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Journal

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December/décembre 1999

Journal

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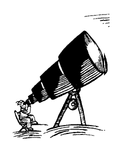

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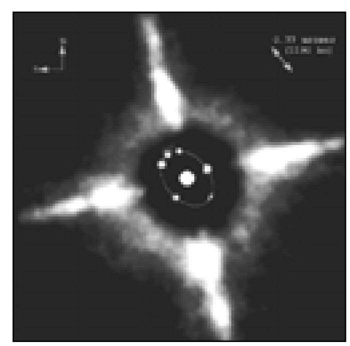

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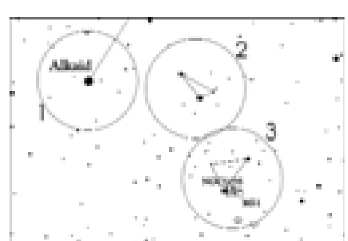

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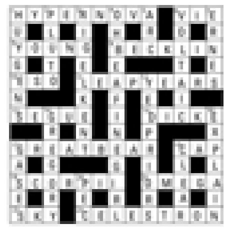

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Cover:
Some astronomical devices defy modern limitations regarding data integrity! Happy Y2K to all!
(photo-montage by Brian G. Segal)

From the Editor

by David Turner

Clear autumn evenings are a bit of a rare commodity in Canada's maritime provinces, which form the focus for the tracks of most storm systems affecting the east coast of North America. The turbulent hurricane season can be particularly frustrating for avid sky watchers. The evening of Wednesday, October 27th was a welcome break in that regard, since the region was greeted by crystal-clear skies with almost unlimited visibility.

At about 9:26 p.m. EDT a spectacular fireball lit up the area for a few seconds when a presumably larger-than-average meteoroid plunged through the Earth's atmosphere, in the process producing a very bright flare-up that was seen from portions of New England and Quebec as well as from New Brunswick and Nova Scotia. Numerous conflicting reports of the event were received. Unfortunately, many of the region's most experienced observers were engaged in indoor activities at the time. I was also indoors, but noticed the event from the bedroom of my house when the en suite bathroom was suddenly illuminated through curtains (!), almost as if it had been lit up by several floodlights. Roughly three minutes later the houses in my neighbourhood, as well as those in several other areas of Nova Scotia's eastern shore, were shaken by a sonic boom from the fireball. Although I had witnessed several fireballs previously, it was the first instance on which I recall being treated to associated audible sounds.

In a region that only a year ago was the site of the disaster resulting from the crash of Swissair Flight 111, it naturally took some time to sort through the various reports of "downed aircraft" to establish that the event was a fireball. I myself was initially puzzled by the bright light viewed indoors and by the subsequent explosion. A neighbour's house had been destroyed in a spectacular morning blaze a few weeks previous, and that disaster is still being investigated as a possible case of firebombing. Believe me, my initial feelings about the bright light and subsequent explosion on the evening of October 27th only remotely included the possibility of a fireball! It was somewhat of a relief to discover that the event was observed over such a large area.

In an age when, if it doesn't happen on the Internet then it just doesn't happen, it is gratifying to find that so many people are still able to witness celestial spectaculars in their natural setting.

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.

The *Journal of The Royal Astronomical Society of Canada* is published at an annual subscription rate of $80.00 by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Annual fees for 1999, $36.00; life membership is $720. Applications for subscriptions to the *Journal* or membership in the RASC, and information on how to acquire back issues of the *Journal* can be obtained from:

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President's Corner

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

A major part of the mandate of the RASC is to stimulate interest and to promote and increase knowledge in astronomy. As we head into the 2000s, I am taking steps to fulfill our mandate. Currently the RASC promotes astronomy locally through the various activities of the Centres and through our national publications. I am looking for more ways to promote astronomy in Canada. I hope we will be able to support astronomy at the high school level and to sponsor prizes for astronomy projects at the Canada Wide Science Fair once again. I am also talking with the Canadian Astronomical Society about organizing a joint series of talks on astronomy for next year that would be given in communities across the country that do not have colleges or universities with astronomy programs.

By joining Canada's national astronomy organization, you are helping to promote astronomy in Canada. Your membership fees support activities at your centre as well as national programs such as the ones I have proposed here. I would appreciate hearing your ideas about how we can promote astronomy in Canada.

I am pleased to report that the new membership and product accounting system in our National Office is working very well. I am sure many of you have or will notice the improved service now that we are processing memberships in house. As I have mentioned before, this improved service is most likely going to cost us more, but I feel it is worth it. By next March we should know if the extra costs will require a fee increase.

Many of you noticed on the membership renewal form that the information in the "Member since" area is wrong if you joined prior to 1996. We are aware of the problem and, over the next year, plan to update it with the information we have. In the future, when you receive your renewal form, if there is anything incorrect on the form, please correct it and highlight it right on the form, send it in, and it will be corrected in our files.

At the National Council meeting in Toronto on October 23, the editorial structure for the *Journal* was changed. The *Journal* will now have an Editor-in-Chief who is responsible to the National Council for the running of the *Journal*. Associate editors will handle the technical paper section and popular section. I think such an arrangement will work better and help spread the workload around, making it easier for us to find volunteers to work on the publication. If you are interested in learning more about the editor positions, please let us know.

We have been receiving complaints from members regarding lateness in the delivery of the *Journal* and *SkyNews*. I understand the frustration that is felt when you receive *SkyNews* late. The volunteer editors of the *Journal* try to get the *Journal* and *SkyNews* in the mail in time to reach you by the first of the month. Unfortunately, sometimes the *Journal* is delayed for one reason or another at the printing or distribution phase. After the *Journal* is printed in Halifax and *SkyNews* is printed in Winnipeg, both are shipped to Ottawa for bagging and mailing. Once the packages are mailed, they are in the hands of Canada Post. You can see there are many opportunities for delays. Please be patient — we are doing our best.

It is not too early to start thinking about attending the General Assembly in Winnipeg in July. Why not design a display or make an outline for a paper presentation? For more information, look in the next issue of the *Journal*.

Finally, I know I speak for all members of the Society when I wish Leo Enright a continued speedy recovery from his recent serious illness.

Clear skies!

RASC PUBLICATIONS WANTED

1. 1997 Observer's Handbooks
2. February, 1999 Journal of the Royal Astronomical Society of Canada
3. April, 1999 Journal of the Royal Astronomical Society of Canada

If you have a copy of these publications, in good condition, and no longer need them, please contact:

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DOUBLE SUNRISE

Dear Sir,

The recent article "Nailing the Equinox Sunrise" by Michael Attas and Jude McMurray (JRASC, 93, 163, 1999) reminded me of an unusual sunrise I witnessed while flying from Calgary to Edmonton one morning in late November. I saw the Sun rise twice! The flight left Calgary at approximately 8:00 a.m., and arrived in Edmonton, which is almost 3° due north, at roughly 8:40 a.m. The *Observer's Handbook* indicates that sunrise for observers in Calgary was at about 8:03 a.m. that morning, but occurred 11 minutes later for observers in Edmonton. What I observed was that the Sun rose shortly after takeoff for those on the right (east) side of the aircraft. A few minutes later it set below the horizon as the plane flew north. A few minutes after that it rose again, this time permanently. It was broad daylight by the time we arrived in Edmonton.

Walter Driedger, Driedgew@cadvision.com
Edmonton, Alberta

SOUTHERN HEAVENS HOMESTAY

Dear Sir,

I was pleasantly surprised to receive quite a few E-mail messages regarding my article "Orion Upside Down," which appeared in the February 1999 issue of the *Journal*. Most included inquiries about how to contact the astronomy-oriented bed-and-breakfast in New Zealand. Peter Knowles, the owner, wrote recently that two Canadian couples came over to stay and observe at his Southern Heavens Homestay, and that three others were making inquiries — all as a result of the article. What follows is contact information for any other readers who may be interested.

Peter & Joan Knowles
Southern Heavens Homestay
1A Kingsley Place
Nelson, Richmond
New Zealand
Electronic mail: p&jknowles@xtra.co.nz

Ray Berg, berg3@netnitco.net
Kingston Centre

AUGUST SOLAR ECLIPSE

Dear Sir,

I have just received my copy of the October issue of the *Journal* and thought I would add to Randy Attwood's list of those who witnessed the August 11th eclipse. It was also seen by a number of Canadian astronomers who attended IAU Colloquium 176 on Large Scale Surveys of Pulsating Variables held in Budapest. On the morning of the 11th we woke to cloudy skies, but as we travelled in five buses to southern Hungary the skies began to clear. Instead of proceeding to the chosen site, the organizers decided to stop at an abandoned parking lot in an area where it was completely clear.

We had a view of the eclipse from 1st to 3rd contact that was awe inspiring with large prominences visible. We could pick out bright stars as well as Venus. There was a pale light in a circle around the horizon as if sunrise were in every direction. I took pictures that appear very much like the centre and left shots at the bottom of page 240 of the October issue. We then continued on to lunch at the original site, to discover it had been completely clear there as well.

On a different subject, it is stated in the News Note on *WIRE* on page 209 that "starquakes had only been observed on the Sun and abnormal objects." Yet Jaymie Matthews has been observing them regularly on Ap stars (although they are perhaps not quite "normal") for quite a few years. In fact, the Plaskett Medal lecture reported on page 233 was concerned with asteroseismology.

Amelia Wehlau, afwehlau@astro.uwo.ca
London Centre

Editor's Note. Yes, sometimes there are dangers in following astronomical press releases too carefully! Non-radial pulsation has been observed in Delta Scuti variables (post main-sequence A and F-type stars), white dwarfs, the Sun, and rapidly-oscillating Ap (roAp) stars, to name but a few, and starquakes have also been observed in pulsars. The primary result of the WIRE *observations is to indicate that in future just about any star may fall within the range of detectability for acoustic waves. The* MOST *mission should provide exciting results on that score.*

Are Telescopes Becoming Too Smart?

by Joseph O'Neil, London Centre (joneil@multiboard.com)

Consider the following list: mirror blanks, grinding kits, complete mirrors, eyepieces, focusers, mirror cells, complete telescopes, image processing software, planetarium software, telescope control software, mounts, computerized interfacing for mounts, observing furniture, dew zappers, planispheres, observatory parts, books, and magazines. All of the above astronomical items, and many more, are currently manufactured in Canada — not imported and sold, but designed, produced, and sold in Canada by Canadians.

A while ago when I went to make a list of Canadian astronomical equipment manufacturers, I very quickly learned the Herculean nature of such a task. From the Atlantic to the Pacific, one can purchase just about anything needed for amateur astronomy, all of it made right here in Canada. Such an impressive list of Canadian manufactured items did not exist perhaps ten years ago, yet it shows every sign of continuing to grow.

What reasons exist for the explosion in full-time and part-time businesses in Canada? The weak Canadian dollar clearly plays a role by making exported items less expensive in the United States market. It also helps that the government has not interfered with astronomy-related industries. I was surprised to discover, as I learned more about the people involved in the trade, that many such highly skilled and intelligent people chose their path, in part or in whole, because of being "downsized" or "restructured" at their previous place of employment.

My friend "Dave" is a good example. A pattern maker for 20 years in a small business that made prototype engines, Dave was not given the reasons for his "downsizing." But it can be noted that someone fresh out of college does not

> **"Just as I feel it is wrong to hand a schoolchild a calculator until he or she can do math in their head, I also feel it is wrong to hand an astronomy novice a computerized mount until they know how to find objects on their own."**

command the same salary level as a worker with Dave's seniority. Dave tells me that many of the recently hired machinists and pattern makers have excellent training in handling the new computerized lathes, and can move about in computer-aided design software like a Russian ballet dancer. But take away their computers and ask the same people to calculate something in their head or on the fly, and many become totally lost. Imagine an accountant who cannot do math without a calculator or computer.

The same attitude is becoming commonplace. I recently telephoned a company in Hamilton to check some records from 1965. The young clerk on the phone told me that records from "that far back" are not on the computer, and — this is an exact quote — "I'll have to get you the manager, because he is the only one here who knows how to look things up in a book." Such experiences make me realize that "Monty Python's Flying Circus" is no longer as funny as it used to be when I was a teenager. The real world is now more humorous.

I fear that a similar attitude is behind one of the growing trends in astronomy, namely the proliferation of computerized mounts aimed at the beginner. Just as I feel it is wrong to hand a schoolchild a calculator until he or she can do math in their head, I also feel it is wrong to hand astronomy novices computerized mounts until they know how to find objects on their own.

I must admit some bias in the matter, since I utterly detest computers. I have five myself, and have been using them since before the VIC–20, yet I still detest them. The main reason is because of the way people use them. For instance, a few months ago intravenous pumps in a Montreal hospital were tested for Y2K compatibility. About 50% of them failed and needed upgrading. The true problem, as it turned out, was that less than 20% of the nurses in the hospital knew how to operate a manual intravenous drip.

There are other examples, but the point is that people misuse computers. Instead of being used to augment skills, they are being used to replace them.

I still recall the first discussions on the Internet concerning the use of digital setting circles versus the traditional techniques of "manual" setting circles and star-hopping. It seemed to me then that those opposed to the new technologies were similar to those who objected to the introduction of indoor plumbing. Now that I am older, however, I can see the wisdom of my elders. Like a fine bottle of wine, some things are meant for enjoyment over time. Computers, on the other hand, represent the epitome of a society interested in instant gratification.

There is one specific area where I find computerized mounts to be detrimental, and that is in the loss of quiet time while observing. Next time you observe with a group of people, whether it is a major star party or a local group, take time to note how quiet it is. Activity normally takes place all night, sometimes until dawn. People talk and telescope drives whir, yet there is an overall sense of silence at a star party. Very few people ever listen to music, and even those who do listen to something soft – classical, new age, or Celtic revival, *etc*. When is the last time you encountered someone at a star party with a boom box cranking out the latest rap or dance tune at full volume? One of the primary attractions of astronomy is its quiet nature.

Our lives are surrounded at all levels by noise and rushing about. And yet people who share an interest in amateur astronomy, despite their different philosophies, interests, and personalities, all share a quiet love for the skies in one form or another. With computerized mounts, however, the skies no longer offer refuge from a wearing lifestyle. Instead, we become part of the giant rat race ruled by the computer. How long will it be before telescope computers become like home computers, outdated within six months and obsolete within two years? The stars may never change, but if you do not have the latest bug fixes and software updates, that 675× 60-mm refractor may not stay on target so you can view that wonderful fuzzy ball of mush in the eyepiece that is supposed to be Jupiter.

"My fear is that the availability of computerized mounts for novices will make them so tied to the technology that they lose sight of the beauty of astronomy."

Gone is the quiet evening with an old pair of binoculars. Now one can waste most of an evening setting up a computer and opening its software, checking that the reboot switch is illuminated for use in the middle of the night. It may not be quite that bad at the moment, yet I still wonder how long it will be before the debate begins on the advantages of installing *Windows, MacOS*, or *Linux* as one's operating system.

I should not complain too much about the inevitable. Recently a video game company released a new 128-bit game system, and first-day sales were estimated at over US $20 million. Conversely, if NASA spends the same amount on a space vehicle, activists will point out how the funds would be better spent on social programs. There is a part of our society that accepts the concept of dollars spent on computers, but rebels at the concept of spending the same amount in other areas. I am the treasurer of a local community health centre funded by the provincial government. If one of its baby scales breaks, it can take up to six months to secure funding for a replacement. If funds are needed to repair the same scales or other medical equipment because of a Y2K compatibility problem, however, the funding comes immediately, and without question.

In view of the rapid rate at which computers become obsolete and how willing individuals and large organizations seem to be to spend endless resources on upgrading computers, I wonder if the move to computerize novice telescopes is a long-term marketing strategy. Once the idea gets across to purchasers of new telescopes that a computer and mount go hand in hand, they will be hooked for life. The same concept is used for new cameras aimed at entry-level photographers, which have auto "do-all-your-thinking for you." Once people become used to a new technology, they become dependent upon it, as well as an endless stream of "improvements."

My fear is that the availability of computerized mounts for novices will make them so tied to the technology that they lose sight of the beauty of astronomy. I have an old laptop computer, and I have used it in the field while observing. Take it away from me, however, and I can soldier on contentedly using either a $15 planisphere or, for that matter, memory. Fifty years from now, will a generation weaned on computerized mounts be able to do the same, or will our descendants view us with the same awe that we hold for the builders of the great pyramids?

A member of the London Centre of the RASC and regular contributor to the Journal, Joe O'Neil has been interested in astronomy since grade school. In his spare time he enjoys planetary and lunar observing from the light polluted skies of London, and black and white astrophotography from the family farm near Granton, Ontario, about five kilometres due north of Western's Elginfield Observatory.

News Notes
En Manchettes

POOR GALAXY CLUSTERS FALL IN LINE

Like a herd of obedient animals, the overall orientation of richly populated clusters of galaxies usually follows that of its most dominant member. Invariably a huge elliptical galaxy sits in the centre of such clusters, and if its long axis points north, so do the long axes of galaxies in the rest of the cluster. Todd Fuller, University of Western Ontario, Michael West, University of Hawaii (on leave from Saint Mary's University), and Terry Bridges, Cambridge University, have recently found that even the more poorly populated clusters of galaxies appear to follow such a pattern.

Fuller obtained a series of CCD images of sparsely populated galaxy clusters in April 1994 using the 1.0–m Jacobus Kapteyn Telescope of the Observatorio del Roque de Los Muchachos on La Palma in the Canary Islands. A computer routine was then employed to determine the orientation of the central galaxy and those of galaxies in the surrounding cluster (July 1 issue of the *Astrophysical Journal*), leading to the result described above. The team has also speculated about the mechanism behind such grand alignments. They argue that the cluster might have formed from the infall of matter from huge elongated filaments of gas. The original orientation of the filament would then dictate the final orientation of the major axes of galaxies in the resulting cluster. Computer simulations of the formation of galaxy clusters appear to support their claims.

BEIGE DWARFS AND DARK MATTER

A new kind of object has been proposed to help explain one of the biggest mysteries of the cosmos — the identification of dark matter around galaxies. Nicknamed beige dwarfs, the proposed objects would be more massive than typical brown dwarfs, tipping the scales at between 0.1 and 0.3 solar masses. Our current understanding of stellar evolution suggests that normal objects more massive than about 0.08 solar masses should have undergone hydrogen fusion in their cores and would therefore be classified as common stars. Because of their unusual construction, however, beige dwarfs could exceed such a mass limit while still lacking a hydrogen furnace.

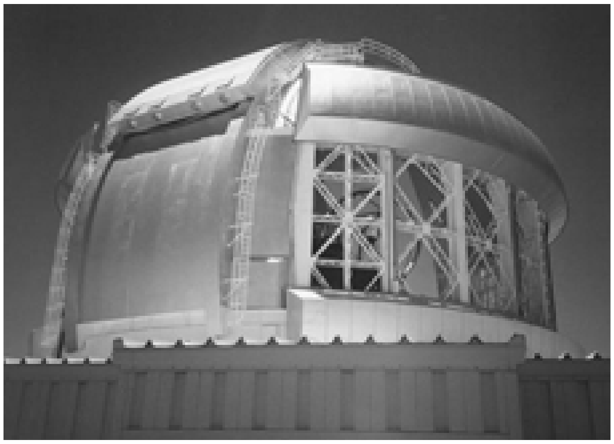
Such diminutive objects were first postulated by Paolo Lenzuni, David Chernoff, and Edwin Salpeter (*Astrophysical Journal*, July 1, 1992). Their plan requires three special conditions. First, a brown dwarf would need to receive a very slow influx of gas, between about one billionth to one hundred billionth of a solar mass per year. Secondly, the infalling gas would have to be metal free (*i.e.* consisting only of hydrogen and helium). That ensures that the outer atmosphere is transparent and thus promotes cooling. Metal free gas would be possible only in the very early universe, since subsequent supernovae have "polluted" the intergalactic medium with heavier elements. Finally, the infalling gas must have very small entropy, meaning it would impart very little heat to the growing brown dwarf. So far, beige dwarfs remain purely theoretical and have yet to be observed directly.

Brad Hansen of the Canadian Institute for Theoretical Astrophysics (CITA) has now proposed that such objects may account for some of the "missing mass" surrounding galaxies (May 20 issue of the *Astrophysical Journal Letters*). The "missing mass" or "dark matter" problem has perplexed astrophysicists for years. From the study of the gravitational behaviour of individual galaxies and clusters of galaxies, it has become increasingly obvious that as much as 90 percent of the matter in the universe is dark and unidentified. One possible candidate may be a halo of dim stellar objects or invisible non-stellar objects surrounding each galaxy. Invisible brown dwarfs or faint white dwarf stars have traditionally been the most likely candidates, and collectively have been given the moniker MACHOs for MAssive Compact Halo Objects. The acronym was devised in reaction to a competing notion that the dark matter might consist of a postulated subatomic particle called a WIMP — a Weakly Interacting Massive Particle.

Hansen shows that gravitational microlensing events produced by possible MACHOs in the Large Magellanic Cloud may be caused by beige dwarfs (Alcock *et al.* and Auboug *et al.* 1993, *Nature* 365, page 621 and 623). Microlensing is the sudden brightening of a background star by the gravitational focusing of an object passing directly between the observer and the star. Light curves observed for such events suggest that the lensing objects may be more massive than brown dwarfs. The most popular candidates are common white dwarf stars, but Hansen argues that hypothetical beige dwarfs could also fit the bill. Hanson has also developed an evolutionary model that demonstrates the likelihood of beige dwarf formation during the early epochs of our universe. His calculations suggest that they could exist in large numbers, although the proof will be in finding one.

CANADA-FRANCE-HAWAII TELESCOPE WELCOMES NEW NEIGHBOUR

A giant new telescope, the first of a pair known as Gemini, was opened on June 25th on the summit of Mauna Kea on the Big Island of Hawaii. With an 8.2 metre diameter primary mirror, the Gemini North Telescope is considerably larger than the Canada-France-Hawaii telescope, sharing the summit with it and with many other telescopes. Both telescopes handily beat the Hubble Space Telescope's (HST) 2.4 metre diameter, but the HST has had



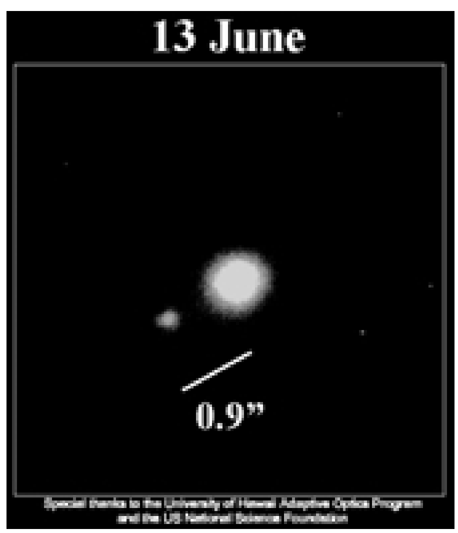
The Gemini dome with its sides open to permit smoother flow of air and thus less turbulence

the upper hand in resolving power because it is above the distorting effects of the atmosphere. New technologies, however, mean that ground-based large telescopes can be more than light-buckets. The 4200 metre altitude of the summit location of Mauna Kea puts the telescopes above 40% of the atmosphere, and usually well above clouds and much of the lower atmosphere's water vapour, which absorbs infrared light.

The observatory dome, built by Coast Steel of British Columbia, has sides that may be opened to permit smoother flow of air and thus less turbulence. The support structure for the thin (20 cm thick) main mirror can slightly deform it to cope with gravity and wind deformations. But the biggest improvement in effective optical quality comes from stages of adaptive optics. The secondary mirror can be tilted slightly up to 100 times per second to remove the effects of atmospherically induced twinkling of stars.

Nearer the imaging end of the telescope, an even faster adaptive optics system uses a deformable mirror to actively correct the image to the theoretically best possible resolution, the diffraction limit. The system used in testing the telescope was the University of Hawaii Hokupa'a (North Star) imager, similar to the CFHT Adaptive Optics Bonnette described in the August edition (JRASC, 93, p. 168). A new system called Altair is being built at the Herzberg Institute of Astrophysics in Victoria by the National Research Council. The Hokupa'a imager has already yielded resolutions of 0.08 arcsecond and better, enough to handily split Pluto and its moon Charon in test images. The adaptive optics system works best at infrared (IR) wavelengths, which are longer in wavelength than visible light. Use of IR imaging is particularly important in the study of relatively cool objects, and in many cases allows one to see into regions obscured by dust at visible wavelengths.

The Gemini North telescope has now been dismantled from its test form, and will be reassembled late in 1999. Regular observing will commence in summer 2000, with Canadians getting a share of time reflecting Canada's 14% contribution to the US$176 million project. Canadian Jean-René Roy, Chairman of the Gemini Board, expressed satisfaction after the opening ceremony that the project had been on budget and on schedule. It augurs well for the other "twin" of Gemini, an identical 8.2 metre telescope being built on Cerro Pachon in Chile.



An image of Pluto and its moon Charon taken with the Gemini telescope and the University of Hawaii's Hokupa'a adaptive optics system.

ASTEROIDS WITH CANADIAN CONNECTIONS

(3666) HOLMAN = 1979 HP

Discovered 1979 April 19 by J. C. Muzzio at Cerro Tololo. Named in honour of Matthew J. Holman (b. 1967), astronomer in the planetary sciences division at the Harvard-Smithsonian Center for Astrophysics. He is particularly known for his long-term investigations on the stability of the outer solar system by means of the symplectic integrator he co-developed, and he has studied the stability of planets around other stars. Recently, he has also become an active observer of centaurs and transneptunian objects.

(7638) GLADMAN = 1984 UX

Discovered 1984 October 26 by E. Bowell at the Anderson Mesa Station of the Lowell Observatory. Named in honour of Brett Gladman (b. 1966), a Canadian astronomer and dynamicist who has made important contributions to modelling the dynamical evolution of near-Earth objects and the transport of meteorites, including those from the Moon and Mars. Gladman has also carried out observational surveys of transneptunian objects, and in 1997 was co-discoverer of the two irregular satellites of Uranus. Name proposed and citation written by P. Farinella.

