	+42:20	2.1,4.8	9″.6	Gold, blue; C m 6.0, BC 0″.5
Omicron	Cet	Var	2:19.4	−03:00	..	..	Mira: orange, watch m rise with NE
NGC 869,884	Per	OC	2:19.0	+57:09	4.4	3′, 30′	NE; Double Cluster; 350 st
NGC 891	And	G-Sb	2:22.6	+42:21	10.0	14′×3′	Edge-on; 24-in shows dl
M34	Per	OC	2:42.0	+42:47	5.2	35′	NE; fine in small scopes
Beta	Per	Var	3:08.2	+40:57	..	..	Algol: NE eclipsing binary
A Per	Per	OC	3:22.0	+48:36	2.3	240′	Alpha Per Assoc; use binoculars

Note: I have never seen the four objects in Tucana: GC NGC 104, Beta Tuc, the SMC, and GC NGC 362.

Abbreviations used

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

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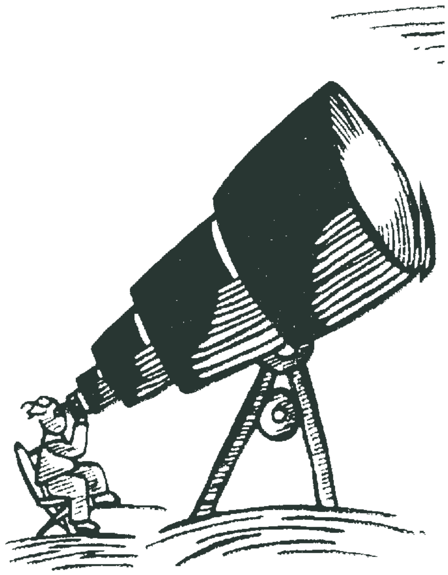
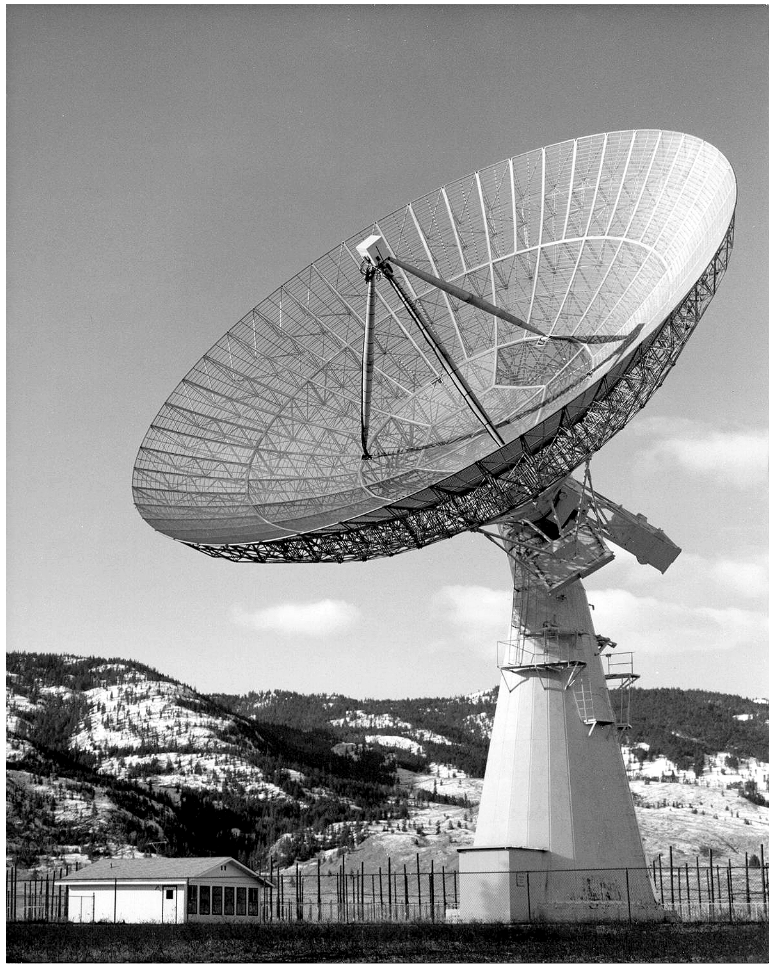
Most deep-sky data are from NGC 2000.0. For the few facts not available from NGC 2000.0, the following Observer's Handbook 1999 lists were used in this order of preference: Galaxies: Brightest and Nearest by B. Madore (for the dimensions of elongated galaxies and for LMC and SMC data), The Messier Catalogue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

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

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

Ask Gazer





One of a number of "communications satellite dishes" that have been erected in the Avonport area over the last ten years.

Dear Gazer:

I am a long-time member of the Society, and one of the things that I really enjoy is reading about what people in other Centres are up to. For most of the time that I have been a member, I have been limited to reading the national publications, attending the occasional General Assembly, and occasionally getting my hands on copies of newsletters from other Centres. The Internet has helped my interest immensely, as some Centres are now putting issues of their newsletters on their web site so that anyone can read them. The Halifax Centre is one of them, and I have found the goings-on in your centre to be quite interesting. There is one thing that I was hoping that you could help clarify for me. I have noticed that there are occasional references to a phenomenon whereby it is alleged that if you want to ensure seeing some celestial event, you should get as close to Roy Bishop's observatory as possible, as he always manages to have clear skies on such occasions. Is that true? Does he have some sort of supernatural power over the clouds, or is it just Centre folklore or an inside joke? If he has found a way to dispel the clouds, I would like to know his secret so that I could use it too.

