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DAO's 90th Birthday!

Journal

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Building for the International Year of Astronomy (IYA2009)

October / octobre 2008

Journal

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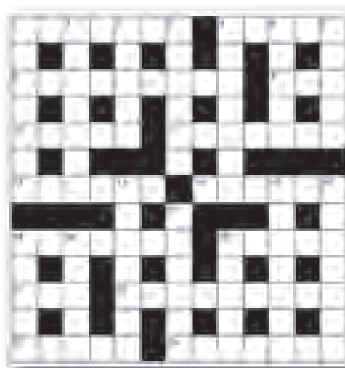

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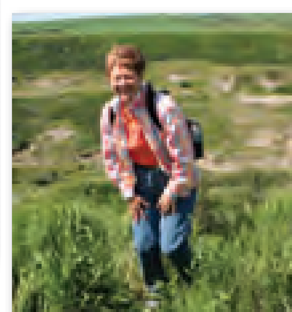

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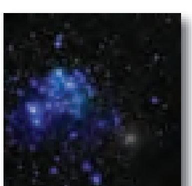
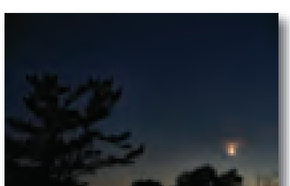

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Editorial

by Jay Anderson

The issue before you represents a bit of an experiment on our part and a welcome "collaboration," if you will, between the RASC and CASCA. The authors, some of the major players in the evolution of Canadian astronomy in the modern era, have stories to tell and achievements to boast, and the *Journal* is pleased to provide them with the space to do so and an audience that will appreciate their lifetimes of work.

The stories you will read were playing while I was studying astronomy at UBC in the 1970s, and so they have a familiarity to me that you probably don't share. On the other hand, no undergraduate would have known of the need to bribe the Mafia to acquire the site for the CFHT, and so the accounts not only reveal some of the inside details of the advance of astronomy, but also lend a sense of mystery to astronomers and astronomy in general. No more the boring nighttime occupation of vapid nerds — astronomy in these pages oozes with political intrigue, infighting, organized crime, and the triumph of the human side of science.

The story is not done, as two of our writers have noted, and perhaps these accounts will persuade one of you to take on the job of writing a more definitive history of the development of the modern era of Canadian astronomy. Be quick — the original players are reaching retirement age, new faces are developing new technologies, and the world is moving on to a completely different Universe inhabited by nightly all-sky surveys, far-distant orbiting telescopes, and huge monolithic mirrors. That story may be told in these pages in another 40 years, but for the time being, this issue of the *Journal* will engage in a little reflection on the past. We have our own institutional history as well, and the story of the RASC archives neatly complements the reminiscences of the DAO astronomers.

Journal

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

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The Plaskett Telescope at 90

Evolution is a ubiquitous, almost obsessive, concept in astronomy. All celestial objects are in some state of natural evolution, whether slow and mostly stately, rapid and often explosive, or somewhere in between. Our understanding also evolves as new data challenge old hypotheses, and our capabilities evolve as new technologies — tried and tested, then adopted, adapted, modulated, and multiplexed — urge or invite science-driven plans that were until recently simply not feasible. And strong shoulders will continue to be built upon, because the appetite for photons is insatiable. This issue of the *Journal* takes a special look at Astronomy in Canada and its evolution through a number of specific channels.

The front door to the Plaskett Telescope and the DAO.
Photo: Robert Ashworth

Scientific evolution is irreversible. Once a new facility is conceived, a new understanding grasped, or a new fact known, there is no going back. Even so, what is historic does not immediately become obsolete, to be discarded simply on account of age or limitation. At the Dominion Astrophysical Observatory (DAO) the 1.8-m Plaskett Telescope, whose 90th birthday was celebrated this year on May 6, continues in full-time use. Its younger neighbour, the 1.2-m McKellar Telescope (itself approaching its 50th anniversary) is in heavy demand, too, and performs observations in robotic mode for users worldwide. At the same time, the Observatory maintains an archive of the photographic observations that both telescopes delivered during a total of 115 telescope-years. By offering an increased time base, that historic information can be essential to a science of evolving objects, but only new technology can cope adequately with the challenge of rendering those data accessible digitally for modern research.