(9631) HUBERTREEVES = 1993 SL6

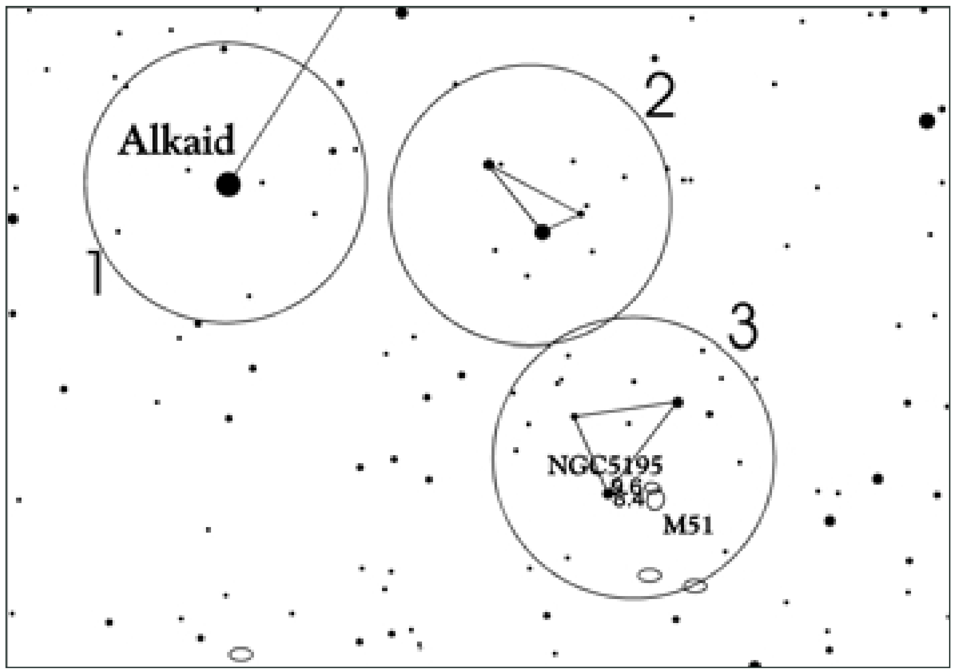
Discovered 1993 September 17 by E. W. Elst at the European Southern Observatory. Hubert Reeves, a professional astronomer at the French CNRS, has become known world wide for his popularization of astronomy through his many books and lectures on radio and television.

A Star Hopping Primer[1]

by Paul Markov, Toronto Centre (pmarkov@ica.net)

Star hopping is a method used by amateur astronomers to locate objects in the heavens. Star hopping is typically used for finding deep-sky objects, although it is just as effective for tracking down asteroids, comets, variable stars, and anything else in the sky that is too faint to be seen readily by the unaided eye or in a finder scope. For all owners of LX200s and other computerized telescopes, put down your keypad and turn off your digital setting circles. Star hopping is the best way to familiarize oneself with the sky.

Star hopping involves "hopping" from star to star with your telescope, until you arrive at the location of the target object. Your starting point and end point are crucial to determining your "hopping path," and not unlike a car trip across a city, there are many paths that could be followed. Although one wants to take the shortest and simplest path, there are times when that approach is not possible owing to a lack of reasonably bright stars to follow. That may come as a surprise, but there are many areas of the sky that are devoid of sufficiently bright stars (tenth magnitude or brighter) when looking through a small telescopic field of view. If there are not enough stars to guide one to the target, it is very easy to get disoriented and "lose one's place" in the sky. The opposite is also true; if there are too many stars, it can get very confusing because it is difficult to create easily recognizable star patterns. A perfect example is the Milky Way area between Deneb and Albireo in Cygnus, where several dozen stars are visible within a small telescopic field of view. If a simple path is not readily evident, one will have to take "the scenic route" to arrive at the object of interest. That may take longer and involve more steps, but it is a good tradeoff if one can be assured of finding the object.



To star hop to M51, the Whirlpool Galaxy, you might begin at Alkaid (the star at the end of the Big Dipper's handle) in field 1, then hop west to the small triangle at field 2, and then find the triangle in field 3 by moving at right angles to the shortest segment of the 1st triangle. M51 is then found adjacent to the brighter two stars of the 2nd triangle. (ECU Chart by Dave Lane)

In the sections below I describe the basic equipment required for star hopping, as well as a few tips and hints that should make searches easier.

Star Atlases: The More Stars, the Merrier

A good star atlas must show enough faint stars to be useful for a star-hopping trek. I recommend, as a minimum, *Sky Atlas 2000.0*. The latest edition of the atlas shows stars to magnitude 8.5 (a total of 81,312 stars), and its oversized (9″× 22″) pages often show entire constellations on one chart, making it easier to relate what is seen on paper to what is in the sky. I highly recommend the desk edition, which shows black stars on white paper. The field edition shows white stars on black paper and is actually much more difficult to use in the dark with a red flashlight. Furthermore, the desk edition allows the possibility of writing small notes, adding objects, or plotting comet positions, because the paper is white. One last suggestion: use a pencil (or a thin permanent marker if your atlas is

[1] Article appeared originally in *Scope*, the newsletter of the Toronto Centre, Volume 38, Number 4, 1999, August.

already laminated) to add the basic constellation lines to the maps. For example, "connect the dots" in Ursa Major to form the Big Dipper, connect the stars in Sagittarius to form the "teapot," and connect the stars in Orion to form the hunter's body. That should be a great help in allowing one to find one's way quickly around a map, and ultimately the sky. If the main objective is deep sky observing, the sky atlas should also include as many deep sky objects as possible. *Sky Atlas 2000.0* is a good intermediate atlas in that regard, displaying over 2,500 deep sky objects.

The next best atlas is *Uranometria 2000.0*. Once one graduates from the Messier list and the brighter NGC objects, the *Uranometria* is essential, because many faint deep sky objects are not plotted in *Sky Atlas 2000.0*. Uranometria comes in two thick volumes that display stars to magnitude 9.5 (for a total of 332,000 stars) and a total of 10,300 deep sky objects. Because each chart is just 9″ × 12″, only a small portion of the sky is plotted on one page, so it is useful to use the atlas in conjunction with a larger scale atlas, such as *Sky Atlas 2000.0*.

The ultimate star atlas is the recently published *Millennium Star Atlas*. This three-volume modern work of art includes stars as faint as magnitude 11 (for a total of 1,058,000 stars), and contains over 10,000 deep sky objects. As is the case for *Uranometria*, it is necessary to use a larger scale atlas together with *Millennium* because each 9″ × 13″ chart displays only a very small part of the sky. The main drawback to *Millennium* is its Canadian price tag of $400.

Finder Scopes: The Bigger the Better

A good finder scope with a wide field of view is very important for star hopping. The absolute minimum is a 6×30 finder. An 8×50 finder is much better, and 9×60s are the best. A finder with a field of view of five to seven degrees allows one to zoom into the correct area of the sky quickly by showing many faint stars at once. There will be instances when one is able to use a star atlas and a finder scope to aim one's telescope precisely. Then, just by looking through the main telescope, one will be able to see the target object in the field of view. Many people like using zero-power finders, such as the Telrad, Rigel QuikFinder, or Tele Vue QwikPoint. Although they are extremely useful for aiming a telescope at objects visible to the unaided eye, they are not effective tools for viewing the fainter stars that guide one on a star hop. For the best of both worlds, I highly recommend using both a zero-power finder and an 8×50 (or larger) finder scope.

Wide-Field Eyepieces: Low Power for More Stars

The next tip for successful star hopping is to use an eyepiece that provides the widest possible field of view. The wider one's field of view, the more guide stars one is able to see through the telescope, which in turn makes it easier to hop from star to star. Never star hop at high magnifications since it will only frustrate you. It is best to switch to high power only when one arrives at the target location and is ready to begin small sweeps of the area of interest.

Field of View: How Large is Yours?

An excellent star-hopping aid that one can make at home is an acetate overlay displaying the fields of view for each eyepiece in one's collection as well as that for the finder scope. They can be extremely useful in those instances where there are not enough bright stars available for star hopping. The way to use an acetate overlay is as follows: place the overlay that matches the eyepiece field of view on the sky atlas, then move the acetate towards the target object and count how many fields of view are required to get there. Next, go to the telescope and move it across just as many fields of view as counted. That will put you fairly close to the target area. Now gently sweep back and forth until you spot the target object.

To make such an overlay it is necessary to know the exact field of view of each eyepiece. A quick method for determining that is to aim the telescope at a known part of the sky, then compare what is seen in the eyepiece with what is visible on a star map. Next, use the map's declination markings (shown in degrees) to calculate how much of the sky is seen with the eyepiece. Another method requires two pieces of data: the eyepiece's apparent field of view and its magnification with a given telescope. Here is an example. Suppose you have a 25-mm eyepiece that has a 50-degree apparent field of view, and your telescope is an 8-inch f/10 Schmidt-Cassegrain telescope with a focal length of 2000 mm. The magnification of the eyepiece for that specific telescope is given by the ratio of the focal length of the telescope to the focal length of the eyepiece, *i.e.* 80 (2000 mm ÷ 25 mm). Next take the eyepiece's apparent field of view and divide by the magnification, which gives the actual field of view, in this case 0°.625 (50° ÷ 80). If you do not know the apparent field of view of your eyepieces, check the ads in astronomy magazines for the same eyepiece, since they often state the value, or check with a telescope dealer, or visit the eyepiece manufacturer's web site.

The most accurate method for determining an eyepiece's field of view is to time how long it takes a star to cross the field of view. Start by aiming the telescope at any star that is within 10 degrees of the celestial equator. Place the star at the edge of the field of view, then turn off the telescope drive (if you have one) and use a stopwatch to time how long it takes for the star to cross the entire field of view. To calculate the field of view, multiply the time (in seconds) by 15 to obtain the field dimension in arcseconds. For wider field eyepieces, multiply the time in minutes by 15 to obtain the field dimension in arcminutes. The calculations are derived from the fact that a star near the celestial equator moves one degree every four minutes.

With knowledge of the fields of view of one's eyepieces, the overlays can be created by simply drawing circles of the corresponding sizes on an overhead projector acetate using a permanent marker. If the equipment is available, you

"Star hopping involves "hopping" from star to star with your telescope, until you arrive at the location of the target object."

can use a computer and a laser printer to print circles right on the acetate. Note that a different overlay is needed for each sky atlas, since the charts have different scales. [The ability to make such overlays is another advantage to using the desk edition of the *Sky Atlas 2000.0*; with the field edition you can make holes of the right size in a piece of cardboard, but it is more awkward to use.]

Inverted and Reversed Images: Weren't We Supposed to Turn Left at Epsilon Eridani?

Depending upon what type of telescope one has and the accessories used with it, what is seen through the eyepiece is generally an image that is inverted (upside-down), or inverted and reversed (mirrored). Most of us are aware of the confusion that can lead to! As a rule of thumb, keep in mind that an even number of reflections result in an inverted image (*e.g.* a Newtonian telescope where the primary and secondary mirrors result in two reflections). An odd number of reflections result in an inverted and reversed image (*e.g.* a Schmidt-Cassegrain telescope where the primary, secondary, and star diagonal mirrors result in three reflections, or a refractor with a star diagonal, since that amounts to one reflection).

Inverted views in the telescope are easy to cope with — simply turn the sky atlas upside down to match what is seen in the eyepiece. There is unfortunately no easy solution for reversed images. It is possible to train yourself to always remember that whatever is seen on a star map is reversed in the eyepiece. It is not too difficult to master, but if similar star patterns are evident on either side of the target object, things can get very confusing and it is possible to star hop in the wrong direction. Another solution is to flip the sky chart and to illuminate it from behind using a light. That works only if the paper is not too thick and if the map is printed only on one side, such as in *Sky Atlas 2000.0*. The trick will not work with *Uranometria* or *Millennium* since they have printing on both sides of each sheet. If a reversed view is causing serious troubles, temporarily remove the star diagonal from your Schmidt-Cassegrain or refracting telescope. Drawbacks to that solution are the need to extensively turn the focussing knob to reach focus, and possibly uncomfortable viewing caused by the eyepiece being in an awkward position.

Sky Directions: I Thought That Way Was West

Suppose you are looking for a galaxy that is just a couple of degrees north of a star you are viewing. You know you have to move your telescope north, but you just cannot figure out which way that is when looking through the eyepiece. Should the star in the field of view disappear towards the top or bottom of the eyepiece as you move your telescope towards the target galaxy? It depends upon many factors — telescope type, whether you are using a star diagonal, and the orientation of your eye. The method I use is to simply nudge the telescope tube up (i.e. north) without worrying about which way the stars move in the eyepiece. This works perfectly each time, assuming your telescope is equatorially mounted. If you are using an alt-azimuth mount, the method may still work depending on which part of the sky you are observing, but remember that will have to make a slight adjustment is azimuth. The same method will work for east or west movements. If your target is east of your current location, just move the telescope to the left, and if it is to the west, move your instrument to the right. Again, this assumes an equatorially mounted telescope, but it may still work with an alt-azimuth mount, depending on which part of the sky you are observing, by just making a small adjustment in altitude. I like the method because I find it easy to relate what I see in an atlas to the sky. For example, the globular cluster M15 is to the right of Epsilon Pegasi, as seen in a sky map. My star hopping path would be to start by aiming the telescope at Epsilon then slowly move my telescope right until I find M15.

Such a trick works just fine when one is facing east, south, or west, but what happens when one is facing north? In some instances it becomes more difficult to match the atlas directions to directions in the sky. If you are facing north and need to move the telescope to the west, you should still move it to the right. It will appear as if you are actually moving it towards the eastern horizon, but in fact you are moving it west. Another way to look at it is as follows. A motor driven telescope moves from east to west (left to right) no matter which way the telescope is pointing, so left is always east and right is always west. This may be a rather unorthodox methodology since most observing books and articles will teach you to always think in terms of east, west, north, and south. The method used here for determining which way to move the telescope (left, right, up, and down) has never failed me, however.

Although the method outlined above is primarily for equatorially mounted telescopes, there will be many instances where it will also be effective with an alt-azimuth mount. Remember that the required "slight adjustments" mentioned above will become increasingly large as you observe areas of the sky further away from the meridian/celestial equator. An excellent method for regaining your bearings if you are "lost in space" with your alt-azimuth mounted telescope is to nudge your telescope tube towards Polaris. New stars will enter the field from the north side of your field of view. You can also look through your telescope for a minute and note from which direction new stars enter the field of view. That will be east.

If you do not have an equatorial mount, there is no need to panic. Look through the eyepiece, and nudge the tube of the telescope towards Polaris. Stars will enter the field from the north side of the field of view. Next pause for a moment and take note of the direction from which additional stars enter the field. That will be east. Give either method a try, depending upon the type of telescope you have.

I hope all the above information will help with your star hopping adventures. If you have tips and hints of your own, I would like to hear from you via email at pmarkov@ica.net.

Paul Markov is a program manager with ATI Technologies Inc., a computer graphics card manufacturer. He joined the Toronto Centre in 1982 at age 15. Since then he has star hopped to over 740 deep-sky objects and catalogued the same number. He has also star hopped to over 100 Messier objects in each of two separate Messier Marathons. Readers can visit his home page at `http://home.ica.net/~pmarkov`.

Simple Pleasures:
Spellbound — A Story for Winter

by Fae Collins Mooney

"...the appearance of a ghostly apparition circling Capella overhead, its outer edge fluted and undulating. This tiny pie in the sky hugged and danced around its glittering captive, mesmerizing and enthralling the lone human looking skyward."

It was deep in a Yukon winter that it happened. I fell under its influence, victim of its spell. Brief hours of daylight. Nights of icy silence, endless and dark. That is when it casts its spell.

In a velvet black sky the stars, like brilliant sparks, flicker and flash throughout the long night. Phantoms of wispy light frolic and dance, play hide and seek, and cause a mere mortal to shiver — not just from the cold, but in awe.

From early evening through to a late dawn, a black eternity swallows whole that frozen land. But for this insignificant human (and romancer of her stars) dwelling in that land of ice and night, the naked-eye viewing was exceptional. No need to set the alarm for unearthly hours of the morning to enjoy a celestial performance. Romancing my stars happened each time I stepped outside.

An after-supper load of laundry hung out on the line to freeze-dry (not very romantic, but necessary) would afford me a glimpse skyward. Arrayed in all their icy splendour, the Big Dipper, and Cassiopeia, and that Great Square of Pegasus almost filling the western portion of the sky, were crisply defined in the blackness, their stars dazzling and sparkling with a clarity and intensity not experienced farther south.

A dash to the neighbour's, and a lingering glance at heaven's gems: golden Capella glittering high above me. Vega and Deneb, those silver stars of summer suspended above the mountains to the north, reminding me that winter would not last forever, sparkled like crystal. And yellow-white Polaris, twinkling almost directly overhead, revealed just how far north I really was.

Too cold to stay out for long, I took advantage of such brief (and frigid) interludes to enjoy the panorama above me.

One night, still vivid in my memory, the aurora stole the show: the appearance of a ghostly apparition circling Capella overhead, its outer edge fluted and undulating. This tiny pie in the sky hugged and danced around its glittering captive, mesmerizing and enthralling the lone human looking skyward. Across the sky, shimmering curtains of celestial light waved and fluttered, and as quickly as they appeared they changed, transformed, fanned, and then, like a ribbon, unfurled across the black expanse, stretching off to the east and to the west. Then directly overhead a rayed arc metamorphosed into a brilliant bow — the northern sky thus gift-wrapped for my upturned eyes to behold.

Through a long and dark Yukon winter I beheld a glittering world. Stars, like crystals of ice, sparkled on a flawless velvety veil of pure black where ghostly lights danced to unheard music.

Deep in a Yukon winter the Spell was cast. If you leave the North, as I did, it haunts you, calls and beckons you to return. I could not resist that call. I had to return. And I did, at the beginning of a winter's embrace. Here, in northern British Columbia, at the fringe of its influence, the Spell holds me captive still. Our winters are not quite so long, nor our nights. But the sky is equally as black, the star-studded constellations as crisply defined. Here, too, a dazzling procession stretches across the sky in pursuit of the Sun — winter's spell-binders.

Against the inky blackness, my favourite of all the glittering stars of winter, Capella in Auriga, glows warm golden-yellow directly overhead. Rising in the east, blue-white Regulus, a brilliant spark at the base of the backwards question mark (better known as Leo's head), follows the Gemini twins, Castor and Pollux, in their westward journey. Below them, Procyon in Canis Minor glitters brilliant yellow-white. South and west of it, the brightest star in our night sky and near neighbour in space, diamond-bright Sirius in Canis Major, flashes all the colours of the rainbow.

Westward, between Sirius and Capella, my eyes seek out bloated Betelgeuse, fiery red armpit of the mighty hunter Orion, his belt and sword studded with gems, and blue-white Rigel sparkling at his foot. Above and to the northwest is Aldebaran, bloodshot orange eye of Taurus the bull. Close by resides that precious cluster of blue-white stars, the Pleiades.

These countless sparks of light on a clear black winter's night romance me, and I think I faintly hear, echoing softly, Aurora's serenade.

Through the long dark nights of a northern winter I remain bound by that Spell cast so many years ago, my sight — and my very soul — filled with the images of shimmering, vapourous phantoms and sparkling points of light trembling in icy suspension. I am become as one with them, wrapped in that swaddling black veil of a northern winter's night.

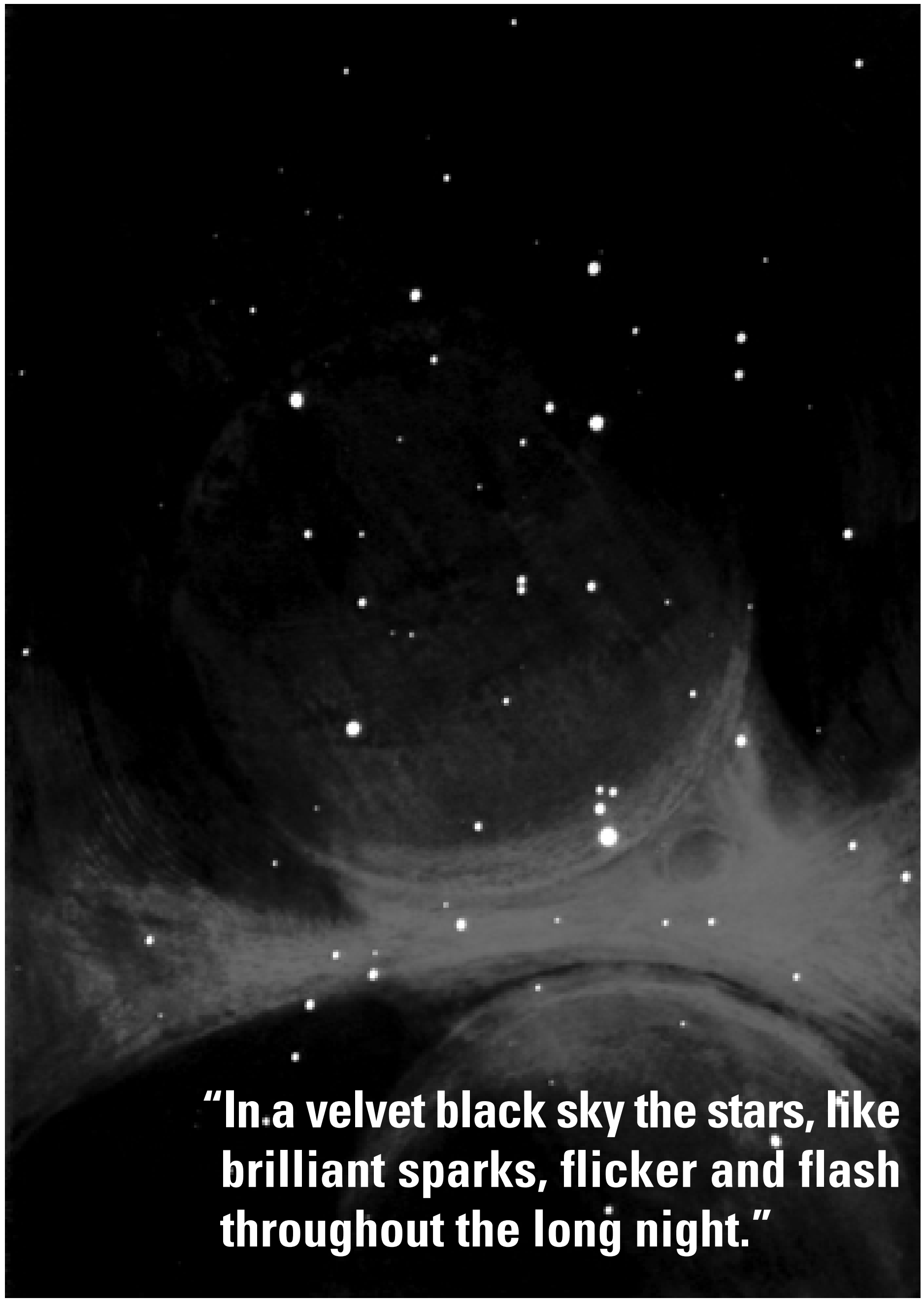


Illustration by Brian G Segal

Unattached member Fae Collins Mooney sometimes forgets what a clear night sky looks like from her home in cloud-shrouded northwestern British Columbia. But she believes in miracles and occasionally they occur, when the pewter-gray overcast dissipates to reveal the star-studded splendor of a northern winter night sky.

Edwin P. Hubble and the Extragalactic Nebulae

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

If you step outdoors tonight and look up, about halfway between the Great Square of Pegasus and the familiar "W" of Cassiopeia, you should be able to spot the Moon-sized fuzzy patch that is the Andromeda Galaxy. (Unfortunately, in the city you might have to use binoculars.) If you succeed, congratulate yourself on having spotted the most distant object that is clearly visible using the unaided eye. At a distance of 2.3 million light years, it is so far away that the nebular light that your eyes capture tonight was emitted in its host galaxy before civilization began, before fire was tamed, even before our species *Homo sapiens* existed.

In the 1999 *RASC Observer's Calendar*, the historical note dated December 30 highlights Edwin Hubble's announcement of the discovery of Cepheid variable stars in the Andromeda Galaxy and other spiral nebulae (as they were known at the time). Although astronomers could pick out individual stars in these fuzzy nebulae, there was a spirited debate over whether the nebulae were inside our Galaxy or beyond. At first thought, Hubble's discovery of Cepheid variables in the nebulae does not seem all that remarkable. In view of the period-luminosity relationship of Cepheid variables, however, the simple observation of these standard celestial beacons (with their implied cosmic yardstick) provided the first reasonable estimate of the distance to the nebulae. In writing the *Observer's Calendar* entry on Hubble, I would have been tempted to add "thereby giving birth to modern cosmology," since Hubble's announcement 75 years ago proved once and for all that the spiral nebulae are themselves distinct galaxies of stars well outside our own Milky Way galaxy. Overnight, our grasp of the scope of the universe expanded from tens of thousands of light years out to millions of light years, and Hubble resolved the long-standing debate among astronomers over the distances to the galaxies.

Edwin P. Hubble (1889–1953)

Hubble did not rest on his laurels. Vesto Slipher had already established that the spectra of almost all galaxies are red-shifted, indicating that they are receding from us at high speed. Five years later, Hubble dropped another observational bombshell: the speed of an individual galaxy's recession is proportional to its distance, a relation known as Hubble's law. In other words, the entire universe is expanding — although Hubble himself had some difficulty accepting it at first. (If you have trouble imagining the concept, think about blowing up a polka-dotted party balloon: as the balloon inflates, all the dots move away from each other, with no dot in particular marking the "centre" of the expansion.)

Edwin Powell Hubble was born in Missouri in 1889. His family moved to Wheaton, Illinois (a suburb of Chicago), in 1898, where he attended high school. (Fellow celebrity alumni from Hubble's high school include radio astronomer Grote Reber, journalist Bob Woodward, and the Belushi brother actors, John and Jim. Grote Reber's mother taught Hubble in Grades 7 and 8.) Hubble did not exhibit academic genius in his early life. Rather, he excelled at sports. He set a State high jump record, played university basketball, and took up boxing. He was even offered a bout with Jack Johnson, the heavyweight champion of the world! His first degree was in mathematics and astronomy, but his mix of talents earned him a Rhodes scholarship to Oxford University, where he studied law. When he returned home, he taught high school for a year, and practiced law, but then returned to Chicago University to study astronomy, obtaining his Ph.D. from Yerkes Observatory in 1917.