Kloudy in Kamloops

Dear Kloudy:

I too have read the same observations that you have referred to, and I had always assumed that it was some sort of inside joke. Nonetheless, in the true spirit of investigative reporting, I decided to see what I could learn. I have met Dr. Bishop on several occasions, as well as attended a few of the presentations that he has made to the Centre. He has an extensive knowledge in all aspects of astronomy and physics, yet there is nothing about him that would lead anyone to believe that he has developed any technique in either sorcery, telekinesis, or technology that would allow him to clear clouds from around his home… or at least that is what he would like people to believe!

The truth is out there! All you have to do is follow the clues as I did. The first step of my investigation was to determine if there was anything special about the location of his observatory in Avonport. At first glance, his observatory (which is actually built on top of his house) would appear to be just like most other observatories, so I decided to drive around a bit more to see if there was anything about the landscape that might influence the weather. While doing so, I did notice a large number of satellite ground stations in the area, but at the time the significance of the discovery was not apparent.

Several days later, while puzzling over the problem, I remembered something that, at first, seemed perfectly innocent. I recalled reading in *Nova Notes* (the Centre's newsletter) that the Centre was able to lease the land to build its observatory at a very low cost, because Roy's brother is the president and CEO of the company that owns the property. The company in question produces paper products, and, because of the size of the mill, produces its own hydropower from two dams located on either side of the Centre's observatory.

Now I started to see the lengths to which some people will go in order to get clear skies! The mill does not have a night shift, so there is all that potential for hydropower but no use for it. What if you were to take that power and convert it into microwaves of the same frequency that are used in microwave ovens — the ones that heat water molecules? If you then used giant satellite dishes to beam the microwaves into the sky, with enough power you could vapourize any condensed water, such as fog and clouds, back into a vapour, making the water invisible once again. In effect, you could sweep the sky clear to ensure good viewing whenever you needed it, if the clouds were very thin, or point all the emitters in the same direction to punch a hole in a small area of sky. The first method would have the added advantage of getting rid of mosquitoes and black flies, by making the little rascals boil and explode, but would presumably also have a negative impact on owls, bats, and other night-flying creatures.

Well, that was the theory, but there was only one way to confirm it. Our weather in Nova Scotia has been very dry this summer, which meant I had to wait almost two months before getting a cloudy night with no Moon in an attempt to confirm my theory. On the night in question, the weather forecast was for overcast skies over the entire mainland part of the province, as a result of a system moving in from the west, and that was supported by the latest weather satellite images. I drove from Halifax, and as I reached Windsor (about 15 minutes from Dr. Bishop's house) I noticed that there were holes in the clouds. The closer I got, the better the sky was. I decided to head for the site of one of the receiving stations. Imagine my surprise to find that it was pointed westward and was slowly scanning both back and forth and up and down. About half of the sky was clear, mostly to the west and south. On the way back to Halifax, I detoured past Dr. Bishop's house and noticed that the shutter to the dome was open. As the wind changed direction for a moment, I could have sworn that I heard gentle, but definitely diabolic, laughter...

Gazer is a member of the Halifax Centre who wishes to remain anonymous. Gazer's true identity is known only to the current and past editors of Nova Notes, *the Halifax Centre's newsletter. Questions to Gazer should be sent to gazer@rasc.ca.*

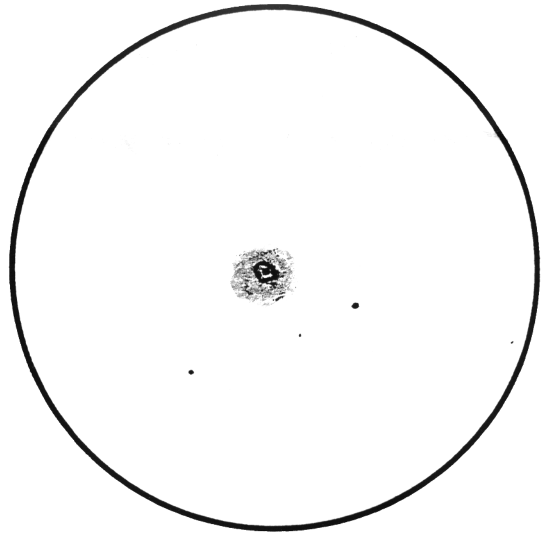
Scenic Vistas: **Observing Buffet**

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

If you are the kind of observer who likes a little variety in your observing, you could hardly do better than the constellation Gemini on a crisp winter evening. With the feet of the Twins dipped into the tranquil expanses of the winter Milky Way, we are looking into the outskirts of our home Galaxy. Compared to the summer vistas of Cygnus, Scutum, and Sagittarius, our Galaxy here is faint and delicate, and there is not much dust to obscure our views into the great beyond. For that reason Gemini is home to star clusters, planetary nebulae, and even a few galaxies. Some of these objects rank with the best that the sky has to offer.