Formal astronomy in Canada evolved through requirements for accurate geodesy and time-keeping, but it did not take long for the merely practical to evolve a strong, predominantly philosophical, branch as interests in astronomy *per se* took root, both as general wonderment and as serious scientific study. The Plaskett Telescope, itself an offspring of Canada's time-keeping observatory, in turn begat the Canada-France-Hawaii Telescope (CFHT) and later the two Geminis, as visions expanded and wish-lists grew. The following articles focus on the Plaskett Telescope's contributions to Canadian science, with emphasis on the instrumentation, ideas and ground-based, optical-infrared telescopes that it has begotten. Celebration of its "90 active years *and still going strong*" was a theme of the 2008 Canadian Astronomical Society meeting held in Victoria in May. Subtitled *Scientific Impact of Canadian Astronomical Facilities and Instrumentation,* it included a 90-minute session devoted to specific developments in HIA/DAO instrumentation. The objective of the session was to present snapshots of some of the innovations and developments as recalled by present DAO staff or associates who were principally involved, though without attempting to be comprehensive. The six talks given then are reproduced here almost verbatim and close with a short list of suggestions "for further reading." Earlier in the meeting an invited lecture, given by Professor Ray Carlberg, also held the DAO and its development strongly in its sights, and it too has been included because of its high relevance to the "DAO at 90" theme.

Professor Carlberg goes beyond (or rather, before) the development of Canadian research astronomy by examining the founding links between the requirements of government and the ensuing practices of astronomical observing. Having thus inspired able Canadians to develop for its own ends the science of astronomy, could the Canadian Government have foreseen which way the worm would turn, the illustrious routes that would follow, and the concomitant requests for the funds to operate them? Whether or no, the stories told in this issue of the *Journal* are packed with innovation, ideas, and a well-justified pride.

The Creation of Canadian Observatories

by Ray Carlberg, University of Toronto

Canadian astronomy and astrophysics has had a remarkable century of accomplishment. From the outset, Canadian astronomers sought national facilities to address some of the most significant problems of our understanding of the physical Universe. A combination of individual achievements, collective vision and purpose, and an understanding of the needs of government has put in place the observatories and has supported the researchers, essential to the success of all. The lessons of history remain powerfully relevant.

Introduction

Astronomy is an observational science that is dependent on telescopes and instruments for making discoveries. Canada enjoys no significant natural benefit for astronomy, having impressively cloudy skies comparable to those of England and Norway. In the relatively clear Canadian prairie sky, where my own interests in astronomy were stimulated, the air over a thousand kilometres or so of continental land mass produces spectacularly "twinkling" images that signal the poor image quality of a thick turbulent layer in the atmosphere. Yet while our vast land area might not provide any natural advantages for observing, it did provide some of the key motivations to initiate astronomy in Canada. Moreover, Canada has benefited from a strong tradition of advanced education and from a succession of governments that have seen the benefits of astronomy in the wider context of their own mandates.

Let us examine some of the threads that brought Canadian astronomy to its current high standing, and lessons that we can take to heart. My attempt to find common themes means that I have been quite selective in choosing examples and have not given a balanced overview. As far as possible the story is told in the words of the relevant publications; it is also readily available through the SAO/NASA ADS (`http://adswww.harvard.edu/`).

Surveys and the Origin of the National Observatories

Canada's first astronomers undertook surveys in the most literal form: mapping our country. Establishing the location of the borders requires diplomacy (since 1812) plus high-precision measurements of latitude, time, and longitude, the latter three all being related astronomical problems. The early explorers, notably Champlain and his successors in the East and Vancouver in the West, came with instructions from their sponsoring states to create maps both for location and for characterization of the contents of the vast landmass of Canada. After the confederation of Canada in 1867 there were controversies over the border shared with the USA for its entire length. The border west of the Great Lakes was so unknown on the ground that it effectively did not exist. The entry of B.C. into confederation and the completion of the CPR railway in 1885 made the matter urgent.