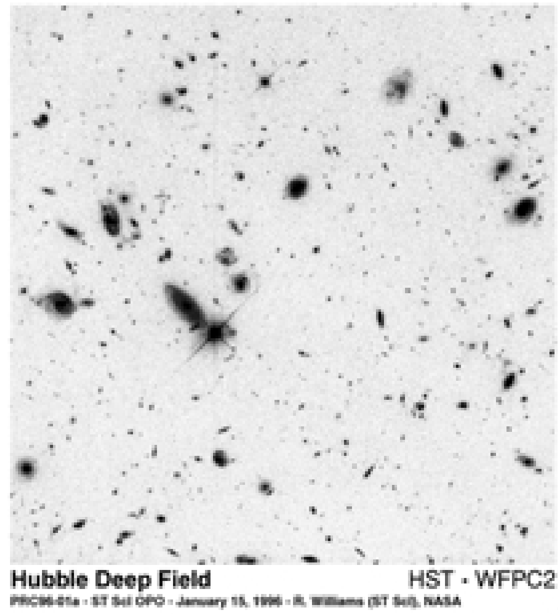
Apart from serving in both World Wars, Hubble spent the remainder of his career at Mt. Wilson Observatory. His first great discovery of the extragalactic nature of the spiral nebulae was made within his first five years there. Hubble also introduced a classification scheme for galaxies, something that was sorely needed at the time. His other research interests included the distribution of galaxies in space.

In an essay republished in Timothy Ferris's *The World Treasury of Physics, Astronomy, and Mathematics* (Little, Brown, and Company, Boston, 1991), the American cosmologist Allan Sandage provides some additional details about Hubble's universe-expanding announcement of 75 years ago — the December 30 date refers to the start date of the thirty-third meeting of the American Astronomical Society in Washington, D.C.; Hubble's paper was actually presented on New Year's Day, 1925. Hubble, only thirty-two at the time, did not present the paper himself. Presumably he was back home in Pasadena, California. Hubble's instrument of choice was the 100-inch Hooker reflector at Mt. Wilson Observatory, the world's largest telescope at the time, and the only one capable of capturing the feeble rays of Cepheids in their distant host galaxy. On the occasion of Hubble's centennial, Allan Sandage also published an appreciation of Hubble's work in JRASC, 83, No.6, December, 1989. The article can be found on the Internet at `antwrp.gsfc.nasa.gov/diamond_jubile/d_1996/sandage_hubble.html`.

Conventional modern cosmology accepts the hypothesis that the universe is expanding according to Hubble's law (although there are alternative theories). Hubble's initial estimate of the rate of expansion turned out to be a gross overestimate, which was of the order 500 kilometers per second of recession speed per megaparsec of cosmological distance. Subsequent re-analyses of Hubble's observations revealed that two distinctly different populations of Cepheid variable stars were involved, one population being significantly dimmer than the other. It also appeared that some non-stellar sources were included in the data. Since Hubble's initial revelation, the value of the Hubble constant has been successively revised downwards, the latest estimates being in the range 50–85 km s^{-1} Mpc^{-1}. This year, an international team led by Wendy Freedman, Jeremy Mould, and Robert Kennicutt announced a value of 70 km s^{-1} Mpc^{-1} with an uncertainty of 10%. It is particularly fitting that the data for the latest announcement was collected with the *Hubble Space Telescope*, which next April will have been operating for ten years.

To me, one of the most impressive images from the *Hubble Space Telescope* is the one in which every object is a galaxy except for a couple of foreground stars. In that tiny patch of sky, there are hundreds of galaxies just like our own, each containing hundreds of billions of stars. It is hard to believe that there is not at least one life-supporting planet circling a star in one of those galaxies. Perhaps on that planet, there are intelligent beings peering back at us through their own instruments.

One final thought: this is my last column before the chronometer turns over to 2000. What better time to adopt the ISO date standard yyyy-mm-dd than the first day of the last year of the millennium: 2000–01–01. Make it a New Year's resolution! For those of you still writing two-digit years, you only have one year left before it gets really confusing. Y2K ain't just about computers!



Galaxies outnumber stars in this deep-space image from the *Hubble Space Telescope.*

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

NIAGARA CENTRE ANNUAL BANQUET

The Niagara Centre of the RASC will be holding its Annual Banquet on Saturday, April 8th, 2000. For those interested in attending, it will be held at the top of the Skyline Brock Hotel in Niagara Falls, Ontario. Our speaker for the evening will be Ken Hewitt-White whose talk, "Skywatching as a Way of Life," will take us on a ride down the rocky road of freelance astronomy. The Niagara Centre banquet is held in conjunction each year with the NFCAAA (Niagara Frontier Council of Amateur Astronomical Associations). The evening will begin at 6:00 p.m., with a fine buffet dinner at 7:00 p.m. Ken's talk will start at approximately 8:30 p.m. Tickets are $45.00 and seating is limited to 100 people. Contact Joyce Sims by phone at (905) 262-5276 or by mail at Niagara Centre, RASC, P.O. Box 4040, St. Catharines, ON, L2R 7S3.

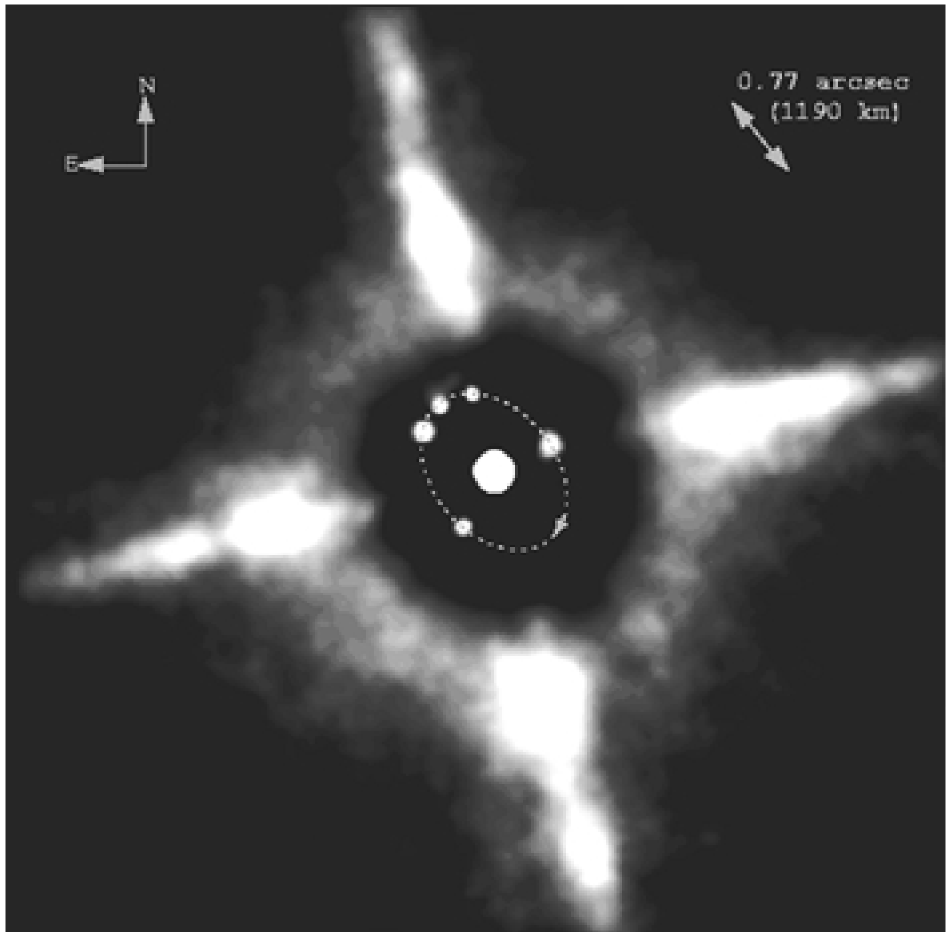
Moons of Asteroids

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

Satellites of asteroids are a curious phenomenon. Over the last decade, we have come to understand a lot more about the chaotic interactions between asteroids. They bang into each other, they attract each other gravitationally, and they are strongly influenced by the gravity of the planets. Moreover, it appears that at least some asteroids are simply piles of different-sized gravel, held together loosely by gravity. Such properties convinced some astronomers that asteroidal moons might be fairly common. The opposing view was that the frequent interactions between asteroids would rip away such moons, which are only loosely bound to their parent asteroids, which have escape velocities of just metres per second.

Most of the planets in our solar system have moons. For decades people searched the areas surrounding asteroids to see if they too have moons. One was detected about five years ago, when the *Galileo* satellite flew by the asteroid Ida on its way to Jupiter (see 27 April 1995 issue of *Nature*). The tiny moon was christened Dactyl. Now, Bill Merline of the Southwest Research Institute and his colleagues have found a second asteroidal satellite, orbiting Eugenia (see 7 October 1999 issue of *Nature*).

There have been many past reports of asteroidal moons that were based on anomalous light curves of asteroids or on the results of occultations. Merline's discovery is the first ground-based observation that seems solid. He used an adaptive optics system developed by François Roddier at the University of Hawaii, and installed on the Canada-France-Hawaii Telescope on Mauna Kea. The remarkable properties of that optics system allowed Merline to discover the moon the first time he looked at Eugenia, when it was over two astronomical units from the Earth. The separation between Eugenia and the moon was only 0.76 arcsecond at the time.



This infrared image is a composite of 5 detections of the new moon (taken — clockwise from top — on the nights of 1998 Nov 6, 7, 9, 10, and 1). The period of the orbit is 4.7 days and the moon travels in a clockwise direction in this view. The radius of the nearly circular orbit is about 1200 km (Image courtesy of Bill Merline, Southwest Research Institute).

Merline was able to track the moon as it orbited Eugenia with a period of about 4.7 days, thereby demonstrating conclusively that it is not a background source. Provided that the moon has a fairly standard albedo (the fraction of incident light that is reflected) for Eugenia's type of asteroid, Merline estimates that it has a diameter of about 13 kilometres. Seeing it at a distance of two astronomical units is comparable to seeing the Magic School Bus at the distance of the Moon. Eugenia's diameter was previously estimated to be about 215 kilometres.

Apart from showing that another asteroid does in fact have a moon, the observations allow Merline to estimate fairly accurately the density of Eugenia, which turns out to be about 1.2 g cm^{-3}, or only 20% more dense than water. At that density it may well be a rubble-pile asteroid, like the other (Mathilde) for which we have a good estimate density. It certainly is not solid rock, which has a bulk density of about 3.5 g cm^{-3}. Alternatively, it may be something like a burnt-out comet, and still contain a lot of water ice.

The origin of asteroidal moons remains unclear. They might be bits of ejecta retained from catastrophic collisions, which are the kind that break large asteroids into smaller pieces. Alternatively they might be made of accreted ejecta liberated from the surface by glancing collisions, at lower speeds. Whatever gives rise to such moons cannot be a common process. Out of 26 asteroids studied so far by Merline, only Eugenia shows clear evidence for a moon. Four close flybys of asteroids have revealed only one other moon, that orbiting Ida. The main limiting factor may well be how asteroids retain such moons, provided they are formed from collisional ejecta, since the escape velocities tend to be very low. But one message of this paper is clear: as we utilize adaptive optics to examine objects with higher spatial resolution, we will see many interesting new results.

A New Distance Scale for the Nearby Universe?

Regular readers of this column will remember that in the last issue I talked about the distance to the nearby galaxy NGC 4258, which had just been determined with unprecedented precision using simple geometric techniques. In that column, I hinted that there may be a discrepancy between the distance determined geometrically and that obtained using the variable stars known as Cepheids, which have long been one of the fundamental rungs on the "distance ladder."

The discrepancy has been confirmed (see 23 September issue of *Nature*). Eyal Maoz of the NASA-Ames Research Center, and many colleagues including Canadian astronomers Peter Stetson, Wendy Freedman, and Barry Madore, find that the Cepheid distance to NGC 4258 is 8.1 ±0.4 Mpc, while the geometric distance is 7.2 ±0.3 Mpc. Maoz suggests that there may be cause to re-examine the fundamental calibration of the Cepheid distance scale. If he chose to calibrate the Cepheids to the geometric distance to NGC 4258, that would increase the Hubble constant to 76 km s^{-1} Mpc^{-1}, and would decrease the age of the universe.

While the statistical significance of the difference may not seem that large, there are other indications that the Cepheid calibration may be in error. Using the massive amounts of data on variable stars resulting from the searches for gravitational microlensing, some groups have concluded that the traditional Cepheid distance to the Large Magellanic Cloud is in error (see a discussion of this by Bohdan Paczynski, also in the 23 September issue of *Nature*). The error is almost exactly the same amount as the difference between the Cepheid and geometric distances to NGC 4258. Just when cosmologists were starting to get comfortable with a Hubble constant of about 65 km s^{-1} Mpc^{-1}, it has gone up again.

A recalibration of the Cepheid distance scale would be such a major shift in astronomy that it must be approached with caution. But ultimately we learn more about the universe from conflicts between theory and observation than we do from concordance.

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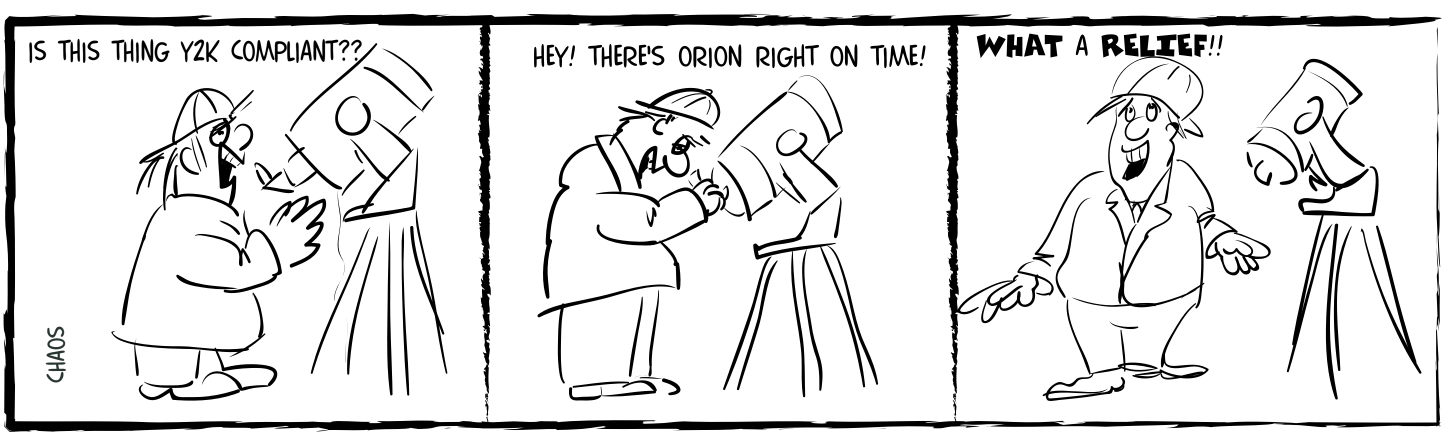
Another Side of Relativity…

Uncle Ernie puts Y2K compliance to the test!



CANADIAN ASTRONOMERS WHO EARNED THE PH.D. AT HARVARD IN THE SHAPLEY ERA

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Abstract. Before 1950 no Ph.D. degrees in astronomy had been awarded in Canada. Physics Professor C. A. Chant at the University of Toronto was the first, in 1905, to give an introductory course in astronomy for seniors majoring in mathematics or physics. Gradually he was able to introduce enough astronomy courses for a student to major in astronomy. A brief account is given of Chant's efforts to obtain a telescope for the university, for research purposes. That goal was finally accomplished in 1935 with a 74-inch telescope, the largest in Canada. But no courses leading to the Ph.D. were introduced until 1946, when Frank Hogg became the director of the David Dunlap Observatory. Until then students wishing to pursue courses leading to the Ph.D. looked to the U.S.A. for opportunities.

Harlow Shapley was the first at Harvard, early in the 1920s, to institute a graduate school program for Ph.D. candidates in astronomy. The assets at Harvard College Observatory were excellent. The famous Harvard plate collection of celestial photographs, begun in 1882, was the largest in the world, covering the sky from pole to pole, since Harvard had telescopes in both the northern and southern hemispheres. The plates contained materials suitable for research in numerous fields of astronomy, and the professional staff at Harvard included several experts in those fields.

During Shapley's tenure (1921–52), 50 Ph.D.s were awarded, including five to future Canadian professional astronomers, three men and two women: Frank Hogg, Helen Sawyer Hogg, Peter Millman, Shirley Patterson Jones, and Donald MacRae. Except for Mrs. Hogg, all had earned their bachelor degrees at the University of Toronto. Their publications, while they were graduate students at Harvard, and their subsequent careers are briefly described. All five were at some time employed at the University of Toronto's David Dunlap Observatory, and two, Frank Hogg and Donald MacRae, became director of the Observatory. Thanks in part to their Harvard experiences they were able to introduce into the University of Toronto curriculum several topics of investigation not previously tackled in Canada. As researchers and as college professors they contributed significantly to the advancement of education and research in astronomy.

Résumé. Avant 1950, aucun doctorat en astronomie n'avait été octroyé au Canada. En 1905, C. A. Chant, professeur de physique à l'université de Toronto a été le premier à donner un cours de base en astronomie aux étudiants séniors dans la concentration mathématiques ou physique. Peu à peu il est parvenu à présenter suffisamment de cours en astronomie pour permettre à un étudiant de se concentrer en astronomie. Un bref compte rendu est offert des efforts de Chant pour obtenir un télescope pour l'université, pour fins de recherches. Ces efforts ont été courronnés de succès en 1935, lors de l'acquisition d'un télescope de 74 pouces, le plus grand au Canada. Néanmoins, aucun programme de doctorat n'a été développé jusqu'en 1946, lorsque Frank Hogg fut nommé directeur de l'observatoire David Dunlap. Avant cette date, les étudiants désirant poursuivre des études visant le doctorat devaient tenter leurs chances aux États-Unis.

Au début des années 1920, Harlow Shapley a été le premier à Harvard à instituer un programme d'hautes études en astronomie visant la candidature au doctorat. Les ressources de l'observatoire de Harvard College étaient excellentes. La collection rénommée de plaques photographiques du ciel, dont l'accumulation commença en 1882, était la plus grande au monde, et couvrait le ciel d'un pole à l'autre étant donné que Harvard avait des télescopes dans les hémisphères nord et sud. Ces plaques contenaient des données permettant la recherche dans plusieurs domaines d'astronomie, et le personnel de l'observatoire comprenait plusieurs experts dans ces domaines.

Au cours des années où Shapley était directeur (1921–1952), cinquante doctorats ont été octroyés, y compris cinq à de futurs astronomes professionels canadiens — trois hommes et deux femmes : Frank Hogg, Helen Sawyer Hogg, Peter Millman, Shirley Patterson Jones, et Donald MacRae. A l'exception de Mme Hogg, tous ont obtenu leurs diplômes de baccalauréat à l'université de Toronto. Leurs publications lorsqu'ils étaient étudiants à Harvard, et leur carrière par après sont brièvement décrites. Durant une certaine période, tous les cinq ont été employés à l'observatoire David Dunlap, et deux d'entre eux, soit Frank Hogg et Donald MacRae, ont atteint le poste de directeur de l'observatoire. Grâce en partie à leur expérience à Harvard, ils ont pu introduire au curriculum de l'université de Toronto plusieurs sujets de recherche qui n'avaient pas encore été abordés au Canada. Comme chercheurs et comme professeurs, ils ont contribué grandement à l'avancement de l'instruction et de la recherche en astronomie. SEM

1. Introduction

Graduate degrees in astronomy were not awarded at Harvard University until Harlow Shapley became the Director of the Harvard College Observatory. During his incumbency from 1921 to 1952, fifty Ph.D. degrees in astronomy were awarded by Harvard University or Radcliffe College. Cecilia H. Payne from Britain was the first to fulfil the requirements. Since Harvard steadfastly refused to award any degrees to women, Radcliffe came to the rescue and awarded her a Ph.D. in 1925. The second under Shapley, but the first awarded by Harvard, was to a Canadian, Frank S. Hogg, in 1929. The third and fourth went to American women, Emma T. R. Williams in 1930, and Helen B. Sawyer Hogg in 1931. (In 1930 Miss Sawyer had married Frank Hogg, and soon after she obtained her degree both settled in Canada.) The following year, 1932, an American woman, Carol Anger, and a Canadian, Peter M. Millman, earned the degree. Through 1932, four women and two men therefore earned their Ph.D.s under Shapley. Thereafter the numbers of men rapidly exceeded the numbers of women. Of the 50 doctorates awarded during Shapley's directorship, 14 went to women. Two additional Canadians awarded the degree were F. Shirley Patterson in 1941 and Donald MacRae in 1943. All five Canadians became successful professional astronomers.

All four Canadian citizens who went to Harvard for their graduate studies in astronomy had undergraduate degrees from the University of Toronto. At Toronto, as early as 1890, C. A. Chant (1865–1956) had been a strong advocate for establishing an undergraduate program in astronomy. During the early years of the 20th century only one course in astronomy was offered, in the department of mathematics, and it was open only to seniors working for honours in mathematics or physics. Later Chant was influential in establishing an undergraduate curriculum in astronomy. But a program leading to a Ph.D. did not begin until 1947, under the chairmanship of Frank Hogg, and the first Ph.D. degree in astronomy at Toronto was not awarded until 1950 (Heard 1951). Prior to that, Canadian students wishing to pursue studies leading to the Ph.D. went to universities in the United States.

Chant taught at the University of Toronto from 1891 until his retirement in 1935 (Heard 1957a, 1957b). He had earned a Ph.D. in physics at Harvard in 1901, and it is likely that his experience there led to his recommending Harvard to some of his able students. It is remarkable that all four of the Toronto undergraduates who earned the Ph.D. at Harvard returned to Toronto to work in its newly established David Dunlap Observatory, erected in 1935, which Chant had struggled for almost 30 years to establish (Russell 1999). Jarrell (1997b) comments, "Until 1950, approximately 70 percent of all astronomers who trained and worked in Canada were graduated by Toronto." Nothcott (1957) mentioned that five of them later became directors of Canadian observatories, but she did not identify them. My compilation (Table I) indicates that two became directors of the Dominion Astrophysical Observatory (DAO), and three became directors of the David Dunlap Observatory. Chant's life has therefore been a model of dedication in making dreams for the advancement of astronomy in Canada come true.

Harvard was well equipped for programs leading to the Ph.D. degree. In 1934 Shapley reported the operation of 27 telescopes and cameras, ranging from 61-inch and 60-inch reflectors down to 1.5-inch lenses, in operation at Harvard's three stations: nine in Cambridge, ten at Oak Ridge (in the country on the outskirts of the small town, Harvard, some 24 miles from Cambridge), and eight at Bloemfontein, South Africa. Some of the work carried out with those instruments included both visual and photographic photometry, as well as studies of variable stars, star clusters, proper motions, spectral classification, spectrophotometry, radial velocities, gaseous nebulae, the Magellanic Clouds, distant galaxies, galactic structure, and sky patrol. The first catalogue of 386 meteor trails found, with a few exceptions, on plates exposed for other purposes was published in 1930 (Fisher & Olmsted 1931). A second catalogue brought the total number of meteor photographs through 1936 to 626 (Hoffleit 1937). Ample materials were therefore available at Harvard for theses in many fields of astronomy.

Astronomers available for instruction and thesis guidance initially included Shapley (on variable stars, galaxies, spectroscopic parallaxes, *etc.*), E. S. King (photometry, solar eclipses), S. Bailey (clusters), C. H. Payne (astrophysics), W. J. Fisher (meteors, lunar eclipses), W. J. Luyten (proper motions), and Leon Campbell (variable stars). Later astronomers on faculty included H. H. Plaskett (astrophysics), B. J. Bok (galactic structure), F. L. Whipple (comets, meteors, orbital computation for interplanetary objects), and E. Öpik (meteors).

Weekly colloquia were conducted at which staff, students, and many visiting astronomers gave talks followed by open discussion. Among the visiting speakers were Ejnar Hertzsprung from Leiden, A. E. Milne from Oxford, Otto Struve from Yerkes Observatory, B. P. Gerasimovic from Moscow, and Henry Norris Russell from Princeton. Russell had been Shapley's mentor at Princeton (Ph.D. 1913), and was a frequent visitor to Harvard. Russell not only gave inspiring lectures, but was able to make lively comments on whatever topics happened to arise. After 1932 (when a new building had been opened, roughly doubling available space), Shapley occasionally substituted hollow square conferences for some of the colloquia. Long narrow tables were arranged in a square configuration so that all attendees could see one another. Instead of one long lecture, numerous short topics were discussed: recent discoveries, new theories, astronomical meetings, promotions, *etc.* Anyone could present topics of current interest, or comment on what others were presenting. To sustain a relaxed, informal atmosphere throughout, tea and refreshments were served. The meetings were especially beneficial for students, since they were privileged to raise questions about their own research topics.

Shapley encouraged scholarship by the students, and also had their general welfare and happiness at heart. There were several social activities yearly, such as a Christmas party at the observatory residence, apple blossom picnics at the Oak Ridge observing station, and a Ping Pong table in the basement of the new building, where not only students but also faculty and staff competed with the students. Shapley became aware of special talents among staff and students. For the American Astronomical Society meeting in Cambridge in December 1929, the observatory presented "Observatory Pinafore," a parody on Gilbert and Sullivan, ironically portraying astronomy during the early years of the Pickering regime (1877–1819). The piece was written in 1879 by Winslow Upton, then on the staff of the observatory, but it had never been performed or published. Shapley discovered the text, and convinced staff and students to put on a very successful performance (Jones & Boyd 1971). Peter Millman and Helen Sawyer were among the actors. Later an "Observatory Philharmonic Orchestra" was inspired and conducted by Cecilia Payne-Gaposchkin (Haramundanis 1984). It gave several performances at the observatory, including Mozart's "Jupiter" symphony. All performers were observatory employees or students. At a memorial when Shapley would have reached age 100, one of his sons jokingly remarked that Shapley's own children felt somewhat neglected by the concern Shapley felt for the well-being of his large "adopted family" of students and staff!