A good place to start is in the vicinity of Delta Geminorum. A little over two degrees southeast of that luminary is one of the sky's finest planetary nebulae, NGC 2392, also known as the Eskimo Nebula. The nebula does not quite have the cachet of the Ring Nebula, the Cat's Eye, or the Helix Nebula, but in my mind it outclasses them all. In November 1993 I had a spectacular view of the Eskimo Nebula. The night was cold, but the seeing was well above average, and with my 15-inch reflector I was able to use a magnification of 466× to view the planetary, the highest magnification I had used on a deep sky object to that point in time. The central star of the nebula is one of the easiest to observe in a small telescope, and on that evening it fairly blazed forth. A dark zone immediately surrounded the star, and then a bright, donut-shaped ring about fifteen arcseconds across could be seen. Beyond that was the nebula's outer envelope, just a little fainter, almost perfectly round and very mottled in appearance. The outer envelope appeared just a little darker at the eastern edge. At low magnification the nebula appears as a small, out-of-focus star. If you ever observe this beauty, do not stop there. Use the highest magnification your telescope will allow.

Another two degrees to the northeast we come upon NGC 2420, an intriguing open cluster, well suited to a small telescope. My only view of the cluster came in March 1993 when I observed it with my old Schmidt-Cassegrain from the dark skies near Ways Mills, in Quebec's Eastern Townships. Easily located at low magnification, the tight, little cluster appeared as a hazy V-shaped spot with the apex pointed toward the south. About a half dozen stars of magnitude twelve and fainter shone through the haze and helped define the cluster's shape. The haze was just at the threshold of resolution, but higher magnification only suppressed the glow without bringing out fainter members.



The Eskimo Nebula from the author's sketchbook, using a 15-inch reflector at 466×, November 12/13, 1993.

Another interesting cluster that will challenge the small-scope user is NGC 2304. It is a small, faint cluster located in a rich star field, and should remain unresolved in a six- or eight-inch telescope. In my fifteen-inch reflector it appeared as a nebulous haze at 48×. At 272× the cluster is well resolved, with most of the members being at magnitude thirteen or fainter and appearing very uniform in brightness. Like NGC 2420, the cluster appears triangular in outline with the northwest flank appearing especially flat. A faint chain of stars leads away from the cluster to the southwest.

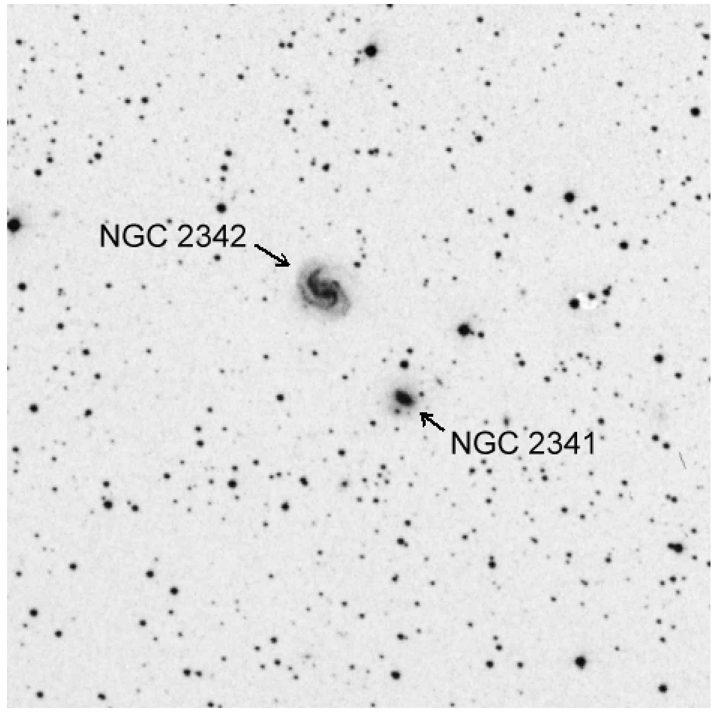
If you are interested in galaxies, Gemini contains several, though none are particularly bright or spectacular. The most prominent is probably NGC 2339. Located not far southeast from Zeta Geminorum, NGC 2339 is fairly bright in a 15-inch aperture, though the envelope is rather diffuse. The galaxy appeared gradually brighter to the middle, with a faint stellar nucleus visible at 272×. I also noticed a very faint star bordering the outer envelope to the northeast.

If you have any luck with that galaxy, you can head a couple of degrees almost due north to the faint pair NGC 2341/42. Of the two galaxies, NGC 2342 is larger and brighter, with an oval envelope of light oriented SW/NE. Though the galaxy is brighter to the middle, I found it lacked a stellar core. The extremities were well defined. NGC 2341 is small and well condensed, located due south from a magnitude-eleven field star. The galaxy initially appears stellar to the eye, but averted vision will bring out its outer envelope. It appears elongated north/south, but the photograph in this article clearly shows it slightly elongated northeast/southwest.