The Surveyor General of Canada, E. Deville, commissioned Otto Klotz (an astronomer by training) and others to begin the western border work. The work with the Americans was collegial, Klotz noting that the western co-ordinates were initiated from Seattle, the only convenient accurately established location (1919, *JRASC* 13, 1). In 1872 William F. King, C.M.G. (1854 - 1916; see the obituary for Plaskett: 1916 *JRASC* 10, 267) became a staff member of the Boundary Commission (during his third year of undergraduate studies at Toronto) and later rose to Chief Inspector of Surveys. Mapping with positional measurements had advanced considerably, with many locations in the eastern part of the country having been defined relative to Ottawa. The fact that the location of Ottawa was not accurately known and that accurate time was a national need for the railway and other industries appeared to make a clear-cut case for establishing a permanent government observatory. Many letters were then sent back and forth between astronomers and their somewhat more cautious superiors, deputy ministers, and ministers. Finally, in 1890 the Cliff Street Observatory was established, with appropriate positional instrumentation, in a modest wooden building, now someplace under the Supreme Court of Canada. King was appointed to the new position of Chief Astronomer for Canada. This small observatory heralded a remarkable 20 years of government support for expanding astronomy in Canada. Building observatories fulfilled a practical need and a national ambition, and recognized the tremendous public interest in astronomy in Canada. In fact, 1890 is also the founding date of the organization that grew into The Royal Astronomical Society of Canada. The RASC played a key rôle in the development of Canadian astronomy by providing an its ongoing link between amateur and professional astronomers, and helping to convince government of the inspiration and value that astronomy offered. King advanced these arguments to develop a national astronomical observatory on the scale of those of other nations.

The impressive Dominion Observatory (DO) was completed in 1903, a national symbol announcing that Canada was taking a rôle at the front ranks of science while also pursuing the practical occupation of positional measurements. A deputy minister thoughtfully inserted an adequate budget for research instrumentation. King, as the Chief Astronomer, sent a somewhat brave memorandum to the Minister of the Interior, the powerful Clifford Sifton, stating that the first priority for the observatory would be astronomical research, with arguments for the importance of astronomy to a nation's scientific program, for the attraction and training of scientists, and for the engagement of the public interest that all continue to be relevant today and were echoed in the Canadian *Long Range Plan for Astronomy* of 2000.

William Frederick King (1854-1916) Source: The Observatory, 39, p. 342

The staff of the DO undertook the multiple missions with zeal, fulfilling the promise to the nation to provide time and location information but also initiating coordinated research in astronomy and geophysics. An important aspect of observing facilities is that they require staff. The number of astronomers in the employ of the government rose from zero to a dozen, with several trained in the specialist astronomy program that C.A. Chant introduced into the University of Toronto in 1905. One of the newly appointed astronomers was a largely self-taught machinist and instrument builder from the Toronto physics department — the remarkable J.S. Plaskett, who completed an astronomy degree program that was interspersed with his work, graduating at the advanced age of 30.

The ambitious new group of DO astronomers realized quickly that they could be internationally competitive in the area of stellar spectra. Measurements of line strengths and radial velocities were crucial for advancing understanding of the temperatures, luminosities, and masses of stars (through studies of binaries), studies that culminated in the Hertzsprung-Russell diagram around 1910 and the development of Eddington's theory of stellar structure a few years later. Much of that work required spectra of what were then observationally challenging "faint stars" below fifth magnitude. Plaskett's mechanical background enabled him to realize that commercial spectrographs suffered badly from an inefficient optical design. He built much stiffer spectrographs and introduced a knife-edge slit that allowed more light into the spectrograph, while also realizing that the relatively poor image quality delivered by the spectrographs could be improved, thereby achieving greater sensitivity. Moreover, Plaskett had worked with photographic plates in Toronto and had literally "developed" techniques to further that technology. His leading rôle in that work brought him into contact with virtually all of the leading astronomers of the day, and he was invited to sit on a number of scientific committees.