In a chapter of the book celebrating the 100th anniversary of the founding of the American Astronomical Society (DeVorkin 1999), Jarrell states that Canadian astronomers formed "until relatively recently, a narrower range of disciplinary interests" than is the case for Americans. A comparison of the Annual Reports for the Dominion Observatory in Ottawa with those of Harvard, and those of the Dominion Astrophysical Observatory in Victoria (DAO) with Mount Wilson Observatory reports for 1922–1925 does indicate that Americans had a wider distribution of research interests (Table II). On the other hand, there are more American than Canadian astronomers included in the statistical sample. The ratio of the numbers of research areas to the numbers of astronomers is closely comparable for both nations. The corresponding numbers for 1935–1943 (from the dedication of the David Dunlap Observatory until WW II) indicate that there has been an increase in the number of research areas studied by Canadians, but not by Americans, despite a significant proliferation in the number of Americans involved. (Over the years some research areas got dropped, others added.) Is it possible that Canadians holding Harvard Ph.D. degrees were effective in introducing more research areas into Canada? Indeed, Frank and Helen Hogg and Peter Millman did add to the number of research areas being investigated in Canada, especially on star clusters and meteors, and Donald MacRae added more on instrumentation and the application of radio techniques to stellar astronomy.

2. Frank Scott Hogg (1904–1951), Ph.D. 1929

Frank Hogg graduated with honours from the University of Toronto in 1926. Since the University of Toronto did not have a Ph.D. program, Hogg chose Harvard for his graduate studies. His doctoral dissertation, "A Synopsis of Cometary Spectra" (Hogg 1929), was a pioneering effort to ascertain the reasons for discordance between authors regarding the composition and behaviour of comets. Descriptions of visual observations of cometary spectra, or uncalibrated photographic spectra, had become available beginning with the apparition of Comet Donati in 1864. They were at best crude data, but sufficiently numerous for errors to average out, and hopefully they give a fair representation for an average comet. Hogg found data for 94 comets represented by 830 observations discussed in 410 papers. He sought to find a relationship between the heliocentric distances of the comets and their spectral characteristics. His analysis led him to the conclusion that the heads of comets are composed largely of meteoritic stones.

While still at Harvard (1927–29), Frank Hogg collaborated with Cecilia Payne on six publications dealing with spectrophotometry and the interpretation of stellar spectra. Under his own name alone, he published nine articles dealing with such diverse subject matter as: spectrophotometry and its application to Class M stars; the brighter stars of the Pleiades; a new method for photometry of stellar surfaces with applications to the globular cluster M13; and even the spread of the radiant of three Leonid meteors found on a single plate in 1898 — indicating that not all Leonids are moving in strictly parallel paths.

In 1931 Hogg was appointed Astronomer at the Dominion Astrophysical Observatory. Subsequently, in 1935 he accepted a position as Lecturer at the University of Toronto. At Toronto he advanced successively to Assistant Professor, Associate Professor, and finally to Full Professor by 1946. That year R. K. Young retired as head of the Astronomy Department and as Director of the David Dunlap Observatory, and Frank Hogg became his successor.

After leaving Harvard, Hogg was author or co-author of 17 papers dealing with a diversity of subjects, including globular clusters, white dwarfs, navigation, and meteoritics. Such versatility is an asset to any Director of a large observatory or to a university professor guiding graduate students. In all, he was the author or co-author of some 30 technical articles. In addition, from 1937 through 1950 he was the Assistant Editor to C. A. Chant of the *Journal of the Royal Astronomical Society of Canada* and the RASC's *Observer's Handbook*, and for ten years he contributed a weekly feature, "With the Stars," in the Toronto Daily Star, a paper with a circulation of about 400,000. In 1941–42 he served as President of the Royal Astronomical Society of Canada.

In 1946 Hogg initiated a project to determine radial velocities for 1,041 late-type stars brighter than 9th magnitude for which radial velocities had not yet been determined, and lying in the zone +25° to +30°. That zone includes both the solar apex and the north galactic pole. The data were intended for studies of galactic structure. Later it was also considered important to acquire better spectral classes and more accurate magnitudes. Unfortunately, Hogg did not live to see the completion of his major project. It was completed and published by his successor, Director John F. Heard, in 1956 (Heard 1956).

As an illustration of Frank Hogg's sense of humour, there is a group photograph of the meeting of the American Association of Variable Star Observers (AAVSO) held in Toronto in June 1940. Frank Hogg appears at both the far left and the far right of the photograph (Campbell 1940), which was made with a panoramic camera. Hogg, noting when the camera had rotated away from the left toward the right, skipped behind the group to arrive at the right extremity just in time for his image to be recorded twice!

Obituaries for Frank Hogg published by Chant (1951) and Heard (1951) are both warm in their praises and sad in his passing.

Bibliography[1] of Frank S. Hogg while at Harvard.

1927.

Grating Measures of Effective Wave Length for Castor C, HB, 848, 34–36

On Methods in Stellar Spectrophotometry, HC, 301, 12pp. (C. H. Payne & Hogg)

A Spectrophotometric Study of the Brighter Pleiades I. The Line Intensities, HC, 303, 8pp. (C. H. Payne & Hogg)

A Comparison of Line-Intensities Derived from Slit and Objective Prism Spectra, HC, 304, 9pp. (C. H. Payne & Hogg)

Photometry of the Spectra of Mira Ceti at the Maximum of 1926–27, HC, 308, 9pp. (C. H. Payne & Hogg)

A Spectrophotometric Study of the Brighter Pleiades II. The Continuous Background, HC, 309, 14pp.

1928.

On the Use of a Standard Reduction Curve in Photometric Work, HB, 856, 7–11

The Spread Radiant of the Leonids of 1898, HB, 857, 6–11

Contours of Calcium Lines in Late Type Stars, HB, 859, 4–7

On the Pressures in the Atmospheres of Stars, HC, 334, 8pp. (C. H.

[1] Abbreviations for publications are identified at the end of the paper.

Payne & Hogg)
The Photometry of Unstandardized Slit Spectra, HC, 337, 9pp.
On Methods and Application Spectrophotometry, Proc. Nat. Acad. Sci., 14, 88–93; also HR, 43 (C. H. Payne & Hogg)
Spectrophotometry of Class M Stars, Pop. Astron., 36, 236–237

1929.
A Synopsis of Cometary Spectra, JRASC, 23, 55–89; also HR, 57,
A Synopsis of Cometary Spectra (Abstract), HB, 863, 1–2
A Method for the Photometry of Surfaces, with an Application to the Globular Cluster M13, HB, 870, 4–7

3. Helen Battles Sawyer Hogg (1905–1993), Ph.D. 1931

Helen Sawyer, a native of Lowell, Massachusetts, graduated *magna cum laude* from Mount Holyoke College in 1926. After having observed a total solar eclipse from Connecticut in 1925, she switched her major from chemistry to astronomy. When the famous woman astronomer, Annie J. Cannon, visited Mount Holyoke, she encouraged Helen to attend Harvard to do graduate work with Harlow Shapley. It was Shapley who guided her Ph.D. research in his own field of expertise, globular clusters. Helen completed her thesis, "Studies in Globular Clusters," in 1931. She was one of only a few astronomers who were able to continue their graduate school specialities throughout their professional careers. Helen's *Third Catalogue of Variable Stars in Globular Clusters Comprising 2119 Entries* (Hogg 1973) is a necessary bible for all workers in the field. Right up until the time of her decease she had been working on a fourth edition, which may eventually be updated and published by her younger colleagues.

Her publications through 1932 were based entirely upon her work at Harvard: four in her own name, and six jointly with Shapley. In his monograph, *Star Clusters*, published in 1930, Shapley cites Helen frequently, stating (p. 156), "I am indebted to several assistants at Mount Wilson and Harvard for aiding in this laborious research and especially to Miss Sawyer, who has taken an active part in the recent revision of cluster distances." Helen, on her part, took the opportunity of expressing her indebtedness to Shapley at a symposium held in his memory at Harvard in 1986, describing him as "the man who was probably responsible, more than any other, for the shape my life has taken" (Sawyer Hogg 1988, p. 11).

Helen and Frank Hogg were married in 1930. Following their marriage, she went to Mt. Holyoke to teach while Frank taught at nearby Amherst. She completed the writing of her thesis while at Mt. Holyoke, and was granted her Ph.D. from Radcliffe, regardless of the fact that all of her graduate school work was carried out at Harvard, since Harvard still continued to refuse to award degrees to women. In the summer of 1931 Frank was appointed to the Dominion Astrophysical Observatory in Victoria, where Helen could use the telescopes for her own work on star clusters, even though she was not accorded a paid position. In fact, Helen was the first woman permitted to use the 72-inch telescope. Since the authorities felt it to be improper (morally) for women to be working in the dark at the telescopes where men were also working, Helen was given the necessary permission provided that her husband would be working in the dome with her!

While at Harvard, Helen had been an active member of the AAVSO. Her interests in the Association continued to the end of her life. Leon Campbell (1932), Recorder of the AAVSO, wrote:

> "We must not forget our member in Canada, Canadian only by marriage and adoption, our curator of Charts, Mrs. Helen S. Hogg. There, in the delightful climate of Victoria, B.C., she with her husband, Dr. Frank S. Hogg, a member of the staff of the Dominion Astrophysical Observatory, is keeping the members of the Association well supplied with suitable charts, besides attending to her household duties and carrying on research at the Observatory."

Helen was President of the AAVSO from 1939 to 1941, and was hostess to the AAVSO meeting held in June 1940 at the University of Toronto. At the close of that meeting, Professor Frank Hogg proposed a toast to the AAVSO, praising its work and "expressing the hope that another meeting might be forthcoming soon" (Carpenter 1940), a hope that was first fulfilled in 1965 (M. W. Mayall 1965; R. N. Mayall 1965) and has now (1999) been repeated.

In 1935 the Hoggs moved to the new David Dunlap Observatory, where she worked the rest of her life, except for a tour of duty at the U.S. National Science Foundation, 1955–56. An IAU Colloquium on variable stars held in Toronto was dedicated to Helen Sawyer Hogg (Fernie 1972), and at which 33 papers were presented by 40 authors. Besides her extensive work on globular clusters, she wrote many papers for the *Journal of the Royal Astronomical Society of Canada*, especially her intriguing articles "Out of the Old Books," which encouraged us to take heed of the glories of astronomy of the past. After the death of her husband, for 30 years she carried on his weekly column, "With the Stars," in the Toronto Star. From 1941 she also taught at the University of Toronto, retiring as Full Professor in 1976. Helen's colleagues Christine Clement and Peter Broughton (1993) eulogized her achievements, including her influence on budding women astronomers, remarking,

> "Professor Hogg was an important role model for women in the physical sciences. Throughout her life she encouraged women to pursue careers in science. In fact, only a few days before her death she participated in the taping of a video by the University of Toronto to attract young women into the sciences. On this occasion, she gave some sage advice — 'Not to know what's beyond is like spending your life in the cellar, being completely oblivious of all the wonderful things around us'."

Frank and Helen Hogg had three children. The first, Sally, was born in Victoria. While Helen was taking photographs of globular clusters at the 72-inch telescope, the baby slept in a laundry basket in the dome. Their second child, David E. Hogg, was named after David Dunlap, whose wife had financed the establishment of the Observatory as a memorial to her husband following his death in 1924, thus fulfilling a fervent dream of C. A. Chant, the first Professor of Astronomy at the University of Toronto. [Chant had worked since 1908 at finding a sponsor for an observatory, but found none until he met Dunlap, who became interested after hearing one of Chant's lectures (Anon. 1985).] David Hogg followed in his parent's footsteps. Working under Donald MacRae, David Hogg was the first Canadian to obtain a Ph.D. in radio astronomy at Toronto in 1962, and is now an astronomer at the U.S. Naval Radio Astronomy Observatory in

Charlottesville, Virginia.

Helen was much interested in science education for children. Hence, Webb (1991) was inspired to write a biography of her, "A Lifetime of Stargazing," especially for young readers. For obituaries of Helen Sawyer Hogg, see Clement (1993) and Clement & Broughton (1993).

Bibliography of Helen Sawyer Hogg while at Harvard or based primarily on work at Harvard

1927.

The Galactic Cluster N.G.C. 6231, HB, 846, 1–5 (H. Shapley & Sawyer)

Note on the Supposed Variable Star TX Scorpii, HB, 847,10

Photographic Magnitudes of Ninety-five Globular Clusters, HB, 849, 1–4 (Sawyer & H. Shapley)

A Classification of Globular Clusters, HB, 849, 11–14 (H. Shapley & Sawyer)

Apparent Diameters and Ellipticities of Globular Clusters, HB, 852, 22–26 (H. Shapley & Sawyer)

1929.

The Distances of Ninety-three Globular Star Clusters, HB, 869, 1–10 (H. Shapley & Sawyer)

Photometric Observations of TU Cassiopeiae, HB, 871, 9–13 (H. Shapley & Sawyer)

1930.

The Star Cluster N.G.C. 2477, HB, 875, 16–20

Variable Stars in Globular Clusters, Pop. Astron., 38, 408–409, (H. Shapley & Sawyer)

1931.

Periods and Light Curves of Thirty-two Variable Stars in the Globular Clusters N.G.C. 362, 6121, and 6397, HC, 366, 36pp.

1932.

Note on Luyten's Nova in the Large Magellanic Cloud, HB, 886, 15

Periods and Light Curves of Twenty Two Variable Stars in the Northern Border of the Small Magellanic Cloud, HC, 374, 16pp.

4. Peter M. Millman (1906–1990), Ph.D. 1932

From age 2 until 19, Peter Millman lived in Japan where his parents were missionaries. He had an early interest in the heavens, and as a teenager observed with a 3-inch telescope. In 1924 he observed Mars from a mountain having an elevation of 3500 feet. He shared his enthusiasm with some 20 workmen, showing them Mars and other objects and explaining to them whatever he was showing. After the family's return to Canada, his first publication in 1926 was a paper entitled "Observing Mars in Japan." He entered the University of Toronto in 1925, graduating in 1929. During that interval he spent the summers of 1927 and 1928 at the Dominion Astrophysical Observatory in Victoria, where astrophysicists J. A. Pearce and Harry Plaskett were his mentors. His work at Victoria resulted in three publications: one on the orbits of two spectroscopic binaries; one on the cause of novae (in which he speculated on the possibilities of collisions; favouring collision of a star with a nebula); and one on the quality of the light of the eclipsed Moon. Since there was still no graduate curriculum in astronomy available in Toronto, young Millman went to Harvard in 1929 to study under Harlow Shapley and Harry Plaskett, the latter of whom was appointed 1928–32 especially to teach theoretical astrophysics (Shapley 1929).

At Harvard, Shapley encouraged Millman to examine the spectra of meteors. At the time eight spectra had been photographed: two from Harvard's Southern Station at Arequipa in Peru; two at Mount Wilson; three in Moscow; and one at Bergedorf in Germany. In December 1931, Millman succeeded in getting a ninth. Among the spectra available, from six to 53 bright lines were measured and identified on each. Seven elements were identified in the spectra; iron lines were found in all of them, and calcium in most. The inferred elemental abundances agreed with the compositions of meteorites (Millman 1932). In a second paper (Millman 1935) he described the results of a concerted effort to obtain additional spectra. He obtained 14 with the aid of devoted observers, and found that they fell into two distinct categories: Type Y in which the lines of ionized calcium predominated; and Type Z in which those lines were missing. The first spectra obtained of the Leonids were all Type Y, indicating that the meteors originated from stony objects. In an obituary of Plaskett, Millman (1980b) mentioned that he had carried out most of his graduate studies under the direction of Plaskett, whom he described as "every bit as good a lecturer and teacher as he was a research scientist."

In all, Millman spent just four years at Harvard, earning an M.A. in 1931 and the Ph.D. in 1932. He remained at Harvard for another year as an Agassiz Scholar. After leaving Harvard, Millman was employed at the University of Toronto. During his seven years there, he worked on stellar radial velocities and began an extensive program for the observation of meteors, especially for obtaining meteor spectra. His radial velocity work was included in R. K. Young's (1939) compilation of David Dunlap Observatory (DDO) radial velocities, which included determinations by numerous individuals, including all five of the Harvard Ph.D. recipients. The original radial velocity program at the DDO included 500 stars brighter than visual magnitude 8.00. Of the 500, Frank Hogg obtained spectra for 151, and Millman 136. In all, some 3387 measurements were made, of which Shirley Patterson contributed 1218, Donald MacRae 445, and Millman 102.[2]

In Toronto Millman also began his series of "Meteor Notes" in the *Journal of the Royal Astronomical Society of Canada*, a series maintained from 1934 through 1971 that included 121 articles amounting to about 520 pages. It comprised all aspects of meteoritics, from the smallest meteoritic dust particles to the large fossil meteoritic

[2] Of the 500 stars, 86 were suspected to be variable in radial velocity. Helen Hogg contributed measurements for three of them. I have checked all 86 in available later radial velocity catalogues, especially the Dominion Astrophysical Observatory catalogue of spectroscopic binaries (Batten *et al.* 1989), Abt & Biggs' (1972) catalogue of radial velocities, and *Hipparcos* (ESA 1997). Of the 86 stars considered likely to be variable in radial velocity, 54 have been identified as either spectroscopic or close visual binaries. The remaining 32 were searched for possible photometric variability using the listings in variable star catalogues, and 20 were found to be either confirmed or suspected variables. Only three have published amplitudes in excess of 0.5 in *V* magnitude. The three are R Lyr, of type SRb, and RT Aur and T Vul, both Cepheids. All 32 of the variable radial velocity stars not identified as SB or double still merit further observation to account for or refute the reputed variability of their radial velocities.

craters. An important contribution is his listing (Millman 1952) of the spectra for 122 meteors, the majority obtained thanks to his encouragement of observers. A selection of 86 of the spectra represents well-known meteor showers.

During World War II Millman entered the Royal Canadian Air Force (RCAF), from which he retired in 1946. He did not return to the University of Toronto, but instead assumed duties at the Dominion Observatory in Ottawa, where he became Chief of the Stellar Physics Division. In appreciation of his service in the RCAF, Millman was privileged to have access to aircraft for observing solar eclipses (1945, 1954, and 1963) and meteor showers from above the clouds, when ground-based observations were handicapped by the weather (the Giacobinids in 1946 and 1972, and the Quadrantids in 1976).

In 1969 Millman was the editor of *Meteorite Research*, the proceedings of a symposium held in Vienna in 1968. For many years meteoriticists had debated whether or not there was any evidence for meteoritic objects with hyperbolic velocities, a feature expected for objects that came from space beyond the bounds of the solar system. In his own paper at the symposium, Millman (1969, p. 541) reported on orbital determinations for 25 fireballs that deposited recovered meteorites on the surface of the Earth. All of the orbits proved to be low eccentricity asteroidal types; none of the fireballs could be demonstrated to be travelling at hyperbolic velocities. Recent investigations are only just beginning to reveal candidate meteors with hyperbolic orbits (Hawkes & Woodworth 1997). Many ordinary meteors, which are the debris of so-called "dirty snowball" nuclei of comets, do have highly eccentric orbits, but they originate for the most part at the outer boundaries of the solar system. The particles that cause such meteors are generally so small that they are burned up in our upper atmosphere and do not produce meteorites — at best meteoritic dust

Millman's bibliography includes well over 187 articles (Halliday 1991). He was versatile in practically all aspects of meteoritic research, having participated in the extensive airborne searches for fossil meteorite craters and having inaugurated radio and radar projects for observing meteors, techniques that enabled astronomers to observe meteors in daylight or through cloudy skies. Millman & McKinley (1967), in an article "Stars Fall Over Canada," give an historical account of Canadian meteoritics, from the spectacular Leonid shower of 1833 into the age of radio astronomy. An earlier comprehensive paper on the history of meteoritics (Millman & McKinley 1963) is included in *The Solar System* edited by Middlehurst and Kuiper.

In addition to Millman's extensive contributions to meteoritics, I call attention to his beautifully illustrated history of the Herschels (Millman 1980a). Another of his articles, "Seven Maxims of UFOs — a Scientific Approach" (Millman 1975), is perhaps unusual, but informative. As a meteoriticist, Millman would naturally have been confronted by UFO believers and skeptics. The article does not discuss or evaluate any specific UFO observations however. His seven maxims nevertheless are good guidelines for reserving definitive conclusions about new discoveries in any field. The seven are:

1. There is no new thing under the Sun.
2. Seeing is not believing.
3. Instruments can deceive.
4. Beware the printed word.
5. Records are never complete.
6. Man makes mysterious machines.
7. Knowest thou the ordinances of heaven?

In 1980 an IAU Symposium was dedicated to Peter Mackenzie Millman (Halliday & McIntosh 1980), at which he contributed a history of meteor spectroscopy as well as giving a summary of the papers presented at the symposium (Millman 1980c, 1980d).

It seems fair to conclude that Peter Mackenzie Millman was not only the greatest meteoriticist in Canada, but also one of the greatest world wide in the 20th century. Complementing his great scientific accomplishments, he also had a charming personality. Obituaries have been published by Halliday (1991) and Russell (1991).

Peter M. Millman's Publications before entering Harvard

1926.
Observing Mars in Japan, JRASC, 20, 198–200

1928.
The Spectroscopic Orbit of H.D. 176819 and a Note on H.D. 185936, Pub. DAO, 4, 97–101
Causes of Novae, JRASC, 22, 352–354

1929.
The Quality of the Light of the Eclipsed Moon, JRASC, 23, 201–207

Peter M. Millman's Bibliography based on his work at Harvard

1930.
Note on the Magnitudes of Photographed Meteors, HB, 872, 3–5 (Millman & George W. Wheelwright)

1931.
A New Cepheid Variable Star in Scorpio, HB, 881, 19–20
Second Note on the Magnitudes of Photographed Meteors, HB, 885, 18–20
Investigation of the Errors of Objective Prism Radial Velocity Measures, HC, 357, 14pp.
Objective Prism Radial Velocities, JRASC, 25, 281–293; also HR, 69

1932.
An Analysis of Meteor Spectra, HA, 82, No. 6, 113–147

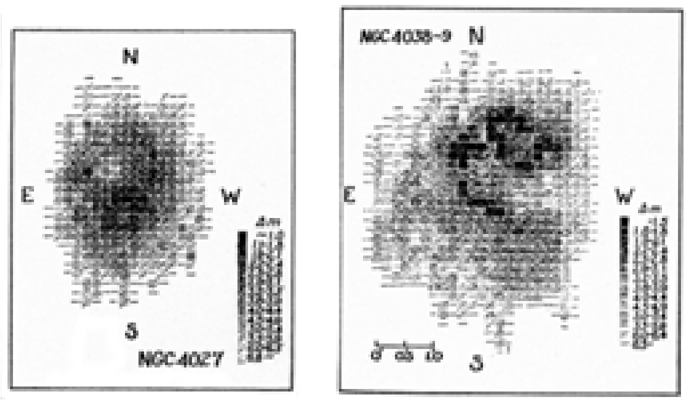
1933.
Note on Meteor Spectrum Photography in 1932, HB, 891, 6–8
The Theoretical Frequency Distribution of Photographic Meteors, Proc. Nat. Acad. Sci., 19, No.1, 34–39; also HR, 82
Amateur Meteor Photography, Pop. Astron., 41, No. 6, 298–305; also HR, 94

1935.
An Analysis of Meteor Spectra: Second Paper, 1936, HA, 82, No. 7, 149–177

1936.
A Study of Meteor Photographs Taken Through a Rotating Shutter, HA, 105, No. 31, 601–121 (Millman & D. Hoffleit)

5. F. Shirley Patterson Jones (1913–), Ph.D. 1941

Florence Shirley Patterson was born in Toronto, and attended the University of Toronto, receiving the B.A. degree in 1935 and M.A. in 1936. From 1936 to 1938 she was employed as a Computer at the David Dunlap Observatory. From there she became a graduate student



NGC	α (1950) h	m	δ °	′	Mag.	′	Diam. ′
4027	11	57	−18	59	11.6	1.0	1.5
4038	11	59	−18	35	11.0	1.5	1.5

Fig. 1 — F. Shirley Patterson's photometric tracings of the one-armed spirals, NGC 4027 and 4038, separated in the sky by 43 arcminutes (from HB, 913, 1940).

at the Harvard Observatory, working under the direction of Harlow Shapley. She gained her Ph.D. from Radcliffe in 1941, the title of her dissertation being "Surface Photometry of External Galaxies." While a graduate student in 1939, she was co-author with two other women on a study of the photometry of early-type stars, and independently in 1940 wrote two papers on the photometry of galaxies. The first was a study of two one-armed spiral galaxies (nicknamed "ring-tailed snorters" by Shapley), NGC 4038 and NGC 4027, that are separated by only 43 arcminutes (figure 1). Shirley surmised that they may be the remains of a single disrupted galaxy, or that they might "result from the extra-galactic combat of two ordinary galaxies" (Patterson 1940).

In 1942 Shirley married Donald A. Jones, a physicist with a Ph.D. from McGill University. They had two daughters, one of whom, Lorella M. Jones (1943–1995), was born in Toronto and attended Radcliffe (A.B. 1964) and the California Institute of Technology (Ph.D. in physics in 1968), subsequently becoming the first woman to become a full tenured Professor of Physics at the University of Illinois. In an obituary, Lorella is described as a true pioneer, who through her writings and talks championed the cause of women in physics. "She served as an inspiration and role model for the women physicists who followed her" (Delbourgo & Greene 1995). Lorella has been Shirley Patterson Jones' greatest gift to science.