We began this article by describing a planetary nebula, and we leave off by mentioning two more. NGC 2371/72 is easily located on a line joining Pollux and Tau Geminorum. The double designation results from the fact that Sir William Herschel, who discovered the nebula, erroneously thought there were two objects here. In fact, it is a double-lobed planetary surrounding a faint central star. The

Observer's Handbook lists the planetary at magnitude thirteen, but I find that hard to believe as I have observed it with my old Schmidt-Cassegrain from the driveway of my Dorval home. In my 15-inch reflector from a dark site it is quite impressive and holds magnification well. At 313× it is clearly seen as two separate objects oriented northeast/southwest, with the southwestern lobe brighter and more condensed. The central star was not visible.

If you are up for a challenge, though not concerned if you fail, you might want to try to observe the aptly named Medusa Nebula in southern Gemini. Marc Ricard and I had an unforgettable view of that enormous, though faint, planetary nebula on the last day of December 1994. On a perfect winter evening (clear but not too cold) we used my 15-inch reflector and his Lumicon [O III] filter to observe this fine object. We could see pretty much the full extent of the nebula and its partial ring structure. Some of the tendrils were even detectable as slightly brighter zones in the glowing nebulosity. I returned to the object two months later, the next time trying to observe the planetary without a filter, but with little success. The nebula was visible, but only as an ill-defined haze enveloping a faint, flat triangle of stars.



A 13 arcminute square digitized sky survey image of NGC 2341/42[1]

A deep sky filter and low power eyepiece brought a little more success, increasing contrast somewhat, but the view was a far cry from what we had seen earlier.

This is but a short summary of what that large and bright constellation has to offer. Winter nights may be cold, but the rewards are often worth it.

Mark Bratton, who is also a member of the Webb Society, has never met a deep sky object he did not like. He is one of the authors of Night Sky: An Explore Your World Handbook, *which is scheduled to be published in the U.S. by Discovery Books in the summer of 1999.*

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

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Reviews of Publications
Critiques d'ouvrages

The Search for Life on Other Planets, by Bruce Jakosky, pages ix + 326, 17.5 cm × 24.5 cm, Cambridge University Press, 1998. Price US$49.95 hard cover (ISBN 0-521-59165-1), US$19.95 soft cover (ISBN 0-521-59837-0).

Is there life on other worlds? The question is a not a new one. Its philosophical underpinnings reach back at least twenty-five centuries to Leucippus and Democritus, who spoke of the universe as an infinite space stocked with an unlimited number of atoms. Some of those atoms once swirled together to create our living Earth. It is a short step to imagine that elsewhere other atoms are similarly engaged. Today such ancient reasoning is a key rationale for astrobiology (or exobiology), the study of life in the universe.

Although the question of life on other worlds is venerable, technology has only now put us in a position to do something about it. Recent discoveries, including planets around nearby stars, the existence of a subsurface ocean on Europa, the presence of bacteria in extreme environments on Earth, and the hotly disputed microfossil evidence for life on Mars have all helped raise the scientific profile of astrobiology. The creation, last year, of NASA's Astrobiology Institute is a further manifestation of this shift. Despite the conspicuous lack of extra-terrestrials available for study, astrobiologists are clearly living in heady times.

In *The Search for Life on Other Planets*, Bruce Jakosky offers readers an entry point to the latest ideas and issues in astrobiology. A planetary scientist who began his research career with the *Viking* missions to Mars, Jakosky is currently an interdisciplinary scientist with the *Mars Global Surveyor* mission and a professor of geology at the University of Colorado. Jakosky's name may also strike a familiar chord with those who have been following the trials and tribulations of the Martian microfossils since 1996. He was among the early challengers to question whether the putative fossils formed at temperatures low enough to admit a biological origin.

This book is written as a text for an introductory course in astrobiology, not as a piece of popular science writing, so personal anecdotes or reflections are not to be found here. On the other hand, Jakosky's considerable experience as a geologist and teacher thinking about this material is evident in the book's superb organization and progression of ideas.

The first third of the book deals mainly with Earth and the conditions that led to the emergence of life here. Jakosky draws particular attention to how early in Earth's history life appeared — literally as surface altering bombardment was just beginning to taper off — suggesting life can develop quickly when conditions are right. Life, or at least large fractions of it, can also disappear quickly during mass extinction events. Jakosky succinctly reviews the connection between an impact at the end of the Cretaceous period and the extinction of the dinosaurs as an example of the constraints on life. Equally significant, though perhaps less familiar for many readers, is the intricate feedback loop between life, plate tectonics and Earth's climate via the carbon cycle. Jakosky gives a good description of this vital stabilizer in Earth's life support system, and paints a fascinating portrait of the oxygenation of the atmosphere some two billion years ago.

For those with less biochemistry than astronomy in their backgrounds, Jakosky performs a welcome service by detailing how different chemical reactions can be used to drive life. That includes not only the metabolic processes that keep most plants and animals alive, but the more exotic sulfate-reducing chemistry of bacteria that live near hydrothermal vents, or the indirect use of iron oxidation as an energy source by bacteria recently discovered in the Columbia River Basalts. The diversity of such processes has important practical implications for the frequency and tenacity of life on other worlds.