After obtaining her own Ph.D., Shirley Patterson Jones lectured or taught at various institutions. She was employed as a physicist at Research Enterprises, Ltd., in Toronto during 1941–45, was a Lecturer at the Buffalo Museum of Science in 1948–1955, a Research Associate at the University of Buffalo during 1949–53, Research Associate at Harvard Observatory over the period 1956–67, a Lecturer at Wellesley during 1957–60, Visiting Assistant Professor at Carnegie Institute of Technology 1962–64, and Lecturer at Trinity College, Hartford, 1964–72. Her changes in appointments varied largely according to the various locations where her husband was employed.

Her publications are not as numerous as those of the other Canadian astronomers holding Harvard degrees, since she concentrated more on teaching. While working at Harvard under Donald Menzel, she helped him with his research on solar prominences (Menzel & Jones 1962). In 1972, while at Trinity College, she investigated the radial velocities of stars in the open cluster NGC 1893, which lies towards the galactic anticentre (Jones 1972). At the predicted time of the 1954 solar eclipse, Shirley had been ready to participate in observations scheduled by personnel at the David Dunlap Observatory, but unfortunately the eclipse was itself obscured by fog, clouds, and rain. She was, however, fortunate to observe the 1970 eclipse from Nantucket, where some fog prevailed but most of totality was only slightly and intermittently affected.

F. Shirley Patterson's Publications while at Harvard

1939.
Color Indices of Early-Type Stars from the Harvard Mimeograms, HB, 911, 17–23 (Mary Hunt, F. Shirley Patterson, & Esther A. Raymond)

1940.
Photometry of Two One-Armed Spirals, HB, 913, 13–14
The Luminosity Gradient of Messier 33, HB, 914, 9–10

6. Donald A. MacRae (1916–), Ph.D. 1943

Donald MacRae graduated from the University of Toronto in 1939, then enrolled at Harvard, gaining an M.A. in 1940 and a Ph.D. in 1943. His dissertation, under the direction of Professor B. J. Bok, was entitled, "The Structure of the Galaxy from a Study of Regions Not in the Galactic Plane."

Between 1941 and 1942 MacRae was an instructor at the University of Pennsylvania, became an instructor at Cornell during 1942–44, and then engaged in war work at the Oak Ridge Carbide and Carbon Chemical Corporation, followed by an assistant professorship at Case Western Reserve University in 1944. Finally, in 1946 he returned to the University of Toronto as Associate Professor, becoming Full Professor in 1955. Following the retirement of J. F. Heard in 1965, MacRae became the Director of the David Dunlap Observatory until his early retirement on June 30, 1978[3].

MacRae, together with J. B. Oke, designed a unique photoelectric spectrophotometer for use with the 74-inch telescope (Heard & Hogg 1967, p. 261). In 1956 the Departments of Astronomy and Electrical Engineering inaugurated a program in radio astronomy for studying radiation from the Sun and radio stars (J.F.H. 1956; Jarrell 1997a). They studied the two brightest radio sources, Cas A and Cyg A (MacRae & Seaquist 1963). MacRae (1960) wrote:

"The work of the radio astronomy project is built around a

[3] One of the last appointments that he made to the Astronomy faculty of the University of Toronto prior to his retirement was the hiring of the current Editor of the *Journal* to a sabbatical replacement position. — Ed.

programme of graduate students. At the present time we have four graduate students who are working full time in radio astronomy, and two others whose work is closely associated with it."

He concluded,

"The research work in radio astronomy at Toronto is varied in nature in order to give scope to the interests and abilities of the graduate students and at the same time to enable them to attack problems of significance."

Another of MacRae's interests was the origin of the surface of the Moon. Heard & Hogg (1967, p. 269) commented on that as follows:

"In the early 1960s, MacRae made extensive studies of published lunar photographs, and put forward some interesting new speculations on the nature and origin of the surface of the Moon. Some of his ideas of the vesicular character of the lunar surface have been rather dramatically confirmed by recent close-up photographs of the lunar surface from space vehicles which have landed there."

MacRae was elected a Trustee of the University Space Research Association in 1967, a member of the Lunar and Planetary Institute at Houston, Texas, 1969–76, and a member of the Canada-France-Hawaii Telescope Corporation, 1973–79.

In all, MacRae published some 70 papers, about a third of which dealt with departmental progress reports. The others included studies in the history of astronomy, astronomical instruments, radio astronomy, photometry, the spectra and chemical compositions of stars, the motions of A-type stars, the icy conglomerate of the Moon, book reviews, and obituaries. MacRae's interests and activities reveal versatility appropriate to the directorship of a large observatory and the advisor of advanced students having diverse astronomical interests.

Bibliography of Donald MacRae while at Harvard

1940.

A Note on the Milky Way in Scorpio, HB, 914, 21–23

The Southern Milky Way, The Telescope, 7, No. 4, 83–89

Tests of R. W. Wood's Bi-Prism Grating, Pub. AAS, 10, 60 (MacRae & B. J. Bok)

1941.

The Stellar Distribution in High and Intermediate Latitudes, Ann. N.Y. Acad. Sci., 42, 219–258 (B. J. Bok & MacRae)

1942.

Fireball of 1934, July 23, Pop. Astron., 50, 329–330

Fireball of 1936, October 21, Pop. Astron., 50, 500–501

7. Summary

Formal education in astronomy in Canada was slow in getting started. C. A. Chant struggled for years to establish regular undergraduate courses in astronomy at the University of Toronto and to acquire a large telescope for the university. But graduate programs leading to a Ph.D. were even longer getting started. The first such program began in 1947, about a dozen years after the first large research telescope, the 74-inch, was erected at the David Dunlap Observatory. Hence, prior to that time, students wishing to pursue graduate courses looked for opportunities in the United States.

Until Harlow Shapley became the Director of Harvard College Observatory in 1921, it was exclusively a research institution. He soon instituted a program for graduate students leading to the Ph.D. degree. Prior to his retirement in 1952, 50 scholars received the doctoral degree in astronomy. They included four Toronto graduates: Frank Hogg in 1929, Peter Millman in 1931, Shirley Patterson in 1941, and Donald MacRae in 1943, as well as the American Helen Sawyer in 1931, who became a Canadian after marrying Frank Hogg.

All five carried on distinguished careers in astronomy, and all were at some time employed at the David Dunlap Observatory. Also, all but Massachusetts-born Helen Sawyer held undergraduate degrees from the University of Toronto. Would the four native Canadians have continued towards a Ph.D. at Toronto if a graduate program had been available to them?

Two of the Harvard Ph.D.s, Helen Sawyer Hogg and Peter Millman, were fortunate in being able to pursue the topics of their doctoral degrees as their major research interests throughout their professional careers. Both became world wide acknowledged experts in their fields. Millman became the Chief of the Stellar Physics Division at the Dominion Observatory in Ottawa, and finally head of Atmospheric Research at the National Research Council of Canada in Ottawa. Millman and Helen Sawyer Hogg both had asteroids named in their honour (Schmadel 1997).

Two others became Directors of the David Dunlap Observatory: Frank Scott Hogg (1946–51) and Donald A. MacRae (1965–78). Both Hogg and MacRae were versatile in several fields of astronomy, exemplifying the best qualifications of directors of a large observatory and as professors of astronomy. Finally, F. Shirley Patterson Jones was an influential teacher of undergraduates and an advocate for the advancement of women scientists. The five Harvard-trained Canadian astronomers published over 400 research papers among them, in addition to hundreds of popular articles. Moreover, as a consequence of their experiences at Harvard, they were able to introduce research topics that had not previously been studied in Canada, notably meteors, globular clusters, and radio astronomy, to students at the University of Toronto.

Both the American Harvard College Observatory and the Canadian David Dunlap Observatory may well be proud of the influences they have had upon their gifted students, all of whom cited here having served to advance the education of future astronomers.

This article originated when Joseph Tenn of the Astronomical Society of the Pacific invited me to give a paper at the joint meetings of the ASP, the AAVSO, and the RASC held in early July 1999 in Toronto. I am grateful to an anonymous referee for numerous editorial corrections, and especially for suggestions for amplifying the original draft.

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References

Abt, H. A. & Biggs, E. S. 1972, Bibliography of Stellar Radial Velocities, vii + 502 pp.

Anon. 1985, The David Dunlap Observatory: the First Fifty Years, 1935–1985, 19pp.

Batten, A. H., Fletcher, J. M. & MacCarthy, D. G. 1989,"Eighth Catalogue of the Orbital Elements of Spectroscopic Binary Stars, Pub. DAO, 17, 317pp.

Campbell, L. 1932, Personality Paragraphs, Variable Comments, 2, 59

Campbell, L . 1940, The 1940 A.A.V.S.O. Spring Meeting in Toronto, JRASC, 34, 217

Carpenter, C. B. 1940, The Twenty-ninth Annual Spring Meeting of the A.A.V.S.O. at Toronto, Variable Comments, 3, 105

Chant, C. A. 1951, Frank Scott Hogg, 1904-1951, JRASC, 45, 1–3

Clement, C. 1993, Helen Sawyer Hogg, 1905-1993, JAAVSO, 22, 83–86

Clement, C. & Broughton, P. 1993, Helen Sawyer Hogg, 1905-1993, JRASC, 87, 351–356

Delbourgo, R. & Greene, L. H. 1995, Lorella M. Jones, Physics Today, 48, 90

DeVorkin, D. H., Ed. 1999, The American Astronomical Society's First Century, 350pp.

European Space Agency 1997, The Hipparcos and Tycho Catalogues, 17 Vol.

Fernie, J. D., Ed. 1972, Variable Stars in Globular Clusters and in Related Systems, IAU Colloq., No. 21, 234 pp.

Fisher, W. J. & Olmsted, M. 1931, Catalogue of the Harvard Observatory Meteor Photographs, HA, 87, Part 3, 230–254

Halliday, I. 1991, Peter Mackenzie Millman, 1906-1990, JRASC, 85, 67–78

Halliday, I. & McIntosh, B. A., Eds. 1980, Solid Particles in the Solar System, IAU Symp. No. 90, 439 pp.

Haramundanis, K., Ed. 1984, Cecilia Payne-Gaposchkin. an autobiography and other recollections, Cambridge University Press, 47

Hawkes, R. L. Woodworth, S. C. 1997 Optical Detection of Two Meteroids from Interstellar Space, JRASC, 91, 218-219

Heard, J. F. 1951, Frank Scott Hogg, 1904-1951, Pop. Astron., 59, 173–176

Heard, J. F. 1956, The Radial Velocities, Spectral Classes and Photographic Magnitudes of 1041 Late-Type Stars, Pub. DDO, 2, 105–143

Heard, J. F. 1957a, Clarence Augustus Chant, JRASC, 51, 1–4

Heard, J. F. 1957b, Clarence Augustus Chant, MNRAS, 117, 250–251

J.F.H. [Heard] 1956, David Dunlap Observatory, JRASC, 50, 187

Heard, J. F. & Hogg, H. S. 1967, Astronomy at the David Dunlap Observatory 1935–1967, JRASC, 61, 257–276

Hoffleit, D. 1937, The Second Catalogue of Harvard Observatory Meteor Photographs, HA, 82, No. 8. 179–195

Hogg, F. S. 1929, A Synopsis of Cometary Spectra, JRASC, 23, 55–89; also HR 57; Abstract, HB, 863, 1–2

Hogg, H. S. 1973, A Third Catalogue of Variable Stars in Globular Clusters Comprising 2119 Entries, Pub. DDO, 3, No. 6, 75 pp.

Hogg, H. S. 1988, The Harlow Shapley Symposium on Globular Cluster Systems in Galaxies, IAU Symp. 126, Eds. J. E. Grimm and A.G. D. Philip, pp. 11-22

Jarrell, R. A. 1997a, Canadian Astronomy, p. 112 in J. Lankford, Ed. History of Astronomy, 110–114

Jarrell, R. A. 1997b, David Dunlap Observatory, in J. Lankford, Ed., History of Astronomy, 189–190

Jarrell, R. A. 1999, Honorary American Astronomers: Canada and the American Astronomical Society, DeVorkin, Ed. The American Astronomical Society's First Century, pp. 61–73

Jones, B. Z. & Boyd, L. G. 1971, The Harvard College Observatory, the First Four Directorships, 1839–1919, pp. 189–193

Jones, F. S. 1972, Radial Velocities from Some Stars in NGC 1893, PASP, 84, 459

MacRae, D. A. 1960, Report, JRASC, 54, 86

MacRae, D. A. & Seaquist, E. R. 1963, Flux of Cas A and Cyg A at 320 Mc/sec, AJ, 68, 77

Mayall, M. W. 1965, Variable Star Notes, JRASC, 59, 245–248

Mayall, R. N. 1965, Papers Presented at the Toronto Meeting, 21–23 May 1965, AAVSO Abstracts, May 1965, 24pp.

Menzel, D. H. & Jones, F. S. 1962, Solar Prominence Activity, JRASC, 56, 193–202; also HR, 497

Middlehurst, B. & Kuiper, G. 1963, The Solar System, 810 pp.

Millman, P. M. 1932, An Analysis of Meteor Spectra, HA, 82, No. 6, 113–147

Millman, P. M. 1935, An Analysis of Meteor Spectra: Second Paper, 1936, HA, 82, No. 7, 149–177

Millman, P. M. 1952, Photographic Meteor Spectra, JRASC, 46, 121–125

Millman, P. M., Ed. 1969, Meteorite Research, Reidel. Pub., 941 pp.

Millman, P. M. 1975, Seven Maxims of UFOs — a Scientific Approach, JRASC, 69, 175–188

Millman, P. M. 1980a, The Herschel Dynasty, JRASC, 74, 134–146, 203–215, 279–290

Millman, P. M. 1980b, Harry Hemley Plaskett 1893–1980, JRASC, 74, 234–236

Millman, P. M. 1980c, One Hundred and Fifteen Years of Meteor Spectroscopy, IAU Symp. 90, 121–128

Millman, P. M. 1980d, Summary of IAU Symposium 90, IAU Symp. 90, 429–432

Millman, P. M. & McKinley, D. W. R. 1963, Meteors, in The Solar System, B. Middlehurst and G. P. Kuiper, Eds., 4, 674–773

Millman, P. M. & McKinley, D. W. R. 1967, Stars Fall Over Canada, JRASC, 61, 277–294

Northcott, R. J. 1957, A Pioneer in Canadian Astronomy, Sky & Telescope, 16, 172

Patterson, F. S. 1940, Photometry of Two One-armed Spirals, HB, 913, 13–14

Russell, C. H. 1999, C. A. Chant and the David Dunlap Observatory, JRASC, 93. No. 1, 11–14

Russell, J. A. 1991, Memorial for Peter Mackenzie Millman, Meteoritics, 26, 173

Sawyer, Helen, See Hogg, H. Sawyer.

Schmadel, L. D. 1997, Dictionary of Minor Planet Names, 3rd Ed. Springer, pp. 376 and 378

Shapley, H. 1929, 83rd Annual Report of the Director of the Astronomical Observatory of Harvard College, p. 1

Shapley, H. 1930, Star Clusters, McGraw-Hill, 276 pp.

Shapley, H. 1934, 89th Annual Report of the Director of the Astronomical Observatory of Harvard College, pp. 2–3

Young, R. K. 1939, The Radial Velocities of 500 Stars, Pub. DDO, 1, 69–123

Webb, M. 1991, A Lifetime of Stargazing, Copp Clark Putnam Ltd. (For young people)

Abbreviations used in the References

AAS	American Astronomical Society
AJ	Astronomical Journal
DAO	Dominion Astrophysical Observatory, Victoria
DDO	David Dunlap Observatory
HA	Annals of Harvard College Observatory
HB	Bulletins of Harvard College Observatory
HC	Circulars of Harvard College Observatory
HR	Reprints of Harvard College Observatory

IAU Symp.	Symposium of the International Astronomical Union	Pop. Astron.	Popular Astronomy
JAAVSO	Journal of the American Association of Variable Star Observers	PASP	Publications of the Astronomical Society of the Pacific
JRASC	Journal of the Royal Astronomical Society of Canada	Proc. Nat. Acad. Sci.	Proceedings of the US National Academy of Sciences
MNRAS	Monthly Notices of the Royal Astronomical Society	Pub.	Publications
Obs.	Observatory		

Table I
Toronto Graduates Who Became Directors of Canadian Observatories

Name	U. of Toronto Bachelor Earned	Ph.D. Awarded	Observatory Directed
C. A. Chant (1865–1956)	1890	1901 Harvard[1]	DDO, 1935[2]
J. S. Plaskett (1865–1941)	1899	1923 Toronto[1]	DAO, 1918–35
R. K. Young (1886–1977)	1909	1912 California	DDO, 1935–46
J. A. Pearce (1893–1988)	1920	1930 California	DAO, 1940–51
F. S. Hogg (1904–1951)	1926	1929 Harvard	DDO, 1946–51
D. A. MacRae (1916–)	1939	1943 Harvard	DDO, 1965–78

Notes: [1] Degree in physics.
[2] Honorary title, Director Emeritus.

Table II
Numbers of Research Areas and Astronomers

Period	Observatories Compared	Research Areas	Astronomers	R/A[1]
1922–25	Dominion Astrophysical Observatory	6	7	0.86
	Mount Wilson Observatory	15	18	0.83
	Dominion Observatory, Ottawa	5	9	0.56
	Harvard College Observatory	18	15	1.2
1935–43	Dominion Astrophysical Observatory	11	6	1.83
	Mount Wilson Observatory	14	26	0.54
	Dominion Observatory, Ottawa	6	4	1.5
	David Dunlap Observatory	12	11	1.08
	Harvard College Observatory	17	22	0.77

Note: [1] R/A = Average number of research areas per astronomer.

DORRIT HOFFLEIT officially retired 24 years ago as Senior Research Astronomer and Lecturer at Yale University, but continues to be active as a volunteer researcher on star catalogues and the history of astronomy, variable stars, and women in astronomy. Following graduation from Radcliffe College (A.B. 1928 in mathematics, M.A. 1932 and Ph.D. 1938 in astronomy) for work done at Harvard College Observatory, she had an interesting and varied career primarily in New England, holding positions at Harvard College Observatory, Aberdeen Proving Ground, Wellesley College, and Yale University Observatory. Between 1957 and 1978 she served as the director of the Maria Mitchell Observatory on Nantucket. She is the author of over 400 articles in scientific journals from about 1930 to the present, and well known as the editor of the 1964 and 1982 editions of The Bright Star Catalogue*, as well as its 1983* Supplement*. She has been the recipient of numerous academic and humanitarian awards, and continues to be a member of more than a dozen scientific organizations. Between 1957 and 1968 she was a volunteer editor for the Meteoritical Society, and asteroid Dorrit was named in her honour by the International Astronomical Union. Dorrit Hoffleit has had a long and productive career in astronomy, and continues to be a tireless promoter of the role of women in science.*

AWARD OF THE FRANKLIN MEDAL TO DR. SHAPLEY

The Franklin Institute has announced the selection of Dr. Harlow Shapley, Director of the Harvard College Observatories, as 1945 winner of the Franklin Medal. The award is "in consideration of his many valuable contributions to the science of astronomy, and especially of his work in the measurement of the vast distances necessary for the determination of the nature and extent of our Galaxy, as well as of those other galaxies external to ours."

The Franklin Medal award is made to "those workers in physical science or technology, without regard to country, whose efforts have done most to advance a knowledge of physical science or its applications." Edison, Marconi, Jeans, Orville Wright, Einstein, Kapitza, and W. D. Coolidge are among the familiar names of past recipients of this medal.

When Franklin's own versatility and participation in so many fields of scientific and cultural endeavour are recalled, it is interesting to note that Dr. Shapley is president of the American Astronomical Society, of the National Society of Sigma XI, and Science Clubs of America, Chairman of the Board of Science Service, the Worcester Foundation for Experimental Biology, and the World Wide Broadcasting Foundation. He is past-president of the American Academy of Arts and Sciences.

While most readers of this *Journal* are familiar with some of Dr. Shapley's numerous astronomical writings, from his early Princeton work on eclipsing binary orbits to his classical studies of star clusters, and his recent Harvard Monograph, Galaxies, fewer astronomers are aware of the fact that he has also contributed research papers in the fields of entomology and geology. On behalf of Dr. Shapley's wide circle of friends in this country, the editors of this *Journal* extend to him warmest congratulations on this award.

by Frank S. Hogg,
from *Journal*, Vol. 39, pp. 158–159, April, 1945.

ABSTRACTS OF PAPERS PRESENTED AT THE 1999 RASC GENERAL ASSEMBLY HELD AT THE UNIVERSITY OF TORONTO, JULY 1 — 3, 1999

Ocular Hazards of Pinhole Defects in Mylar™ Solar Filters, B. Ralph Chou, Toronto Centre.

It is well known that solar filters made of aluminized polyester (Mylar™) exhibit pinhole-coating defects with a typical size of 20 to 30 μm. The recent discovery in the United Kingdom of commercially constructed solar eclipse viewers with coating defects of size up to 500 μm has raised questions about the safety of such devices. Three defective viewers and one sample of defective filter material rejected by the manufacturer were examined by light microscopy, and the sizes of the defects were measured. The retinal exposure was calculated for an unaided eye viewing the Sun through the filter with the defect centred on the pupil. The results were compared with maximum permissible exposures for occupational exposure to optical radiation. Microscopic analysis revealed that the defects are attributable to gaps in one of two layers of aluminum deposited on the polyester substrate. No defect was devoid of aluminum. Although the computed retinal exposure is significantly higher than for the case of an intact filter, the risk of a retinal burn is much lower than for viewing the Sun directly through a 1 mm pinhole. The properties of a solar filter material that eliminates the pinhole defect are described.

The MOST Satellite (MOST = Microvariability & Oscillations of STars): A Canadian Astronomy Satellite in Earth Orbit, Kieran Carroll, Dynacon Enterprises, Toronto.

The scientific purpose of the MOST mission is to place a small astronomical telescope in orbit around the Earth, and to use that telescope to measure fluctuations in the brightness of several bright stars, over periods as long as two months and with sample periods selectable between 0.1 and 100 seconds. Aspects of the development and construction of the telescope are presented.

Simulating the Solar System on Your Home Computer, Michael S. F. Watson, Unattached Member, Toronto.

The combination of modern high-speed personal computers and high-accuracy planetarium programs makes it possible for the amateur astronomer to recreate, in graphically striking form, the motions of solar system objects, as well as ephemeral events such as eclipses and occultations. Watching the day-to-day and month-to-month motions of planets and comets at high speed on the computer monitor helps us understand and appreciate the orbital movements of such objects much better than observing them in real time in the sky. During this computer presentation, the author demonstrated orbital motions of the inner planets, planetary conjunctions, occultations of planets by the Moon, and the movements of comets through the night sky, using his two favourite programs, *The Earth Centered Universe* and *RedShift 2*.

The Creation of a Prototype "Dark Sky Reserve" as an Initiative of the Muskoka Heritage Foundation in the Province of Ontario, Peter Goering, Toronto.

The growing awareness of light pollution in the night sky and the inability of large sectors of the population to experience and enjoy astronomical events has created an opportunity to initiate the development of a "Dark Sky Reserve" in the District of Muskoka in the Province of Ontario, here in Canada. The initiative, undertaken by a community-based volunteer organization called "the Muskoka Heritage Foundation" has brought together the astronomical community and local government to establish the "Torrance Barrens Conservation and Dark Sky Reserve," which is located in an accessible rocky barren wilderness right in the heart of Ontario's "cottage" country.

Geographically situated directly north of Metropolitan Toronto and centred in an urban and suburban metropolis serving some four million people, the "Reserve" will provide unobstructed and protected sky viewing for astronomy groups, individuals, and complementary eco-tourist activities. Co-operation and support from the local and district governments to minimize artificial light intrusion is part and parcel of the Dark Sky Reserve. The Provincial Government is developing appropriate management objectives for the Reserve to protect its special natural values, which include enjoyment of the night sky.

Hydrocarbon Potential of the Steen River Impact Structure, Alberta, Canada, Donald W. Hladiuk, Armin W. Schafer, and Lorne Schoenthaler, Calgary, Alan R. Hildebrand, Robert R. Stewart, and Michael Mazur, University of Calgary, Mark Pilkington and Richard A. F. Grieve, Geological Survey of Canada, and Dean Sinnott, Calgary.

The ~25 km-diameter Steen River impact structure, (59° 30′ N, 117° 38′ W) is the remnant of the largest known impact crater in the Western Canadian Sedimentary Basin (WCSB). The eroded crater lies buried under ~200 m of cover with no surface expression, necessitating the use of geophysical and drilling data to map the crater's structure. In this area the WCSB is composed of ~1 km-thick gently southwest-dipping strata. The crater rim hosts gas production amounting to 845×10^3 m^3 d^{-1} from the Slave Point Formation, and seasonal petroleum production of ~190 m^3 d^{-1} from the Keg River Formation. Gulf Canada Resources Limited has drilled several Slave Point gas wells with sandface AOF (Absolute Open Flow) potential up to 2680×10^3 m^3 d^{-1}, and has recently completed a 845×10^3 m^3 d^{-1} gas plant. Proven gas reserves of 2.0×10^9 m^3 have been booked in the Slave Point on the northeast rim, with upside potential of another 2.5×10^9 m^3 for the remainder of the crater. Pressure data from Slave Point production tests indicate a highly permeable reservoir with a dual porosity system. The Sulphur Point Member has also tested gas from two wells located on the eastern rim. Although the Steen River structure was discovered more than thirty years ago with documented evidence of shock metamorphism, little has been published about it in the open literature. A re-examination of a recovered drill core from the central uplift confirms the presence of abundant evidence of shock metamorphism. This paper also examines the global significance of terrestrial impact structures.

The Story of Sock's Star: A Bright Nova Discovered by a Schoolgirl in War Time, Osao Shigehisa, Kanagawa, Japan.

In November 1942, during World War II, a bright nova (named CP Pup) appeared in the southern sky. Although many amateur astronomers discovered the nova in Japan, the earliest discoverer was an obscure student in a junior high school for girls. Today most Japanese astronomers call the nova "Sock's star." The origin of the nickname is explained here.

The Landing of Apollo 11 and How It Almost Did Not Make It, Randy Attwood, Toronto Centre.

Thirty years ago the first manned landing on the Moon took place. The world held its breath while listening to the voices of Armstrong and Aldrin as they steered the lunar module *Eagle* to a safe landing. Few people know how close the mission came to failure. Invalid data from Mission Control, mistakes in the astronauts' checklists and procedures, inadequately designed fuel tanks, a poorly designed heat exchanger, an overloaded guidance computer, and just the fact that it was the first landing attempt, all nearly contributed to an aborted mission.

The North York Astronomical Association: Who We Are And What We Do, Andreas Gada, Unattached Member.

The North York Astronomical Association (NYAA) is a small, informal group of amateur astronomers who are actively involved in hands-on observational astronomy. One of the things that makes the NYAA unique is the use of a vision statement to clearly define the nature of the club and what it wants to accomplish. Presented here are an exploration of the club's achievements over the past 19 years, and how its vision statement has helped to focus efforts of the club. Major achievements include Starfest, Canada's largest annual observing convention and star party, and the construction of three observatories.

The Millennium Star Atlas: An Observer's Assessment, Leo Enright, Kingston Centre

Celestial cartography's most significant event of the past decade has been the publication of the "entirely new" *Millennium Star Atlas*, based entirely on data from the *Hipparcos* Astrometry Mission. The present paper analyzes the features of this remarkable achievement, and assesses them from the point of view of an active observer.

ASTRONOMY COURSES FOR THE PUBLIC

by Suzanne E. Moreau
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Abstract. Developing astronomy courses for the general public requires a lot of thought and planning to ensure the success of the programme. The issues of target market, venue, advertising, course contents, fee structure, and myriad other things all need careful consideration, if the effort and the funds invested in such courses are not to be wasted.

Résumé. Le développement d'un cours d'astronomie pour le grand public demande de mûre réflexion et de la planification soignée afin d'assurer le succès d'un tel programme. Les sujets tels que quel groupe d'étudiants faut-il viser, le lieu du cours, la promotion, le contenu des leçons, les tarifs, et bien d'autres sujets doivent être examinés avec attention afin que l'effort et les fonds investis dans le programme ne soient pas gaspillés.
SEM

1. Introduction

Promoting public awareness of astronomy can take many forms, whether by means of courses, star parties, open houses, or participation in introducing the subject to school curricula, as described in a recent article by Winston Stairs (Stairs 1998).

During the early 1990s, I was a member of the Board of Directors of the RASC Montreal Centre. My colleagues and I held an Open House twice a year to "educate" the public and to attract new members. During every one of those events, I was repeatedly asked the same question, "Do you give courses?" Regrettably, I had to answer no, explaining that both McGill and the Université de Montréal give astronomy courses — the former in Continuing Education while the latter's was a degree granting programme. The inevitable reply was, "But, that's not what I want! I want to be able to look up at the sky and identify what I see. I'm also interested in buying a telescope, but I don't know what kind is best."

Such recurring questions did show me that there was a strong latent demand for basic courses in astronomy for beginners, and, when I and some of my fellow members formed a new group in 1995, one of our first priorities was developing and giving courses to fill that demand. We are now in our 5th year offering such courses, and we have acquired considerable practical experience that others, contemplating presenting such courses, may find useful.

2. Planning and Marketing the Course

From the beginning, we decided not to compete with the academic programmes. Rather, we hoped to supplement them with the development of some practical, observation-orientated skills. The following are the steps we took to develop the course programme.

The Target Market. Identifying one's target market is not as trivial a problem as first appears. The demand for children's courses is as strong as that for adults. Our small membership, and the fact that most of us work full-time, forced us to be realistic — at least to begin with. We chose to target adults, and to expand our programme as our number of lecturers increases.

Advertising the Course. We had considerable discussion about this issue too, as commercial advertising is *very expensive*. Our limited financial resources forced us to choose with great care where we place our promotion. After considering radio announcements — both free community services and commercial ads on popular stations — as well as a variety of newspapers, experience has taught us that our ad in a week-end edition of *The Gazette* provides the best return for our money. The main reason is that it can be clipped out of the paper and saved for future reference, as indicated by people requesting more information weeks after it appeared. Moreover, the paper has a wide circulation, providing us with several students and even more application requests from areas outside Montreal city limits, such as the Laurentians, the Eastern Townships, and eastern Ontario.

Course Venue. A classroom that provides projectors of various kinds, astronomical equipment, and other facilities (washrooms, coffee, *etc.*) makes teaching easier for the lecturer and more comfortable for the students. Moreover, the "reputation" of the venue of the course, like the Montreal Planetarium where ours takes place, adds to the cachet of the programme and makes it easier to attract students.

Course Structure. To cover the essentials and to give the students some "hands-on" experience, we concluded that a total of six sessions would be required to cover all the course material. Among these sessions, one should be devoted to a "field trip" to a semi-dark location on the outskirts of Montreal, the choice of site depending on the time of year. During the lectures we emphasize practical skills, encouraging the students to try planispheres and the displayed telescopes.

Course Duration. Twice a year, the course is given once a week in the evening for two hours or so, over a six-week period. A short break held half-way through the evening permits students to ask questions of either the lecturer, or of the teaching assistant who also attends the class.

Class Size. We restrict the maximum number of persons per class to about 20, to ensure that each student gets individual attention where necessary, and the opportunity to try out equipment and other observing aids. The minimum number should at least cover the cost of advertising and course material — in our case eight students. It should be noted that the fall courses always attract more students than the spring ones.

Lecturer Resources. Although it seems obvious, no course should rely on a single lecturer. If an organization is unable to supply at least one substitute lecturer at short notice, it should not consider the course at all. Word of missed or delayed lectures can quickly give a bad name to a programme, wasting both advertising funds and the efforts put into developing the course in the first place.

At present, our group has at least three lecturers available on short notice, and one Montreal Planetarium lecturer to teach the celestial co-ordinate system using the planetarium's Zeiss projector. A teaching assistant to handle administrative tasks and answer questions also helps ensure a successful programme. Experience has proven that this is by no means an overabundance of resources.

3. The Course Contents

Louie Bernstein and I translated course material used by the French sector at the Planetarium, customizing it for our students. We have added an expanded bibliography to include the latest astronomy software, a sample observation reporting form, and other information we deemed useful for beginners. Finally, short exercises that the student can try at home are used in the course material, where appropriate. It should also be noted that the course contents are dynamic, constantly being updated and refined as we test student response. That is essential if they are to keep up with the latest news about astronomical events, which most students follow avidly.

Each student is provided with a course outline and a loose-leaf binder with the course contents — some 80 pages of text and diagrams that closely track the lecture material. The six sessions are described as follows:

Lecture 1. To give the students some context, the first lecture is devoted to basic concepts about planetary and stellar objects (lunar phases, fixed stars, wandering planets, *etc.*), as well as celestial orientation. When the Planetarium's main auditorium is available to us, celestial co-ordinates are taught with the use of the Zeiss projector. A brief slide show featuring a "Tour of the Universe" completes the lecture.

Lecture 2. Since most students want to know where to find things and to identify what they are seeing, star maps and other sources of data (lunar and planetary tables, almanacs and ephemerides, *etc.*) are introduced. The types of planispheres available and their use are explained in detail, and students are encouraged to acquire one of their own. Several are circulated around the classroom so students can try them out and ask questions, or get help if they have trouble following directions. Atlases and copies of the *Observer's Handbook* are also circulated.

Lecture 3. To provide some understanding of the behaviour of light under reflection and magnification, a review is made of the properties of lenses — including oculars and the eye — and of mirrors. The use of binoculars as a first introduction to observing instruments is also covered.

Lecture 4. This class is devoted entirely to the two types of telescopes, their mounts and accessories. Refractors, and reflectors of various kinds, are displayed at the front of the classroom, and students are encouraged to try them out. Information on price ranges and other factors to consider when purchasing a telescope is discussed.

Lecture 5. To answer frequent questions during class breaks early in the programme, a section on cosmology was recently added to the course module. We include a brief review of the meaning of terms like the Hubble Constant, redshift, the Big Bang, infinity, and other universes, *etc*. As the last formal lecture, it also emphasizes observing projects, like the Messier list and the Grand Sightseeing Tour of the Universe, and the methods of recording observations.

"Lecture" 6. The most problematic part of the course is the field trip. Regrettably, in the past five years, the weather has not co-operated much. So, to complete the programme, a 6th lecture is substituted when the field trip proves impossible to hold. This class covers the elements of stellar classification, and the course is concluded with a showing of the film *Comet Odyssey.*

4. The Fee Structure

To cover course costs, and hopefully to build some reserves, we charge $65 ($50 for our paid-up members) per person, regardless of age. The fees include the course material, and are similar to fees charged for the French-language astronomy courses given at the Planetarium. Moreover, they are in the range of fees for other "hobby-type" courses offered in Montreal.

5. Conclusions

How have we fared to date? So far, we have given the courses to almost 100 persons, ranging in age from 12 to 79. Since September 1995, the course has been given six times, with an average of 16 persons per class. Response problems in February 1996, and the ice storm of 1998, prevented our holding the spring sessions in both of those years. The 7th session is about to begin, and other programmes are in the works.

Teaching astronomy to the public is very satisfying on a personal level. It may not be a huge money-maker, but, if you want to have fun, watch the look of amazement on a student's face when he or she suddenly understands the concept of distance in astronomical terms, or just sees the Moon through a telescope for the first time. That is reward enough!

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Reference

Stairs, W. D. 1998, JRASC, 92, 201

SUZANNE E. MOREAU has been a self-employed consulting economist for the past 20 years, specializing in the aviation and aerospace fields. Before that she worked in both the airline and the banking industries, in Canada and abroad. A university student for 30 years, she has earned B.A., B.Com., and M.B.A. degrees. A B.Sc. in physics is in abeyance until she retires. She is Editorial Assistant for the Journal, *and edits another astronomy newsletter. She has been a member of the RASC since 1982.*

A Visit to the VLA Radio Observatory

by Susan Vonesh, North Shore Erie Amateur Astronomers (svonesh@julian.uwo.ca)

Those who saw the 1997 movie *Contact* will recall the dramatic moment when Ellie Arroway's SETI team first made contact using the Very Large Array (VLA) radio antennae in the New Mexico desert. I know I do! So, when the opportunity recently presented itself for me to holiday in New Mexico, I made a special point of visiting the VLA for a closer look at the facility.

There are few paved two-lane roads in New Mexico, and those that exist tend to be lonely and breathtakingly scenic. On heading down Route 60 through the Datil Mountain foothills, I came to the Plains of Saint Agustin, a wide, flat plateau about 2100 metres above sea level and surrounded by mountain ranges. It certainly looks like a desert, despite the altitude. I later learned that the NRAO (National Radio Astronomy Observatory in Greenbank, West Virginia), which operates the VLA, chose the site especially because the surrounding mountains mask noise from local radio sources and military installations — such as White Sands missile base at Alamogordo — that would otherwise interfere with signals from space. The site also has the advantage that 85% of the sky can be observed from its latitude of 34 degrees. That area includes the region of the Milky Way's nucleus, which is heavily obscured optically.

Despite the desert conditions, the high altitude means that there is often very low cloud cover over the plateau, even if there is little actual precipitation except in winter. That was certainly true on my visit. It was very eerie being able to see a thin line of mountains on the horizon, yet to have heavy fog only about 30 metres overhead. I felt as if I was inside a sandwich!

Each telescope of the VLA is 25 metres in diameter. Incoming radio waves are first reflected from the primary surface (the dish) towards the secondary surface near the apex of the structure. These waves are reflected downward to a focal point near the middle of the dish. Here the radio waves are converted to electrical currents and transported to receivers inside a room just under the centre of the main reflector.

The facility occupies many square kilometres, and is set back about fifteen kilometres from Route 60. Visitors can stop at the interactive museum and do a hiking tour around the facility and outbuildings. Each antenna is over 28 metres (94 feet) tall, and moves on rail tracks, so the repair maintenance sheds are enormous. The heart of the complex is the computer building, and there are offices for the staff as well as dorms for visiting scientists.

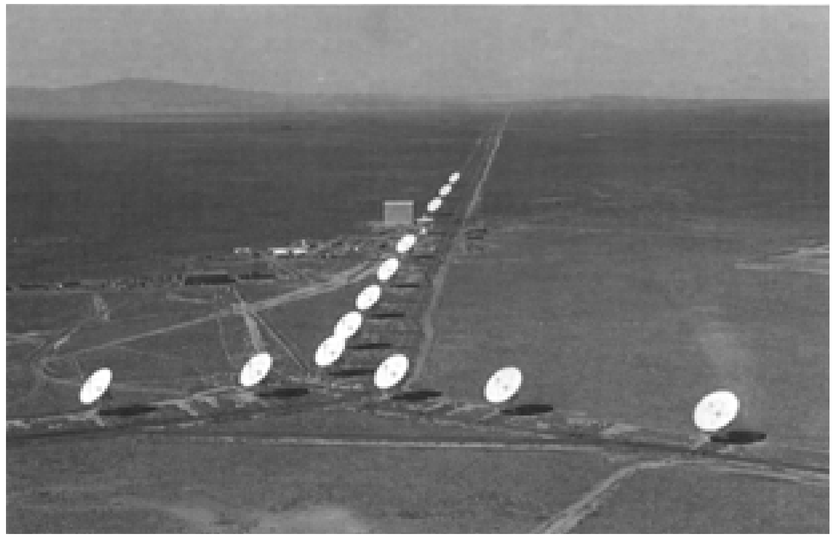
Much to my surprise, I learned that while much of *Contact* was filmed there, the VLA actually does no SETI work at all. The SETI project makes use of the radio dish at Arecibo, Puerto Rico, exclusively. By contrast, the VLA's mission is to map the sky at radio wavelengths, and to act as a component of the VLBA (Very Large Baseline Array) antenna system. The VLBA makes use of radio dishes on Mauna Kea (Hawaii), Kitt Peak (Arizona), the VLA, and the Virgin Islands to act as a 8000-km wide radio dish, and is used to study quasars and other distant objects of small angular size. It is headquartered at the New Mexico Institute of Mining and Technology in Socorro.

The VLA was dedicated in 1980 and completed in 1982 at a set-up cost of US$78.5 million. It consists of 27 movable, co-ordinated, radio dishes on a Y-shaped set of railroad tracks, plus one spare antenna for repair replacement. Like optical telescopes using CCD cameras, the antennae detectors use an extremely low temperature refrigeration system to get clear deep sky signals. Each antenna consists of a 25 metre dish (82 feet) with an aluminum paneled parabolic surface accurate to 0.5 millimetres (20 thousandths of an inch), and can focus radio waves with wavelengths as short as 1 cm. Each antenna weights 235 tons and rises 28 metres (94 feet) tall from its mount.

Signals from each antenna are passed to the banks of computers inside the onsite buildings via a "waveguide," an underground pipe containing electrical cables that allows the antennae and the computers to communicate. Signals from the waveguide are re-amplified, converted to numbers (which show the signal's strength), and sent to the heart of the computer complex — the Co-ordinating Computer. Here signals from the many antennae are combined and matched to form a single, digitized image. After use, a permanent record is made of the image on magnetic tape, which is stored at the VLA archive.

The Y-shaped array is 21 km long on each axis, and, depending upon the configuration and spacing of the antennae, can produce a synthesized radio picture equivalent to a single antenna 27 km in diameter. The antennae are placed in four different configurations to achieve different resolutions, much like a zoom lens on a camera. The wider the spacing between the dishes, the greater the resolution. A staff of 120 serves about 700 astronomers per year at an annual cost of about US$6 million. There is no cost to astronomers for using the antennae, who submit proposals for their experiments to the NRAO, as is the custom for astronomers using optical telescope facilities.

Interstellar space is filled with plasma, a moving mixture of charged particles, electrons, protons, light elements, and simple molecules. When plasma becomes accelerated in magnetic fields it emits electromagnetic waves all the way from the energetic gamma ray and X-ray region to lower energy microwaves and radio waves. All waves travel at the speed of light, but they have different wavelengths, radio waves being the longest. The first radio telescope was built in the 1930s by Karl Jansky, a Bell Telephone scientist. Many later improved versions were constructed, including those at Jodrell Bank, England, and Charlottesville, Virginia. Work began on the VLA in the mid-1970s. At present, radio astronomy is playing an important role in the study of distant galaxies, as well as our own Milky Way. As well, many of the beautiful astronomical subjects we see in color print are actually enhanced composites of optical and radio images.

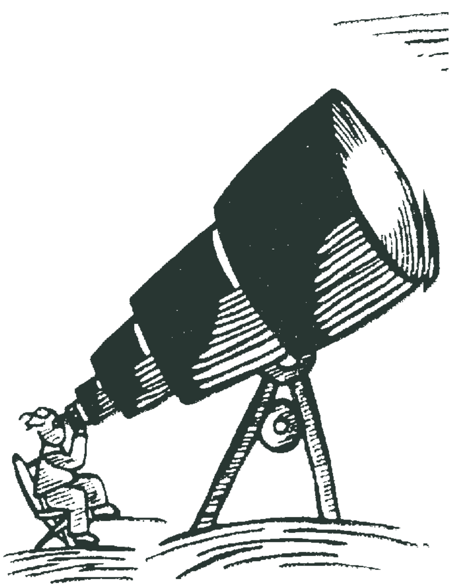


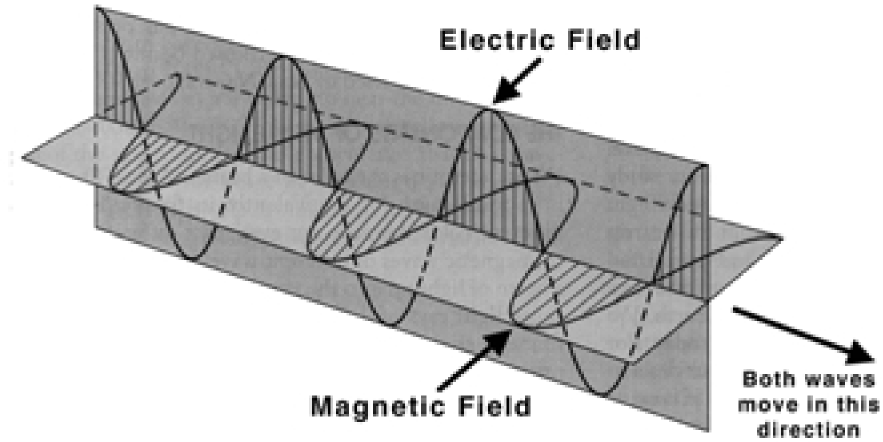
The VLA in the C-configuration, looking down the southwest arm. The sixth telescope along the arm is not in service. Telescope malfunctions occur infrequently and are usually repaired in a few hours. Each of the three arms has nine telescopes. A 28th was also constructed so that maintenance could be made without interrupting operations of the full array. The spare telescope is housed in the rectangular service building.

Although there are other famous government and space-related sites to visit in New Mexico — the Bradbury Museum in Los Alamos, White Sands missile base near Alamogordo, and Roswell — I think my visit to the VLA and New Mexico Tech at Socorro was the highlight of my trip out west. To my mind, that is where the true action is, not with ordnance and hydrogen bombs, but with looking outward and trying to understand better something of the diversity we see in the universe.

Susan Vonesh has been an amateur astronomer for over eight years, two on her own, four with the London Centre, one with the Kitchener/Waterloo Centre, and the past year and a half as an unattached RASC member and member of North Shore Erie Amateur Astronomers out of Simcoe, Ontario. She is a librarian by profession.

Ask Gazer





Dear Gazer,

Welcome back! My question is: Why does light travel? Oh, I know how fast it travels, approximately anyway, and I can look it up to much greater precision than I will ever need, but why does light travel at all? Why doesn't it just hang around where it started from, like some of those slow neutrons that I have read about or like the rocks in my garden.

Cheers and Clear Skies!
Martin Potter

Dear Martin:

Electromagnetic radiation, or "light" as it is known to its friends, has no choice but to move. For all we know, photons might actually want to stay in one place for a bit, put their feet up, and interact with an atom or a molson[1]. Unfortunately, they do not have any choice in the matter.

It took a long time for humans to understand why that has to be the case. If you go back in time, you will find that for most of human history, electricity and magnetism were thought of as two totally different phenomena. For many early humans, their only experience with magnetism came from seeing, or using, a lodestone. Lodestones are pieces of magnetite, a mineral that has an inherent magnetic field. If you tie a lodestone to a sting, and let it hang, one end will always point south. People in the northern hemisphere found the other end to be more useful as it always pointed north. As a result, lodestones were invaluable for navigation. For these people lightning was the most common example of electricity, and those who first studied it, if they lived through the experience, made some "shocking" discoveries.

During the nineteenth century[2] scientific inquiry was all the rage. Technology and science had advanced to the point where electric and magnetic fields could be produced and studied in great detail. Some of the scientists who studied the phenomena are still well known: Ampere, who invented the stereo amp, the nine Volta brothers, who invented the nine-volt battery, and, Coulomb who discovered America. It was in the 1860s that a fellow by the name of James Maxwell realized that you could use mathematics to describe the relationship between electricity and magnetism using just four equations. Maxwell's equations, or "Maxwell's Equations" as they are more commonly known, were such a monumental breakthrough in physics that their discoverer was quickly nicknamed "Maxwell Smart."

How do Maxwell's equations help us to figure out why light has to move? Two of the equations are crucial to solving the problem: one says that a changing magnetic field will produce an electric field, while the other says that a changing electric field produces a magnetic field. Now, if you take an electric field and change its strength with a regular pattern, an observer measuring the strength of the field will interpret the change as being caused by the passage of "waves" of electric force. The same would be true of someone detecting a regularly varying magnetic field. Since a changing electric field will produce a changing magnetic field, and vice versa, is it possible for them to reinforce one another in such a way that the electric field sustains the magnetic field and the magnetic field sustains the electric field? The answer is "Yes."

Look at the figure. The changing electric field produces a changing magnetic field, which forms at right angles to the electric field. In turn, the changing magnetic field produces a changing electric field, which forms at right angles to the magnetic field. Do you see how each of the fields looks like a wave? That is what all forms of electromagnetic radiation are, including light: two intertwined fields, one electric

[1] Like other fermions (*e.g.* electron, proton), a molson is an elementary particle with a spin of +5; it should not be confused with the light molson which only has a spin of +4.

[2] The nineteenth century started on January 1st, 1801, and ended on December 31st, 1900, just as the twentieth century (and the second millennium) will end on December 31st, 2000.

and one magnetic. You may recall the musical line from "The Sound of Music": "How do you keep a wave upon the sand?" You cannot. By its very nature, a wave has to move. Maxwell showed that in order for the electric and magnetic waves to keep each other reinforced, they had to scoot along, at a right angle to both fields, at the speed of light, and that is why light cannot stick around in any one place for very long.

In a way, though, light would not be able to enjoy itself even if it could sit in one place to enjoy the scenery. Time dilation is the effect whereby objects traveling near the speed of light register the passing of time more slowly than those traveling at slower speeds. In one of those weird quirks of nature, light experiences the ultimate time dilation as it moves at the speed of light. For electromagnetic radiation, time does not really exist, at least not in the human sense. To an observer, light from the Andromeda Galaxy takes over two million years to travel from its source to meet its destruction when it interacts with the observer's retina. As far as the photon is concerned, it is created in one place, and immediately destroyed in your eyeball, over two million light-years away. Strange, eh? These sorts of things are best contemplated with the help of some elementary particles, and a fermion sweep of my refrigerator has just turned up some excess molsons which should be disposed of...

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

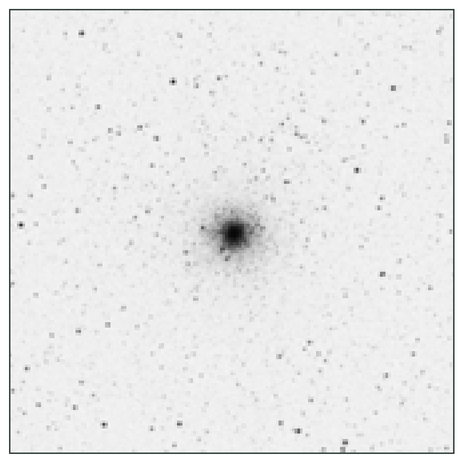
At the Eyepiece

Rare Diffraction-limited Observing

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

If you observe frequently, you will eventually be rewarded with a few rare nights of high resolution observing that you know you will never forget.

One such night was August 9–10, 1999, at the Mount Kobau Star Party, held in the southern interior of British Columbia. That night stars more than 30 degrees above the horizon were not twinkling at all to the unaided eye, while those closer to the horizon were exhibiting only slow scintillation. Well-known Edmonton mirror-maker Barry Arnold and I were observing with his 16-inch f/3.7 Dobsonian. The Sagittarius globular cluster M54 was our first target. Until two years ago, M54 was just another run-of-the-mill-somewhat-faintish-Messier-globular, far overshadowed by such nearby splendours as M55 and M22. M54 was then recognized to be by far the brightest extragalactic globular cluster, a part of the recently discovered Sagittarius Dwarf galaxy that the Milky Way is currently tidally disrupting, but has not yet cannibalized. Since that discovery, I had been waiting for a suitable opportunity to try to resolve M54, which culminates only 10.5 degrees above Kobau's south horizon. The 16-inch showed a small bright core in the concentration class III globular. At 300× there were several brighter stars on the following part of the halo, presumably just foreground Milky Way stars — but, in addition, there were sprinkles of resolution in the granular halo — extragalactic stars! John Herschel said that M54 was "well resolved, clearly seen to consist of stars which are chiefly of 15th magnitude with a few outliers of 14th magnitude."