Leaving Earth, Jakosky proceeds to discuss in detail some other locations in the solar system where past or present environments might have fostered life. Chief among them is ancient Mars, with its liquid water and warmer, friendlier atmosphere. But Jakosky also gives some consideration to the possibility of life on an early Venus, before the runaway greenhouse effect rendered it a waterless hell. Meanwhile, in the outer solar system he focuses predictably on Titan, Io, Europa, and the atmosphere of Jupiter. With the exception of Titan, information relevant to the question of life on these worlds has been significantly augmented by the *Galileo* mission to Jupiter. What is most surprising here, given recent developments, is that Jakosky does not give Europa a chapter of its own.

The book concludes with the formation, habitability, and detection of planets around other stars. As with previous chapters, the material is well presented, but readers can find more in several recent works about the search for extra-solar planets.

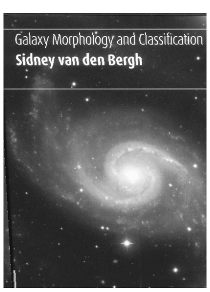
As a textbook, *The Search for Life on Other Planets* is not a work that features lively, personal prose. At times that seems a pity; one senses that in a different format Jakosky would be capable of a more intimate, engaging style. What the book does offer is a good treatment of a dynamic field, highly informative, if a little on the bland side. To his credit Jakosky is particularly careful not to succumb to speculation when the data run out. He frequently reveals where the parameters are too wide for a unique interpretation, even on issues where he likely has some strong opinions, such as the Martian microfossils.

Naturally, where the field is dynamic there is always the question of how long a book will remain relevant. In the present case, I suspect *The Search for Life on Other Planets* is safe from immediate obsolescence. Jakosky capitalizes on several recent developments, and his timing is nearly perfect. The question of microfossils on Mars will remain open at least until the first Martian samples are returned a decade or so from now. *Cassini* is still five years away from Titan, and a comprehensive Europa mission is much farther away than that. New solar systems will continue to be detected as they have been since 1995, but a new chapter in the study of extra-solar planets will depend on the next generation of space-based observatories. Barring an unexpected message from another civilization, this book is likely to remain current for a little while yet.

Ivan Semeniuk

Ivan Semeniuk is book review editor of the Journal, *and suspects there are others like him out there, somewhere.*

Galaxy Morphology and Classification, by Sidney van den Bergh, pages xi + 111, 18 cm × 25 cm, Cambridge University Press, 1998. Price US$39.95 hard cover. (ISBN 0-521-62335-9)



Because of our short lives, galaxies seem immutable — forever frozen in a rich variety of shapes. Galaxy morphology is the study of such shapes; its thoughtful application can go far towards overcoming the limits imposed by biology. In this short book, just over 100 pages including copious references, one of the world's master morphologists summarizes the state of his craft, and in so doing provides a stimulating overview of the study of galaxies.

A series of lectures at the University of Victoria led to this book, which reports the situation as of 1997. The bibliography is as current as possible, even containing a few references to electronic preprints. It is a work targeted at professionals, advanced students, and all those interested in reviewing the current state of galaxy research from an observer's perspective. No attempt is made to survey theoretical work, or to provide the kind of fundamentals that would be required in a course text on galaxies. The writing is vintage van den Bergh — clear, concise, objective, and quite enjoyable. I found few typos or printer's errors. Results presented in tabular and graphical form are carefully described, and trends quantified when necessary using statistical tests (the Kolmogorov-Smirnov variant being preferred). One nice touch: each chapter concludes with a summary of its most important points. It is a practice that deserves to be imitated.

Since the study of galaxy morphology is based on examining images of galaxies, I was disappointed to find so few galaxy images in the book. No doubt that is partly the result of an effort to reduce costs, which are still rather high per page. There are frequent references to specific images in the Carnegie Atlas, which, unfortunately, is probably not in the personal library of most extragalactic researchers. On the other hand, that is not a major deficiency, since the book is not offered as a "how-to" manual for galaxy classification.

The text is arranged in six short chapters, each perhaps the central topic of one lecture. All the major classification systems are included, summarized in the required detail as a prelude to the real meat of the book: what their study tells us about galaxy evolution. The Hubble system, with its signature "tuning fork" diagram, dominates the discussion, as it has the subject of galaxy classification, for the simple reason that it has stimulated the deepest insights into evolution. Hubble classified what his telescopes showed him, which in the 1920s were mostly bright galaxies within the local, low-density part of our universe. Technology now provides routine access to regions of much higher density — the cores of rich galaxy clusters — and, less routinely perhaps, to samples of the universe during the era of galaxy assembly. In such environments other ways of distinguishing galaxies are probably more useful than Hubble class. One is provided by the Yerkes system, whose major sequence separates galaxies by the degree of light concentration (a characteristic implicit in Hubble's scheme). This aspect of morphology is much more amenable to automation than the subtleties of spiral arm patterns, which also do not occur in galaxies occupying high-density environments. A central concentration index, supplemented by some measure of image asymmetry, will form the basis for dealing with the vast output of forthcoming digital surveys.

The Hubble system does not do well at separating galaxies with marginal spiral structure — the ones at the "late-type" end of the famous tuning fork. Perhaps one should look for a nucleus in such systems; its presence would signify type Sm, its absence type Im. Another problem is the separation between elliptical and spiral galaxies. It was the job of the S0 class to span this abyss. But there is a problem: typical S0 galaxies are fainter than their "neighbours" on either side. Also, the S0 class seems to have become a dumping ground for "early-type" galaxies that for various reasons have proven difficult to stuff into other Hubble slots. There is work for the future here!

The Yerkes counterpart of the S0 galaxies might be the class D, which also seems to be a grab bag. However, one particular type of D galaxy, the type cD that is usually (but perhaps not always) found in the centres of rich clusters, has stimulated much productive thinking. Here we probably see an extreme example of the effect of local density on morphology. The nature of the connection, however, is still unclear. Stay tuned!

Half of the tuning fork is devoted to barred spirals, which comprise fewer than half of all spirals. However, bars are easier to see in the infrared and might be much more common. Their importance as global gas movers in spiral disks is widely accepted, yet curiously unsupported by the observations reported here. Bars may also produce some spiral bulges, although that is mentioned only in passing. Other oddities concerning bars is their virtual absence among members of the Hubble Deep Field (our most detailed view to date of young galaxies) and also among low surface brightness galaxies, and in late-type spirals their preference to occupy dimmer galaxies. Suggested explanations, some speculative, push to the edge of our understanding.

The Hubble system does not concern most of the galaxies in the present universe: the dwarf spheroidals, dwarf irregulars, and low surface brightness galaxies. Two chapters are devoted to these interesting objects. As he does elsewhere, van den Bergh presents a stimulating mix of facts, questions, and informed speculation. Do the various dwarf types represent fundamentally different evolutionary paths or different phases along a common path? Are low surface brightness galaxies, and dwarf spheroidals, the results of qualitatively different processes than brighter galaxies? Luminosity effects across the entire range are explicitly incorporated into the DDO system, created by van den Bergh during his years in Toronto and made possible by the production of the *Palomar Sky Survey*. The effects on morphology are pronounced and fundamental. They include the association of high luminosity with grand design spiral patterns and the fading away of spiral structure of any kind at low luminosity. Alas, the extreme depth of the *Sky Survey* also overexposes the centres of most bright galaxies, denying us access to morphological information in this area. Using the *Carnegie Atlas of Galaxies*, van den Bergh has constructed a complementary classification system for the inner parts of galaxies. Important here are features such as bars, bulges, and nuclei, which occur near the bottom of the gravity well. Time will test the utility of such an approach.

The study of elliptical galaxy morphology, once considered boring (if you've seen one elliptical…) has blossomed with the help of detector technology into one of the most active areas of galaxy research. Many ellipticals, especially the dimmer ones, turn out to have high angular momentum components — disks. Perhaps they should be regarded as forming the true base of the Hubble tuning fork, with a more natural connection to at least some S0 galaxies. Brighter ellipticals may be different beasts, as suggested by the fact that the isophotes of many show small departures towards box-like shapes. Curiously, galaxies with boxy isophotes, a phenomenon associated with the galaxy as a whole, are much more likely to have distinct cores (a central feature). All this suggests to some that bright and faint ellipticals have followed different evolutionary paths. Van den Bergh attempts to draw the facts together in a consistent way, and to provide ideas for future work.

If you study galaxies, you should purchase this delightful and rewarding book.

Gary Welch

Gary Welch is an associate professor in the Department of Astronomy and Physics at Saint Mary's University, where he is also the director of the Burke-Gaffney Observatory and presently Chairman of the Department. His research interests include the interstellar medium and star formation in early-type galaxies, and their structure and evolution.

PUBLIC EDUCATION COMMITTEE FORMED

At this year's General Assembly, the National Council established a special committee on public education. Its main purpose is to co-ordinate the work of the Centres in informing the general public, but we also hope to seize such opportunities as the 25 percent astronomy component in Ontario's new Grade Nine science course.

Our membership consists of :

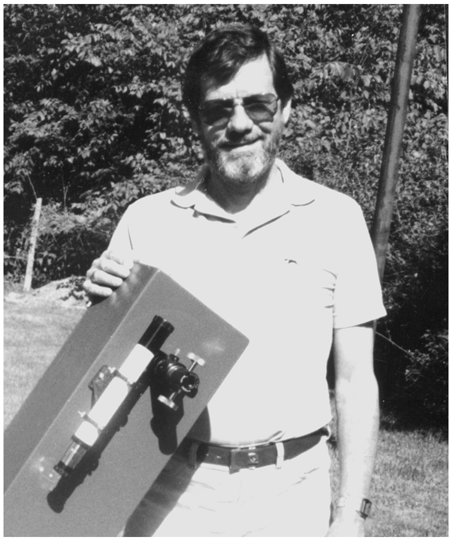
David Orenstein (Chair) (Toronto Centre)
Mary Lou Whitehorne (Halifax Centre)
Leo Enright (Kingston Centre)
Don Hladiuk (Calgary Centre)
Randy Attwood (RASC President, ex officio)

As you can see we have a wide geographic spread in our formal membership, but the informal working group should be much bigger — ideally every Centre should be included. There are two reasonable membership goals we hope to achieve: a substantial representation from French-Canadians, and, since education is a provincial responsibility, we would like a contact person in each province.