A digitized sky survey image of M54 in Sagittarius, by far the brightest extragalactic globular cluster and part of the recently discovered Sagittarius Dwarf galaxy.[1]

Later that night, when the giant planets became well placed, Arnold's 16-inch swung to them. Interesting features seen on Jupiter while using a blue filter at 260× included the thin North North Temperate Belt (NNTB), scallops and contrast features on the North Temperate Belt (NTB), several festoons in the Equatorial Zone (EZ) including a very long one, the Equatorial Belt (EB) which

[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.

has become unusually prominent this year, Io's shadow on the South Equatorial Belt (SEB), a small dark core to the otherwise pale Great Red Spot, and a tiny dark spot in the South Temperate Belt (STB) — smaller than Io's shadow — preceding the Great Red Spot. There were white ovals in the zone between the South Temperate Belt (STB) and the South South Temperate Belt (SSTB).

It was Saturn that provided the thrill of the night (and the impetus for this column). At 260× we admired the mottled detail in its South Equatorial Belt and the gray or blue-gray colour of the crepe ring. Then Barry Arnold pointed out spokes extending from the crepe ring 20 percent of the way across the B-ring, on the following side of the rings. He had seen spokes in Saturn's rings before, but it was my first view of this "Holy Grail" of planetary observing.

I am aware of a few other sightings of spokes in Saturn's rings by RASC observers:

At the 1998 Mount Kobau Star Party, Larry Wood viewed Saturn at 510× with his 12.5-inch f/6 Newtonian. He wrote: "What a stunning view! Encke's gap easily visible, and thanks to Murray Paulson who first noticed them, the spokes on the outer part of the 'crepe' ring and into the inner edge of the 'B' ring were visible." Later that year he and Bruce McCurdy saw the spokes from Edmonton using a 7-inch Astro-Physics Star Fire refractor and a Celestron 14-inch SCT. Wrote Larry Wood: "The spokes are a very subtle feature and we could just see them in a couple of places... Imagine, if you can, a cloud of material blocking the light from striking adjoining parts of the crepe and B rings so that those areas are just a tad fainter then the unaffected areas of the same rings..."

Windsor Centre's Dan Taylor saw the spokes in the B-ring on October 22, 1992 — a night of exceptional seeing even at Saturn's then southerly declination — with his 20-inch Dobsonian, which features a Galaxy Optics mirror. Then, on September 18th–19th of this year, at the Astrofest convention near Chicago, he had another memorable view of Saturn with an 8-inch Astro-Physics apochromatic refractor. He reports: "Saturn's disk was laced with delicate detail. At 332× three distinct spokes could be seen within the B ring. Radial shadings could be discerned in all three rings. Texturing and unconfirmed fine detail were noted in the A-ring. Nearby, at the Astro-Physics compound, a 7-inch Star Fire yielded a nearly identical image."

"In morning twilight at 12:40 UT I had my second-ever view of Encke's Division in the outer part of Saturn's A-ring at 348×. The crepe ring was continuously visible, while the Saturnian South Equatorial Belt had an elongated (east-west) darker area on the central meridian on the equatorial side of the belt."

There were a number of nights of excellent seeing in southern British Columbia during September, 1999, and the Okanagan Centre's president, Ron Scherer, detected Encke's Division in Saturn's A-ring on two nights. His 10-inch f/6 Dobsonian has a mirror figured by John McKee of Comox on Vancouver Island.

Another very memorable night for me was September 14th this year. At 10 UT that night the combination of excellent seeing and transparency allowed me to use my 16-inch f/4.5 Meade Newtonian at 261× to glimpse blue supergiant stars in the OB association NGC 206, which is in the Andromeda Galaxy. I had been waiting for the perfect night to attempt a sighting of these massive young stars, which have an intrinsic luminosity of about 250,000 times that of the Sun! The previous afternoon the weather charts showed that a major upper ridgeline was forecast to pass over the southern interior of British Columbia at 12 UT. That meant that very good seeing was likely. In fact, it turned out to be excellent. In preparation for the hunt I had uncovered my mirror in the early evening, and by 10 UT it had been cooling for eight hours. The transparency was also excellent; for the third night in a row M33 was a naked-eye object. Lastly, M31 was in the zenith. Within M31, the star cloud NGC 206 was overlain with the four or five brighter Milky Way stars that are normally seen, but behind them were perhaps eight stars flickering in and out of visibility at the limit of vision, which is about magnitude 15.6 on that telescope.

I carefully checked four areas of the same size immediately surrounding NGC 206, but did not see any stars in the magnitude 15.5 range in those areas. I am therefore confident that the majority of the glimmerings that I saw were indeed some of the roughly 70 blue supergiants that are so prominent in NGC 206 in the colour photograph of the galaxy taken by the Palomar 48-inch Schmidt camera. While there are other OB associations in M31, nowhere else on photographs of the galaxy is there such a marked concentration of blue supergiants. A careful examination of the Palomar photograph showed eight blue stars that were definitely brighter than the many other blue supergiants in the star cloud, matching my observation. Apparently professional studies list the brightest true stars of NGC 206 as being in the range of magnitude 16.5. However that is surely a photographic magnitude. Since photographic magnitudes are consistently fainter than visual magnitudes, typically by around 0.8 magnitude, it does indicate that the brightest stars in the Andromeda Galaxy should indeed be within the grasp of a 16-inch telescope on a perfect night.

On the same night of exceptional seeing, noteworthy features on Jupiter at 348× and 522× included a large vaguely kidney-shaped darker area in the North Polar Region (NPR), a chaotic jumble of red-brown and white areas within the mostly doubled North Equatorial Belt (NEB), many darker patches, with an especially dark elongated (east-west) patch on the preceding end of the NEB on its northern edge, an unusually large gray festoon on the following side extending from the NEB into the Equatorial Zone, the prominent Equatorial Band, and the South South Temperate Belt (SSTB), which was far wider and darker than the faded, thin South Temperate Belt — very unusual. There was a wide white zone between the SSTB and the South Polar Region (SPR) — I do not recall ever before seeing such a wide zone at that latitude. Even the SPR exhibited a darker contrast feature. The four moons could be distinguished by the diameters of their disks alone, easily graded by size.

In morning twilight at 12:40 UT I had my second-ever view of Encke's Division in the outer part of Saturn's A-ring at 348×. The crepe ring was continuously visible, while the Saturnian South Equatorial Belt had an elongated (east-west) darker area on the central meridian on the equatorial side of the belt.

As I write this in late September, it is with the knowledge that by late autumn when the gas giants conveniently culminate during the evening, the strong winds aloft, characteristic of that season, will very probably ensure that I will not enjoy the memorable "diffraction-limited" views allowed by the massive upper ridges of September 1999.

Notes:
In my June column I wrote, "The colours of the stars of Alpha Herculis are perceived as orange and green not only by my eyes, but also by the eyes of every human observer that I know." At Starfest, Terence Dickinson told me that he saw the companion star as blue. I later received E-mail messages from Daryl Dewolfe, Ron Scherer, and Richard Weatherston also indicating that not everybody sees the companion as green. Well, I should have known better than to use an absolute term like "every." Certainly, different observers have different colour perceptions. For example, my eyes always see solar prominences during totality as bright pink, but I have read descriptions calling them red, ruby red, and even orange. My intention was to suggest that observers allow themselves to enjoy aesthetically the contrasting colours that their eyes perceive in some double stars, and not let any writer tell them that such colours are astrophysically impossible.

The All Splendours, No Fuzzies Observing List will continue in the February issue with the spring section of the list.

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.

The History of Astronomy

Medicine Wheels

by Barbara Silverman, Montreal Centre

Most people today have a difficult time thinking of Stone Age people as astronomers who were capable of building functional observatories, but there is an old saying, "Truth is stranger than fiction." The truth is that ancient people knew more about the skies than most of us alive today, living as we do in densely populated brightly-lit cities. We have no need to look up at the heavens to know the times of planting, harvesting, or holding celebrations. That information, printed on sheets of paper, has already been organized for us. Such was not the case in prehistoric times.

When we think of astronomy and civilizations of the past, the Babylonians, Greeks, and Egyptians automatically come to mind. But there were others. Stonehenge, originally thought to be a place for sacrifices and burials, is in truth also a calendar aligned to the summer and winter solstices. Closer to home we have the Inca, Olmecs, Maya, and Aztecs, who we now know possessed advanced astronomical knowledge, but how many of you know about Chaco Canyon, New Mexico, and the astronomy left behind by the Pueblo dwellers? Have you heard of the Bighorn Medicine Wheel, or of the more than one hundred other wheels, many aligned to the sky, that were left by the Plains Indians?

Over the last twenty to thirty years, thanks to a variety of people who are always searching for answers, a new interdisciplinary study has emerged, that of archeoastronomy. Through it, new and fascinating information has surfaced that has painted a very different picture of the prehistoric peoples who lived on the Great Plains.

The Bighorn Medicine Wheel lies on Medicine Mountain, part of the Bighorn Range near Sheridan, Wyoming. It is found at an elevation of 2900 metres, above the timberline and just below the summit. Because of its location, snow makes it inaccessible for all but two months of the year. Why would something available only from mid-June to late August be of any importance? We shall take a look.

Back in the 1970s, solar astronomer John Eddy of the High Altitude Observatory, National Center for Atmospheric Research in Boulder, Colorado, began to investigate the astronomical connections of the Bighorn Wheel. Beginning his studies a few days before the June solstice in 1972, he quickly discovered why such a location had been chosen. Not only did the site afford an excellent view of the horizon, but, should the harsh climate decide on a summer snowfall, the fierce winds quickly swept the spot clear of any offending snow.

Although it is estimated that the Bighorn Wheel was built between 110–1700 CE, its builders and its exact purpose are still unknown. Legend says that it was built by "people who had no iron," and the Crow Indians refer to it as the Sun's Tipi. Because of similarities between the Wheel and the Sundance Lodge of the Cheyenne and Cree, experts hypothesize that the Wheel was constructed by ancestors of the Cheyenne and Cree, possibly by the Tsistsistas, forerunners of the Cheyenne.

The site consists of a wheel-shaped stone pattern with a diameter of 26 metres (slightly smaller than Stonehenge's Sarsen circle of 29 metres). In the centre lies a doughnut shaped stone cairn three metres in diameter and 60 centimetres high. From the central cairn to the rim run a series of spoke-like lines, twenty-eight in number (possibly only twenty-seven originally). There are six peripheral cairns, five outside the rim and one inside. Of the five outside cairns, one extends four metres past the rim, while the other four lie just at the rim. The six cairns are only 15 to 30 centimetres high, with a diameter of 1.2 to 1.8 metres.

What has the site to do with astronomy? It is simple. Like Stonehenge it has a June solstice alignment. Looking from the cairn along the extended spoke across the centre of the central cairn to the low northeast ridge, you view along the horizon direction corresponding to the sunrise point at the June solstice. The direction from the southeastern cairn across the central cairn toward and just north of the northwest cairn runs along the direction of the sunset point for the June solstice. Three other cairn alignments correspond to directions for the heliacal risings of Aldebaran, Rigel, and Sirius. (Heliacal rising marks the first day of the year when you can see a star in the predawn sky.)

The direction running from the northwest cairn to the north cairn appears to be associated with the rising of Aldebaran. During the period 1600 to 1800 CE, Aldebaran rose heliacally a day or two before the summer solstice, like a runner announcing the approach of a royal procession. Today, the solstice occurs around June 21st, and Aldebaran rises too close to the Sun to be observed.

The direction running from the northwest cairn to the east cairn appears to be associated with the rising of Rigel. Between 1600 and 1800 CE, Rigel first rose in the predawn sky twenty-eight days after the solstice, thus marking the commencement of another month. The direction running from the northwest cairn over the central cairn towards the southeast cairn appears to be associated with the second month after the solstice, since it points to the rising of Sirius in Canis Major. From 1600 to 1800 CE Sirius rose in the predawn sky twenty-eight days after Rigel's appearance.

Although such alignments will explain the locations of five of the cairns, Dr. Eddy was unable to find any alignment for the sixth one. That honour fell to Jack Robinson of the University of South Florida. A view from the northwest cairn south over the southern cairn, gives you the direction for the heliacal rising of Fomalhaut. In the years from 1050 to 1450 CE, Fomalhaut rose in the predawn sky thirty-five days ahead of the June solstice. Perhaps the alignment was an advance messenger, allowing the Wheel's users time to make the necessary preparations required for religious celebrations.

To the prehistoric peoples the June solstice was of major importance, but precision was not as necessary then as it is today. They did not have wristwatches. Nevertheless, the medicine wheel provided adequate information for its intended purpose.

Unlike the people in some science fiction episodes, we are unable to journey back in time to speak with, or to observe the builders and users of the Wheel. Although there seems to be little doubt as to the astronomical alignments of the Wheel, it is worth investigating the question, "Was the construction by chance?" Studies of other similar sites, such as the Moose Mountain Medicine Wheel or the Roy River Medicine Wheel, indicate that they were built to serve not only for religious purposes, but also as calendars.

Located mostly on the Great Plains are over 130 such monuments. Some like Bighorn Wheel have definite alignments, others less so. Some, with the knowledge we have on hand, show no astronomical connections. Their designs are all similar, with a series of stone rows radiating from a central hub or cairn. Some have rims and additional cairns, while others do not. All were built on hillsides, plateaus, or mountaintops with a clear view of the entire horizon. As viewed from above, their shapes appear to represent the Sun symbol.

Investigators trying to determine the astronomical significance of the wheels are faced with two problems: dating and precession. Dating is accomplished from the study of on-site artifacts by employing such techniques as tree-ring analysis of limbs and tree pieces, or carbon dating of campsite materials. When artifacts are either left or destroyed by later visitors, severe problems in dating result.

Then there is the matter of precession. The sky of yesterday appeared slightly different than it does today because of the effects of precession of the equinoxes. Precession alters the times and horizon directions for the rising and setting of specific stars. The confirmation of astronomical alignments for features of medicine wheels with the rising or setting of specific stars therefore requires a knowledge of the dates when the medicine wheels were constructed. Here we have an interesting paradox. The dating of artifacts at a site helps to specify the time period when it was used. That date in turn specifies the precession corrections required to modify the sky as seen today to that viewed by the users of the wheel. On account of precession, the alignments at a site are specific to a particular time period when the rising or setting of specific stars occurred at the corresponding horizon points. The confirmation of obvious alignments for the features of medicine wheels with the rising or setting of bright stars can therefore indicate the time interval when a site was in use, which helps to confirm the date determined for the site's construction.

Bighorn Wheel is estimated to be only a few centuries old, but the Majorville Cairn in Alberta has been dated to an age of 4,500 years. That is as ancient as the pyramids at Giza, making the Majorville Cairn perhaps the oldest of the known wheels. It consists of numerous spokes, a rim, and a fifty-ton central cairn. It was undoubtedly built with considerable effort, but unfortunately it has been badly vandalized, making it very difficult to determine possible astronomical connections.

The Roy Rivers Medicine Wheel in Saskatchewan may be connected to the Sundance ceremony of the Plains Indians. The site was surveyed by archaeologists Alice and Thomas Kohoe, who discovered that there are some similarities between the wheel and the Cree Indians' Sundance Lodge on the Sweetgrass Reserve in Saskatchewan. There is a marked central space, for example, an entrance to the south, a surrounding ring, and stations marked in stone for the dancers. Interviews with Cree tribal elders, while interesting, have not indicated a definite connection. Yet the main axis of the temporary camp established by the Cree for their three-day sundance ceremony aligns with the sunrise point.

"When we think of astronomy and civilizations of the past, the Babylonians, Greeks, and Egyptians automatically come to mind. But there were others … Closer to home we have the Inca, Olmecs, Maya, and Aztecs, who we now know possessed advanced astronomical knowledge."

The Fort Smith Medicine Wheel possesses an ill-defined June solstice sunrise alignment. Located in southern Montana on the Crow Reservation, the Fort Smith wheel has neither a rim nor any associated cairns other than the central one from which six spokes radiate. While the longest, most distinct spoke does appear to align with the solstice sunrise point, other alignments have yet to be found.

The Trail Ridge Wheel in Northern Colorado also possesses an alignment with the sunrise point for the June solstice. It is a very primitive wheel, and lies 3400 metres above sea level in Rocky Mountain National Park. It has only two lines of stones, fifteen metres in length, running northeast and southwest from a central cairn. Although the wheel lies near an old Ute Indian trail in an extremely inhospitable spot, the line of sight along one spoke through the central cairn does indicate a solstice alignment.

Next is the Moose Mountain Medicine Wheel in southeastern Saskatchewan, 680 kilometres north of the Bighorn wheel. The astronomical alignments of the two wheels are the same, except that there is no June solstice sunset alignment at Moose Mountain. The site was surveyed by the Kohoes, who collaborated with Eddy in 1975 to establish celestial alignments. Basically the astronomical plan of the Moose Mountain wheel is the same as that for the Bighorn Wheel, although the sites differ in appearance. Moose Mountain's central cairn is larger, with its 9-metre diameter and a 1.5-metre high central cairn containing eighty tons of rock. There is also an oval-shaped rim surrounding the central cairn that is much smaller than Bighorn's flattened outer rim. It has only five spokes radiating from the hub, all extending far beyond the rim. The largest spoke runs 37 metres southwest from the centre, forming the summer solstice sunrise line. That spoke is four times longer than the rim's radius. Located near the cairn, at the spoke's end, there is a small sunburst arrangement.

Similar sunburst arrangements are found at the Fort Smith Wheel as well as in the Minton Turtle Wheel, which is located in south central Saskatchewan. The latter wheel is perhaps 2,000 years old. At the time of its construction, the direction for the site alignment corresponding to the heliacal rising of Aldeberan is correct for the time period from 150 BCE to 150 CE. That for the heliacal rising of Sirius is correct for the time interval 0 to 1000 CE, while that for Rigel is correct for the modern era. The alignment for the rising of Aldebaran is perhaps the most sensitive test for specifying the date of construction, since Aldebaran's declination is most affected by precession. The site alignments proposed for all three stars do appear to fit into the proper time frame.

The Moose Mountain Wheel also appears to have a connection to Fomalhaut, in similar fashion to the Bighorn Wheel. When viewed from the site's northwest cairn along the direction to the southern cairn, Fomalhaut would have risen heliacally in that direction during the interval from 600 to 900 CE, about a week before the summer solstice. That presents a potential interval of calendric use for the Moose

Mountain Wheel of over 100 years.

To fully appreciate the significance behind the medicine wheels, it is necessary to have a brief understanding of the customs of the Tsistsistas/Cheyenne and their ceremony called the Massaum, which retells the story of creation. Researchers believe that the medicine (or spirit) wheels, called *oxemeo*, allowed the shaman to call down the spirits. In the re-enactment of the Massaum ceremony, there are three canine celestial gamekeeper spirits. Only certain stars, because of their colours, can portray the spirits.

Red Wolf or Wolf Man is represented by the red star Aldebaran. White Wolf or Old Woman is represented by the white star Sirius. The Kit-Fox or Yellow-Haired Woman is represented by the blue star Rigel. The blue star representation is notable throughout the ceremony by a blue painted bison skull, blue on the faces of the nine participants, and blue lines on the faces of the Kit-Fox performers. The Tsistsistas/Cheyenne ceremonial season begins in June, when the Sun is at its "strongest," bringing growing power to the Earth. It commences with the rising of Aldebaran, and ends fifty-six days later in mid-August with the rising of Sirius. The Massaum ceremony ends in July with the rising of Rigel.

There is a story that it took one shaman eight years of studying the skies before he was able to foretell the coming of the summer solstice. When one considers the sizes and positions of many of the wheels, it seems clear that their construction must have resulted from immense dedication, a dedication that could not have been accidental. The constructors may not have understood the skies as we do at present, but they were attuned to them. Changing times can often be associated with the loss of ancient knowledge. Today we no longer stand on a barren, cold mountaintop to witness the power of the Sun at the time of the summer solstice, nor do we call down the spirits through medicine wheels. Yet are we truly that much more knowledgeable than those long-gone shamans, who had a gift that we may lack?

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.

Scenic Vistas: Stardust Oases in the Milky Way

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

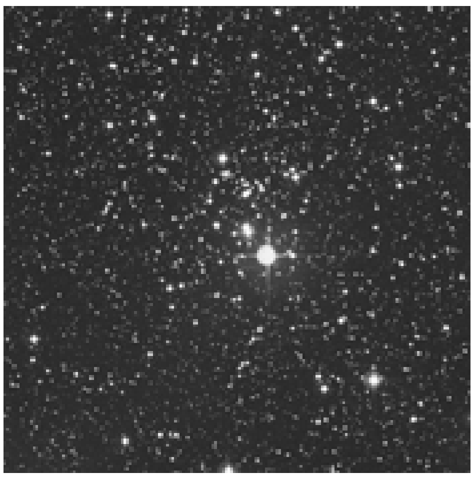
There are many star clusters dotting the winter Milky Way that are of interest to the amateur astronomer. They lie in the Monoceros/Canis Major/Puppis tract of the winter sky. Almost sixty clusters north of declination −30° are plotted on *Sky Atlas 2000.0* in that region. Naturally, not all of the objects are spectacular, but many of them are beautiful and rival the best Messier clusters in the region. Happily, they can be picked out even in light polluted conditions with moderate-sized telescopes. While an exhaustive article is far beyond the scope of the present discussion, a "Winter Sky Top 10" might be an interesting exercise.

Any discussion of winter star clusters must begin with NGC 2244, the star cluster that illuminates the Rosette Nebula. The nebula itself is a notorious object, easily picked up on film emulsions but often frustrating for the small telescope user who is attempting to observe it visually. When I first came upon the bright, coarse cluster in the 1980s, I saw absolutely nothing of the nebula. Years later, from a darker site and armed with a much larger telescope, I had an intriguing view of both cluster and nebula using a Deep Sky filter at a magnification of 48×. The light from the Rosette is very similar to that seen in the North American Nebula. The visual impression is one of observing grayish, sooty smoke that appears only feebly illuminated. The star cluster itself is quite bright and well defined, dominated by four sixth magnitude stars that make a rectangular shape, elongated NNW/SSE. Even small telescopes should reveal at least 50 cluster members.

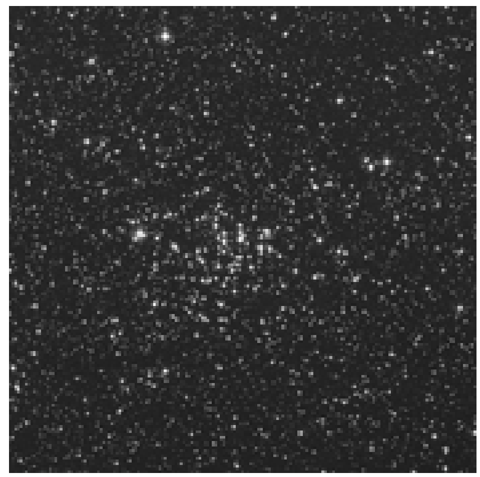
Another large coarse cluster involved with nebulosity is close by — the extraordinary "Christmas Tree" cluster, NGC 2264. Once again, the nebulosity here is difficult to pick up with a small telescope, but starts to reveal itself in large telescopes under dark skies. If you are looking for nebulosity and have a ultrahigh contrast (UHC) or [O III] filter, the best place to start is the northern edge of the cluster around fifth magnitude 15 Monocerotis. Some nebulosity may also be visible to the southwest surrounding a subgroup of five stars. The cluster itself is a large, scattered group that really does appear to mimic the outline of a Christmas tree. The Cone Nebula, the most spectacular

NGC 2264

NGC 2301



NGC 2353



NGC 2360

NGC 2506

NGC 2539

A selection of clusters discussed in this article from the Digitized Sky Survey. All fields are 0.5° × 0.5° except for NGC 2264 which is 0.75° × 0.75°.[1]

[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.

region of nebulosity located at the northern tip of the cluster, was invisible in my 15-inch reflector in December 1993.

I have mentioned NGC 2301 in this column before, but it is such a gorgeous star cluster that its description bears repeating. I will never forget the night in January 1989 when I first came upon the cluster from the backyard of my Dorval home. Even in light polluted conditions with an 8-inch telescope, the cluster appeared spectacular; a long north-south chain of stars dominated by a half dozen stars of the eighth or ninth magnitude, with a fainter spur of stars running off towards the east. Surprisingly, the cluster does not make it into the "Finest NGC Objects" list of our *Observer's Handbook*. Consideration should be given to include this beauty.

Another greatly elongated cluster in the Monoceros Milky Way is NGC 2251. This attractive cluster has most of its members strung out along an axis oriented SE/NW. The two brightest stars are around ninth magnitude, with the rest fainter, to about magnitude 13. Despite its location in a rich star field, the 30 visible cluster members stand out well.

Another Monoceros cluster that is a good target for a small telescope is NGC 2353, located a little less than 10 degrees northeast of Sirius. In March 1993 my observing notes described the object as "a very large, showy cluster of brilliant little jewels arrayed to the northeast of a sixth magnitude. At least 40 stars resolved in a 20 arcminute area, many of the stars arranged in tight pairs."

Shifting 45 minutes of right ascension almost due east will bring us to NGC 2506, a compressed cluster that may present a bit of a challenge for the small telescope user. In my 15-inch reflector the cluster appeared mostly unresolved and quite compressed. The unresolved mass was pretty much crescent-shaped with two magnitude 11 stars resolved on its western cusp. Many more stars of twelfth magnitude and fainter appeared suspended over the nebulous haze.

A similar cluster is visible over the border in Canis Major, about 35 minutes of right ascension ENE of Sirius. I observed NGC 2360 on a spectacular spring night in late March 1993 when I made an extensive tour of the clusters in the region with my old 8-inch Schmidt-Cassegrain. NGC 2360 was the showstopper of the evening, a cluster I described as "an absolutely spectacular cluster of faint star dust. A small, well-resolved, very compressed grouping, elongated east/west with a conspicuous spur angling off to the southeast. The stars are tightly packed and a strong background haze of unresolved members strung out along resolved members is evident. Possibly 50 stars resolvable."

If you are looking for a cluster that is easy to locate, just aim your telescope towards the hindquarters of Canis Major, centring your finder on fourth magnitude Tau Canis Majoris. No other adjustments are necessary. Gaze into your eyepiece and you will be confronted with NGC 2362, a bright well-resolved cluster that easily cuts through suburban light pollution. Most of its stars are luminous O and B giants, and there is some debate about whether Tau Canis Majoris is a member or not. Its spectral class is O9 III, identical to Iota Orionis and, if it is located at the same distance as the star cluster, it becomes one of the Milky Way's major luminaries, with an absolute magnitude of −7.