If you are interested in joining us, contact me at david.orenstein@utoronto.ca or through the National Office.

Obituaries
Nécrologie

Douglas G. L. Middleton



Doug Middleton shortly after he finished building his 6-inch Newtonian Telescope

It is with regret that we inform the RASC of the passing of Montreal Centre member Douglas G. L. Middleton. He passed away on June 20th, 1999 at the age of 75 years, after a brief, but determined, battle with cancer.

A native of Aberdeen, Scotland, Doug attended King's College and upon graduation in 1944, entered the Royal Navy where he served for two years. He came to Canada in 1964 and with his background in electrical engineering soon found life long employment with Canadian Marconi.

Doug developed a casual interest in astronomy early in his life, but his passion grew upon retirement. In 1989 he built a 6-inch f/8 Newtonian, which he always referred to as a "Richard Berry Special." That was about a year before he joined the Montreal Centre. He was an enthusiastic and methodical observer, whether quietly bagging Messier objects at Centre outings or on private trips into the countryside surrounding Montreal to enjoy the splendours of the night sky. He received his Messier Certificate in 1993 and thereafter, realizing the limitations of his telescope, became an accomplished observer of multiple stars.

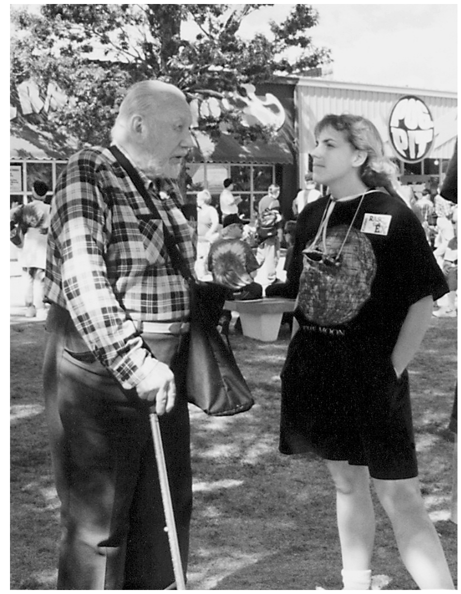
Doug served as Treasurer of the Montreal Centre from 1994 until shortly before his death. He discharged his duties with the quiet competence all Montreal Centre members associated with him. He had many interests outside astronomy, and was an enthusastic tennis and badminton player, as well as a great piano player. In addition, he was an active volunteer at the Morgan Arboretum, a nature preserve on the island of Montreal.

He is survived by his sister, Ruth Davidson of Aberdeen, and by his son, Greg. Doug touched the lives of many at the Montreal Centre, and many counted him amongst their closest friends. He will be missed.

Frederic Laurence Troyer

Frederic Laurence Troyer (1912–1999) passed away at his home in suburban Toronto, Ontario on June 2, 1999 at the age of 86. His death ended a remarkable association that lasted 75 years.

Fred, as he was known to all in Toronto Centre, was born on September 10, 1912, the son of Herbert Lawrence Troyer, a Baptist minister. Herbert Troyer was serving as the minister to a church in Essex, Ontario, when he received an invitation to take up a post in Toronto. Upon his arrival in Toronto, he found that the church was unable to honour its invitation. Nevertheless, he decided to remain in Toronto, and thus, in 1924, a young Fred Troyer attended a lecture sponsored by the Toronto Centre that had a profound influence upon him. He joined the RASC at the age of 12 and became the Toronto Centre's Assistant Curator in 1925, operating the lantern slide projector at meetings.



Fred Troyer reminiscing with Kirsten Vanstone at the Toronto Centre's display at the 1995 Canadian National Exhibition. This was the first involvement of the Toronto Centre with the CNE since Fred's activity in the 1960s.

Fred Troyer began a career of freelance writing and journalism after leaving home. He ran his own newsgathering service, and wrote articles on a wide variety of scientific and technological subjects. By the mid 1930s, Fred had established his career as a writer and was also heavily involved with the Toronto Centre, serving on its Council and volunteering for public education activities. He became a Life Member of the RASC in 1933, a fact of which he often reminded members of Council whenever proposals to increase membership fees were discussed.

In 1941, Fred joined the staff of *The Toronto Star*, where he was to remain until his retirement in 1977. He worked as a copy editor, night assignment editor, and editor for radio and television listings. He quickly established a reputation at *The Star* as a source of scientific facts and a collector of newspapers. He also began to collect a copy of every edition of *The Star*, storing each day's set in a separate manila envelope. It was a habit that lasted until almost the end of his life.

From 1941 to 1964, Fred rose through the ranks of the Council and Executive of the Toronto Centre, serving as Recorder, Secretary, Treasurer, and Vice President. He served as President of the Toronto Centre in 1950-1951. It appears that he printed many of the flyers, renewal notices and other documents used by the Centre during this period on two Gestetner machines that he purchased for his freelance writing and reporting business. He also served as National Recorder from 1952 to 1964.

During that time, Fred was also active in the Toronto Centre's public education programmes, particularly at the Canadian National Exhibition. He would set up his telescope at the CNE grounds, and distribute a four-page pamphlet on astronomy and the RASC's activities. The pamphlet was printed by *The Star* on behalf of the Centre. In later years, he often recounted his CNE experiences to many younger members.

Fred's service to the RASC was recognized in 1960 when he received the Service Award. His contributions to the Toronto Centre were also recognized in 1967, when he, along with Dr. John F. Heard, Dr. Helen S. Hogg, Prof. Ruth J. Northcott, and Mr. Jesse Ketchum, received the Centennial Medal of Canada.

In 1972, Fred Troyer returned to Toronto Centre Council, serving successive terms as Councillor, Recorder, and Secretary. In 1977, Fred was elected National Librarian, a post he held until 1982. Upon his retirement from that position, he was named Honorary Councillor of the Toronto Centre by a special resolution of its Council. He served in that capacity with dedication, advising the Council and Executive about past events and decisions, and meticulously scrutinizing minutes of meetings for typographical errors. Woe to any Recorder who failed to record the Centre's history accurately with proper spelling and grammar!

Upon retirement from *The Star* in 1977, Fred continued to write articles for *The Star* under the by-line "Frederic L. Troyer," and freelance articles as "Laurence Troyer." He regularly attended meetings of the American Association for the Advancement of Science, as well as other scientific and technical meetings and conventions. He would travel by bus or train to these meetings, and write up reports upon his return.

Fred was a fixture at Toronto Centre's meetings, both at the McLaughlin Planetarium and, in recent years, at the Ontario Science Centre. He could always be counted on to be present, regardless of the weather. In his later years, he still made the effort to travel to general and Council meetings by bus and subway trains, despite severe pain and discomfort in his feet and hips. Only serious illness or business travel could keep him away. He quietly encouraged many younger members to participate in Centre activities, and he supplied many of his friends among the membership with copies of *The Farmer's Almanac* that he collected each autumn from National Trust. His razor sharp wit and wry sense of humour were appreciated by many.

Several weeks after Fred Troyer's death, arrangements were made for a small group of members to go through several storage lockers that Fred had rented to store papers and other materials that he could not keep in his home. During three days, we were able to collect over 20 large boxes of RASC memorabilia, records, and personal papers from over 20 tonnes of stored materials. Thanks to the kind co-operation of Stan Troyer, we have been able to preserve some more of the Toronto Centre's history, in accordance with Fred's original intentions when he placed the materials into storage.

Fred Troyer is survived by his brother Stan, his sister Ruth, a nephew, and a niece. His passing is truly the end of an era for the Toronto Centre. He will be missed.

B. Ralph Chou

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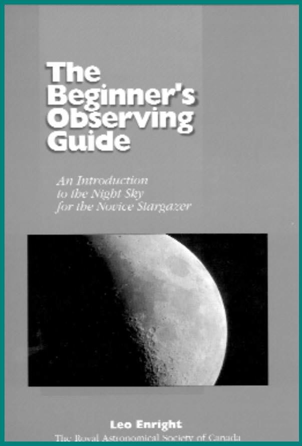
Publications and Products of
The Royal Astronomical Society of Canada

Observer's Calendar — 2000

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. This year all of the photos are in full colour.

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 1999 edition received two awards from the Ontario Printing and Imaging Association, Best Calendar and the Award of Excellence. (designed and produced by Rajiv Gupta).

Price: $13.95 (members); $15.95 (non-members)
(includes taxes, postage and handling)



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.

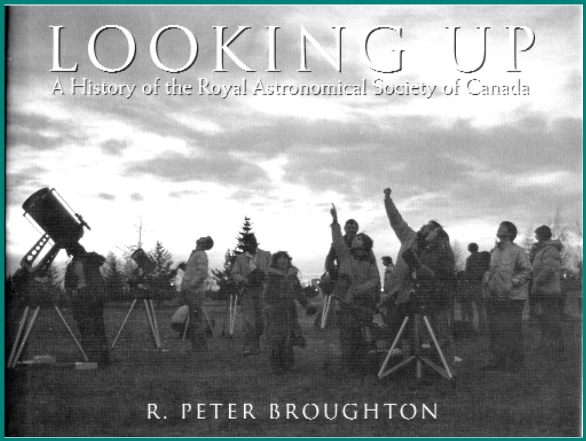
Written by Leo Enright (160 pages of information in a soft-cover book with otabinding which allows the book to lie flat).

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

Looking Up:
A History of the Royal Astronomical Society of Canada

Published to commemorate the 125th anniversary of the first meeting of the Toronto Astronomical Club, "Looking Up — A History of the RASC" is an excellent overall history of Canada's national astronomy organization. The book was written by R. Peter Broughton, a Past President and expert on the history of astronomy in Canada. Histories on each of the centres across the country are included as well as dozens of biographical sketches of the many people who have volunteered their time and skills to the Society. (hard cover with cloth binding, 300 pages with 150 b&w illustrations)

Price: $43 (includes taxes, postage and handling)



*** Special Discount — Looking Up and the BOG — $50 ***

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