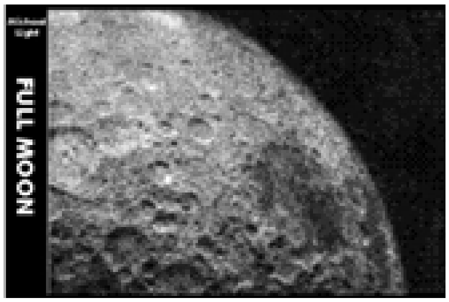
We can round off the present review with descriptions of two clusters in the constellation of Puppis. The clusters were featured on the January spread of the RASC's 1998 *Observer's Calendar*. Located NNE of M47, NGC 2423 is a fairly bright, attractive cluster. The cluster is about 10 arcminutes in diameter, and its stars are primarily of magnitude 11 grouped around one ninth magnitude luminary. I noted a curious subgroup of eight stars immediately ENE of the cluster. The subgroup stands out well in Peter Ceravolo's calendar photo.

We have saved one of the best for last. NGC 2539 is a superb, well-resolved cluster preceding the bright field star 19 Puppis. The cluster members are quite uniform in brightness, predominantly of magnitudes 11 and 12. About 80 stars are visible in a 20 arcminute area, with strong evidence for sub-clustering, most members being arranged in clumps of three to ten stars. Although the cluster appears to be located in a rather blank area of the sky for northern observers, it is well worth seeking out.

To see most of the above objects to best advantage, I would suggest using low to medium magnification. If you intend to do a sketch from your observations, by all means use high power to help resolve tighter cluster members and to aid in producing an accurate drawing. For many amateur astronomers, the observation of star clusters is one of the ultimate aesthetic pleasures of our hobby. For sheer beauty, low and medium magnification usually surrounds these starry oases with plenty of dark, though star-flecked, sky. Dust off your telescope and familiarize yourself with the winter Milky Way.

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.

Reviews of Publications
Critiques d'ouvrages



Full Moon, by Michael Light, pages 244, 28 cm × 28 cm, Sky & Telescope Observer's Guides Series, Alfred A. Knopf Publishing, 1999. Price US$50 (CDN$75) hardcover. (ISBN 0-375-40634-4)

Just as a low-power telescopic view of the Moon is often appreciated more because it provides a view of the entire object framed by the darkness of surrounding space, epic events are often better understood through the wide angle lens of history. That certainly applies to the *Apollo* Moon missions. In their day they represented the cutting edge of exploration and rapidly evolving technology. Front and centre in the public eye, they were the vicarious adventure of a lifetime. Imbued with a single-mindedness of purpose stated by John F. Kennedy's audacious goal, and fueled by a seemingly limitless budget, the race to the Moon was more of a sprint than a marathon. Once past the finish line, our attention wavered in our certainty that better things were bound to follow.

Now that we have resumed our normal footwork — stumbling about, stubbing our toes, stomping the downtrodden, stampeding toward the cliff — Neil Armstrong's small step looks ever more like humankind's giant leap. Accomplished in barely a decade, the Cold War's second greatest triumph — behind only the non-event of avoiding a nuclear holocaust — stands out as one of the high points of a turbulent century.

In recent years, an overview of the significance of *Apollo* has finally begun to emerge. Spurred by the irresistible conjunction of fin-de-siècle retrospectives of all sorts, the retirement of many of *Apollo's* key figures, the declassification of numerous documents, tapes and photographs, and the maturation of the nostalgia industry's "Best After" date, a variety of general interest publications in various media have recently come to the fore. They include Andrew Chaikin's outstanding overview of *Mission Apollo, A Man On the Moon*, Tom Hanks' highly-acclaimed mini-series *From the Earth to the Moon*, Jim Lovell's memoirs *Lost Moon*, the related Hollywood motion picture, Robert Zemeckis' *Apollo 13*, and *Apollo: An Eyewitness Account*, a collection of original paintings by *Apollo 12* Moonwalker Alan Bean.

The latest addition to this collection is *Full Moon*, a visually stunning compilation of photographs chosen by Michael Light. For all of NASA's self-hyped freedom of information, until now the "American way" has been to bury the 32,000 (!) photographs taken by the *Apollo* astronauts in a freezer (in Area 51, perhaps?), leaving a visual legacy of short, poor-quality video clips primarily from *Apollo 11*, and a couple of dozen impressive but timeworn colour photos that graced the likes of *Life* and *National Geographic* way back when.

That has changed, and in a big way. NASA granted author Light access to the entire archive of "master duplicates," one level removed from the originals. Whereas previous photos had been degraded by several generations of duplication, Light uses modern digital reproduction techniques that render images of stunning detail. *Full Moon* contains some 130 large-format (25×25 cm) pictures photographed by the astronauts and selected and remastered by Light.

It takes a few pages to get into the meat of the book. Light has chosen to lay out the images in a pseudo-chronological sequence, as if all of the *Apollo* flights were condensed within a single mission. The opening pages show a launch sequence, followed by photographs in Earth orbit, and eventually, the approach to the Moon. The first section ends with a series of spectacular photographs of the lunar surface taken from orbit at a height of 60 nautical miles (110 km). Most of them were taken not before the landing, as suggested by the sequencing in the book, but by the command module pilot during his solo flight, while his two companions were on the surface. Such detailed mapping photography was an important element particularly of the final three *Apollo* missions — the so-called "J missions" — which received little attention or publication at the time, but which yielded spectacular Moonscapes of which Earthbound observers can only dream. One foldout sequence of four consecutive mapping images shows the area around Timocharis, a mid-sized (34 km) crater in the lava plains of Mare Imbrium. The series shows Timocharis to be a major excavation with terraced walls, a sharp rim, and a complex ray structure. It also reveals the self-similarity of crater structures on a scale much smaller than can be seen from Earth, although I for one will be looking with a fresh eye the next time the area is well placed for observation.

The centrepiece of the book consists of a selection of some 60 photographs taken by the astronauts on the lunar surface using Hasselblad 70-mm cameras. The first few photos show astronauts at work around the lunar module, deploying experiment packages and the like. Light pays attention to mundane details, such as discarded equipment and grimy space suits. There are several close-ups showing the remarkable texture of the lunar surface, including before-and-after shots of Buzz Aldrin's footprint on previously pristine soil.

There follows a breathtaking sequence of lunar landscapes. They too are almost exclusively from the J missions, *Apollos* 15–17, which is not surprising when one considers that those missions had the most challenging and visually interesting landing targets, that each consisted of three long-duration moonwalks, and that the astronauts had a far greater range of motion courtesy of the lunar rovers that were an integral part of the missions. It is unfortunate that the media and the public had all but tuned out by that point. The last three missions were by far the most interesting from a scientific and an aesthetic point of view.

Although the astronauts were not professional photographers, and had difficulty framing their images properly because their cameras were chest mounted, the colourless grandeur of the vistas is reminiscent of the work of the American Midwest landscape photographer Ansel Adams. With one notable exception, whereas great landscape photography on Earth is usually complemented by a complex background sky, the space above the lunar terrain consists of utter blackness. The payback for the absence of atmosphere comes in the truly remarkable amount of detail visible in the lunar features. The reasons for that are twofold. First, all features are lit by harsh, unfiltered sunlight. Secondly, there is no atmospheric extinction between the lighted feature and the observer (or camera). The magnificence of some features is obscured by the very lack of obscuration. For example, in one photograph, Mount Hadley looks like a sand dune just over the next rise rather than a 4,500-metre mountain more than ten kilometres distant. There are no visual clues such as intervening haze or clouds — or for that matter familiar measuring sticks such as trees or power poles — to provide a sense of scale.

Adding to the effect, I feel, is the nature of the images reproduced here. They have in effect been digitally remastered. Audiophiles have long complained that perfectly reproduced sounds in a digital format like CDs lose some of the "warmth" of their analog originals. Colder, harsher views of the Moon, on the other hand, simply intensify what is actually there. Of particular note are the four, metre-wide, foldout panoramas: the astronauts routinely took a series of photos around each major collection site, which have been almost seamlessly correlated by Light using modern electronic stitching techniques.

While the photos published in magazines at the time were predominantly in colour, Light has tended towards black-and-white film as the medium of choice. That is for good reason. The finer grain of B&W film reveals an almost unreal clarity of detail. The lunar surface is nearly colourless in any event — an exception being patches of orange soil discovered by *Apollo 17* geologist-astronaut Jack Schmitt — and the colour film that was used was biased towards an Earth-atmosphere spectrum.

The final, smaller group of photographic plates deals with the return to Earth. Here colour film is used to excellent effect, as the returning astronauts draw ever closer to our island oasis in space. There is a series of magnificent photos that would be of particular interest to the atmospheric scientist. The final shot of the Pacific Ocean seen through the command module window shows a deceptively similar topography to some of the lunar terrain as seen in the previous photographs. The clue to the Earth's liquidity, motion, and to life itself resides in its marvelous ultramarine hue.

The photographic section is devoid of captions or text of any kind. Light considers words to be an unnecessary distraction from the beauty of the images of our airless satellite. Only at the end of the journey has he included two outstanding essays. Andrew Chaikin draws on his wealth of knowledge and many interviews with the astronauts to summarize the physical and emotional impact of the journey. (In fact, I would recommend Chaikin's *A Man On the Moon* as the perfect companion volume to *Full Moon*. As for a companion soundtrack, I can think of no better suggestion than John Cage's infamous *4:33*. The lunar photos evoke a sense of absolute, crushing silence.)

Light follows with his own essay describing the photographers and their subject, and his part in accessing and ultimately choosing the photographs. He is at his most eloquent when describing the quality of light. "The best of the black-and-white images share a kind of delineation through distilled light that is at once highly abstract and yet brutally representational, a combination I have yet to see anywhere else and one that makes me feel like I enjoy divine powers of perception. Truthfully, humans were physically never meant to see so clearly and penetratingly, without an atmosphere to soften the edges of the physical world and protect them from the more overwhelming aspects of the Sun's illuminating force."

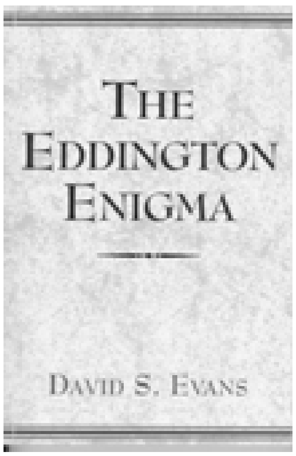
Finally, at the back of the book are thumbnail reproductions of each image, with accompanying captions, that allow the reader to consider the details and perhaps review the photographs afresh.

Is *Full Moon* perfect? Not quite. A few pictures seem to me to be "missing." There are no photos of Neil Armstrong on the Moon, nothing of the *Apollo 12* crew's historic encounter with *Surveyor 3*, no sign of the famous Genesis rock, and no shots from orbit of any of the landing sites, despite the fact that they were chosen from high-resolution photographs from previous missions. (The absence of photos of American flag-waving, on the other hand, was much appreciated by this reviewer.) Side by side photos of the area around the crater Deseilligny (misidentified in the captions as Condorcet) are disconcertingly rotated by 180 degrees. And the total absence of even a small plate number in the page margins makes it difficult to reference images to the captions. But these are quibbles. *Full Moon* would be a fine addition to any coffee table.

Modern attitudes towards the Moon could perhaps be summarized with that oh-so-'90s dismissive "Been there, done that." A trip to *Full Moon* is bound to re-ignite the sense of wonder, of both the magnificence of the destination, and the magnitude of the accomplishment. Been *there*, done *that*!

Bruce McCurdy

Bruce McCurdy is Past President of the Edmonton Centre. He is a committed lunar observer whose interest in astronomy was originally spurred by the Apollo *missions. Bruce is nearing completion of a project to observe every named feature on the lunar near side.*



The Eddington Enigma, by David S. Evans, pages 200, 14 cm × 21 cm, Xlibris Corporation, 1998. Price US$25 hardcover (ISBN 0-7388-0131-3), US$15 softcover (ISBN 0-7388-0131-1).

A faded Dover paperback edition of Sir Arthur Eddington's *The Internal Constitution of the Stars* that I purchased for $2.60 can still be found tucked away on my office bookshelf, although I rarely have occasion to refer to it. Nevertheless, it is an elucidating and comprehensive monograph for its day, and is written in an engaging and understandable manner that is rarely, if ever, matched in recently published research papers in the major scientific journals. I never gave much thought to the matter of why a fairly comprehensive scientific monograph in stellar astrophysics, first published in 1926 complete with detailed equations and their derivations, could be so much easier to follow than today's tomes, at least until I read *The Eddington Enigma* by David Evans. Now I am better equipped to understand the reasons for that.

Eddington was a major figure in astrophysics in the first half of this century. It was he who in 1919 took part in the first major scientific effort to confirm the gravitational deflection of starlight near the limb of the Sun that was predicted by Einstein's general theory of relativity. An eclipse of the Sun that year was observed both from Brazil and Principe, off the coast of Africa, by teams from the Royal Observatory. Photographs taken of the Hyades star field lying in the direction of the eclipsed Sun were compared with photographs taken earlier in order to measure the amount of gravitational deflection of starlight passing by the limb of the Sun. Eddington, who was part of the Principe expedition, was a strong popularizer of Einstein's theory of relativity, and the results, not surprisingly, strongly confirmed the expected gravitational deflection. Eddington was by then beginning to be regarded as one of the major figures in astrophysics through his efforts to popularize advances in the field, so it not surprising that the eclipse results even today are often attributed to him.

During the '20s and '30s, Eddington became a somewhat larger-than-life figure in British astronomy, much in the manner of American Carl Sagan during the '70s and '80s. Eddington had that rare gift of eloquence that enabled him to champion with great clarity many of the tremendous advances in astronomy and astrophysics that were being made in the early years of this century. Some of that eloquence can be seen in the writing of *The Internal Constitution of the Stars*, but modern astronomers still find it difficult to conceive of how great a hold Eddington had on the British public of his era. Alice Vibert Douglas authored the official biography of Eddington published in 1926, and Alan Batten recently published in the *Quarterly Journal of the Royal Astronomical Society* an article on Eddington's thinking on the relation between science and religion. Why, then, did David Evans publish yet another treatise on the life of this individual?

The answer to the question just posed can be found in *The Eddington Enigma* itself. Less than a biography of Eddington, the book reads more as a detailed description of the major events in Eddington's life and how they may have influenced the direction of his career. And Eddington's career was certainly not without controversy. A much-discussed confrontation that took place in 1935 between Eddington and Chandrasekhar concerning the nature of white dwarfs is still occasionally mentioned in print. That event is probably much less curious, however, than Eddington's preoccupation with numerology and how it relates to the fundamental physical constants. Today's astronomers find it remarkable that Eddington could have been so obsessed with relating various combinations of the physical constants to simple ratios of integers that he could ignore all of the contrary evidence. But, as emphasized by David Evans, the answer to this enigma lies in the upbringing of Eddington himself, who was raised in traditional Quaker fashion.

The Eddington Enigma is not a great book, as I shall explain below, but it does present a different view of the life of Eddington than is given elsewhere, and is useful for gaining a proper understanding and appreciation of his life. David Evans has distinct qualifications for writing on the subject. His early British academic experiences had many similarities to those of Eddington, his scientific research lies in a number of the fields to which Eddington himself made great contributions, and he knew Eddington personally. He is therefore able to write about the developments in Eddington's life from the perspective of one who is intimately familiar with the conditions and processes in the England of that era. On occasion, such as in his description of how the young Eddington's views on science and religion may have been influenced by the spectacular tides of the Bristol Basin, near which Eddington once lived, Evans provides insights that may be unique to an observational astronomer like himself.

In general, the book's narrative flows quite naturally from a description of

Eddington's life to considerations of how his Quaker upbringing may have influenced the latter stages of his career. Eddington was born in 1882 and died in 1944, and is regarded as one of the most distinct figures of his era. It is another matter as to whether or not he had a significant influence on the next generation of astronomers, but he can certainly be accorded high regard for his efforts to popularize the latest advances in astrophysics as he did. I gained much from reading *The Eddington Enigma*, and I believe that it would be a valuable read for anyone interested in the history of astrophysics during the first half of the century.

The major flaw of *The Eddington Enigma* lies in the almost total lack of editing that was done to the manuscript prior to publication. Not only is the text riddled with typographical errors, many of which are embarrassingly humourous, but what is intended to pass as "punctuation" detracts greatly from the readability. Just about every possible error in punctuation is repeated *ad nauseum* in the text. Many sentences lack periods, commas are placed in all of the wrong locations, and colons are misused throughout. What might be a readable treatise quickly becomes a struggle of comprehension for the average reader, and many sentences have to be reread numerous times in order to comprehend exactly what the author is trying to say. The inclusion of a little bit of tensor algebra in Chapter 7 is also bound to discourage the casual reader.

In summary, *The Eddington Enigma* is a half-decent monograph in serious need of a good editor, although, speaking as an editor myself, the challenge might be enough to dissuade all but the most avid editor from working on it. It is easy enough to see why the manuscript was eventually published by the Xlibris Corporation. The big-name publishing companies were probably discouraged by the amount of labour required to make the text more readable. That disappoints me greatly, since the text is otherwise a reasonably good addition to the history of modern astronomy. Perhaps the next edition will turn the monograph into a first-rate effort.

David Turner

David Turner is the editor of the Journal. *Although his interests in historical astronomy relate mainly to the classical era, he does profess to a certain fascination with more recent events.*

Obituaries
Necrologie

JOHN EDWARD KENNEDY (1916 — 1999)

J. E. (Ed) Kennedy was born on September 12, 1916, in Kemptville, Ontario. He was the only boy in a family of four children, and was raised on his parents' farm. He obtained his elementary education at a rural school, and took high school classes at Kemptville. He was encouraged to attend university by his parents, and enrolled at Queen's University, where he earned a Bachelor of Arts (B.A.) degree in mathematics and physics in 1937. From there he was accepted at McGill University, where he earned his Master of Science (M.Sc.) degree in physics in 1942.

Following graduation, Ed was employed at the National Research Council as a junior research physicist. His work consisted of repairing instruments and testing new ones, everything from cameras and spectrographic equipment to telescopes on gun barrels.

In 1945 he was accepted as an Assistant Professor in Physics at the University of New Brunswick. He was made an Associate Professor in 1955. While at the University of New Brunswick, Ed first became involved with astronomy where he was involved with an airborne observation of a solar eclipse with Peter Millman. Although his research was in radiotherapy and astronomy, he also began to document the work of William Brydone Jack and the history of astronomy in Canada. During the summer months Ed was invited to work at the Dominion Observatory, which he considered to be "the ground work for all of the valuable history I collected about New Brunswick's place in astronomy."

In 1956 Ed Kennedy was recruited to work at the Research Medical Laboratory in Toronto. There he spent several years working on some very unique projects, including trying to find footwear that would be suitable for soldiers, and clothing for the Canadian high arctic.

In 1965 he joined the University of Saskatchewan in Saskatoon as an Associate Professor in Physics. In Ed's words, "When I came to Saskatoon, it was a good time to get back into academics." He established courses at the university in astronomy, and was responsible for the operation of the university's observatory. Ed was also Assistant Dean of Arts and Science from 1967 to 1982. He was a member of the Royal Astronomical Society of Canada from the mid-'50s, and it was while he was at the University of Saskatchewan that he reorganized the Saskatoon Centre of the RASC. During his time with the Royal Astronomical Society of Canada, he served in many positions, including National Secretary, Chair of the Editing Committee for RASC Publications, and from 1968 to 1970 as National President. He also served as Chair of the Heritage Committee of CASCA.

Ed retired from the University of Saskatchewan in 1984, but continued to do research and to publish on a variety of topics right up to the time of his passing. The papers he was working on at his death will be completed by his co-authors, and will be published at some future date. His list of published papers, including the names of his co-authors, fills more than 15 pages in the University of Saskatchewan Archives. Dr. Balfour Currie wrote that, "to Professor Kennedy belongs the credit for putting the teaching of astronomy at the University on a firm basis, and for reactivating the Saskatoon branch of the [Royal Astronomical] Society [of Canada], as well as for creating a popular interest in astronomy in Saskatoon that brings thousands of people each year to the Observatory."

Ed was also a member of the International Astronomical Union, belonging to Commission 41, History of Astronomy, and Commission 46, Teaching of Astronomy. In 1974 he was elected a Fellow of the Royal Astronomical Society of London.

Over the years Ed received many honours and awards, the most noteworthy being the Centennial Medal for contributions to Canadian astronomy, the Service Award from the Royal Astronomical Society of Canada, a Canada Council Leave Fellowship, and the Canadian Silver Jubilee Medal, which was awarded on the basis of an expression of appreciation of worthy and devoted service rendered by the recipients in their various walks of life and the esteem in which they are held by their associates. In 1998 he received a Special Lifetime Award from the Royal Astronomical Society of Canada, which seemed to give him a lift when one was needed.

Ed Kennedy will be greatly missed by those of us who were fortunate enough to know him. But his compassion, integrity, and his wry sense of humour will not be forgotten. He passed away July 28, 1999.

Jim Young

EARL RICHARD VINCENT MILTON (1935— 1999)

A most lively and innovative mind has departed us with the passing of Dr. Earl Milton, but his life work will likely continue for much time to come.

In 1953 Earl Milton came from the Montreal Centre to Edmonton as a student. He quickly organized the Edmonton Centre's younger members into observing teams that covered a variety of observing disciplines (*e.g.* auroras, meteors, photography, solar, lunar). He was the co-founder, in 1954, of *Stardust*, the Centre's publication, and he served as its first editor. On the national level, as a young undergraduate at the University of Alberta, he became the chairman of the National Committee for Co-operation between Observing Centres.

As a result of his mobilization of aurora observers from all across Alberta and Canada, and his subsequent reduction and analysis of their observations, he earned the Society's Chant Medal for astronomical research.

He also served as the Edmonton Centre's President, and gave numerous talks on a variety of astronomical subjects. While still in his undergraduate program at the University of Alberta, he was instrumental in securing the first public planetarium in Canada for Edmonton by actively promoting the establishment of the Queen Elizabeth Planetarium, the forerunner of the Edmonton Space and Science Centre.

After receiving his Ph.D., he became a professor of physics at the University of Saskatchewan at Regina. He was noted for his irreverent teaching style that was very quickly applauded by his many students. After an initial, most vehement, reaction to Immanuel Velikovsky's "Worlds in Collision," he eventually discovered the man's gems of insight and fully appreciated his tapping of early human "cosmic" experiences expressed in legend, *etc.* It was from that basis that he explored the possibility that our universe was electrically, not gravitationally, driven. Because of the significantly more powerful electrical forces involved, much is changed with regards to such things as stellar evolution and the time scales involved. So too are the geological forces and effects at work on the planets in our solar system. He was delighted when the space age's interplanetary probes confirmed so much of what his theories suggested.

He completed his academic tenure at the University of Lethbridge, where he retired, and then took up residence in Calgary. During that post-retirement period he continued his research and published a number of important books on the role of electricity in the development of the universe, as well as a revolutionary dissertation, "Solaria Binaria," on the origins of the solar system. The latter was consistent with many of the "folklore remembrances" of Earth's indigenous peoples. It is here we see why comets have struck so much dread in peoples' hearts in times past.

In 1998 the Edmonton Centre elected him as their Honorary President, an act that brought him much pleasure. He is survived by his wife Anna, son Davin, brother Robert, sister Joyce and their families, and by his first wife Joan.

Franklin C. Loehde

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by Curt Nason, Halifax Centre

Here are the answers to last issue's clues

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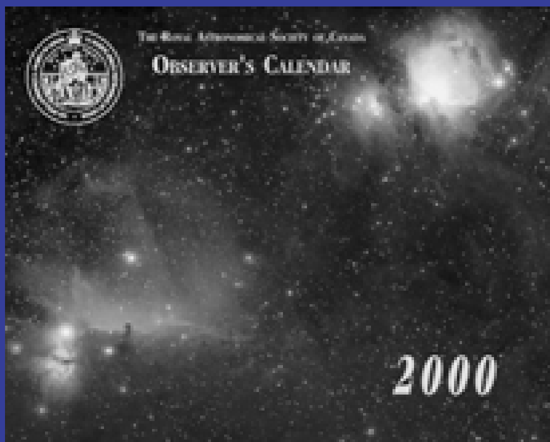
Observer's Calendar — 2000

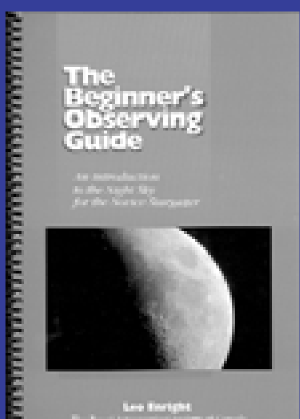


This calendar was created by members of the RASC. All photographs were taken by amateur astronomers using ordinary camera lenses and small telescopes and represent a wide spectrum of objects. An informative caption accompanies every photograph. This year all of the photos are in full colour.

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).

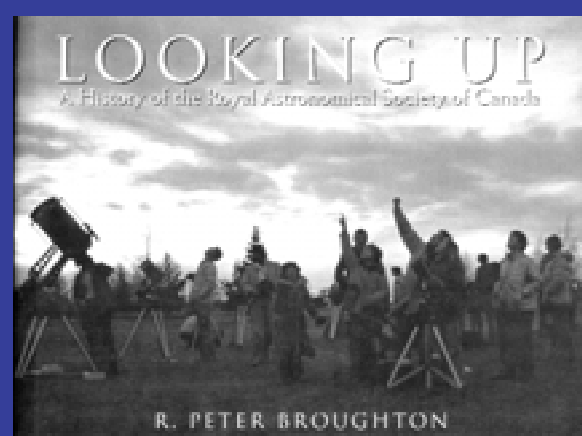
Price: $15 (includes taxes, postage and handling)

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)



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