John Stanley Plaskett (1865-1941). Photo courtesy National Research Council of Canada, Herzberg Institute of Astrophysics, Dominion Astrophysical Observatory

Practical astronomy came to the fore again as the Alaska Boundary dispute raised political passions in North America. The Russians had developed fishing and sealing stations in Alaska and were effectively claiming much of that land. President Monroe's 1823 declaration that European powers were no longer welcome to colonize in the Americas slightly preceded the Anglo-Russian treaty of 1825, which recognized and limited the Russian claim to the panhandle north of 54° 40´, but with vague wording about the interior boundary. The tense border disputes for the Oregon Territory, including all of southern British Columbia, that followed President Polk's election in 1844 gave rise to the slogan "54-40 or Fight!", but Polk's more tempered approach led to negotiations establishing the 49th parallel as the western boundary between the USA and Canada. Not surprisingly, the USA's Alaska purchase in 1867, the year of Confederation of Canada, was of particular concern to British Columbia. B.C. joined Canada in 1871 and in 1872 petitioned for a resolution of the interior boundary. The Klondike gold rush of the late 1890s eventually led to the establishment in 1911 of a Boundary Commission between Great Britain and the United States. In those days Canada was a Dominion of the British Empire, with no separate foreign policy. Canada wanted the border at the headlands of the waterways to control access to the land. The USA wanted the border inland of the waterways for the same reason. The Commission gave the USA a number of important ports, causing the Canadian public and government to feel betrayed by both Great Britain and the USA. Laurier's government was defeated in the 1911 election along with a proposal for trade reciprocity. However, once the border was agreed upon it needed to be mapped, and King was assigned the task. The precision of his work and the diplomacy and good relations he had with the American crews participating in the work completely defused what could have been a continuing aggravation. That high-profile work by Canadian astronomers created a unique opportunity to put forward a request for a major new observatory.

In his 1912 report as Chief Astronomer, Plaskett called for an *astrophysical* observatory that would be "second to none." The one page he devotes to this project remains a useful model of the successful proposal: he lays out a science vision that seeks to surpass anything that had been done before, he points to the excellence of the then-current research astronomers to demonstrate that that could be achieved, and then he proposes that a telescope of the required power can be built within an acceptable budget. After a short round of site-testing (and the usual intervention of *realpolitik*) Victoria was selected from a number of potential sites. The government approved funding for what was to become the Dominion Astrophysical Observatory. Notwithstanding the interruptions of World War I, the DAO began operations in 1918 — a very modest interval from Plaskett's original proposal.

The Dominion Astrophysical Observatory

Research at the DAO immediately focused on problems of the dynamical structure of the galaxy as one of its prime activities. The "great debate" concerned the location of the Sun relative to the Milky Way star system: was it near the centre of an elliptical distribution, as in the Kapteyn model, or orbiting a distant centre? A kinematic puzzle was the problem of "star streams," in which we seemed to be at rest with respect to the hot stars but in motion with respect to cooler stars. Although the tradition at most observatories was to undertake individual research with relatively little interaction, from the outset the DAO staff adopted the collaborative research style that had developed at DO, partly based on the view that a national observatory could and should tackle scientific problems of greater complexity than those that were within the grasp of individual scientists. The DAO staff, led by Plaskett, was acquiring precisely the data required to address the galactic structure problems. Lindblad wrote a series of papers in the mid-1920s that proposed a dynamical model of a disk galaxy. Oort refined the model into simple observational relationships, which, when compared to the data, found extremely good agreement. That remarkable work, occurring over the space of just a few years, coincided with work elsewhere in which the nature of galaxies was starting to be understood and during whichSlipher and Hubble were discovering the expansion of the system of galaxies.

The full suite of honours came to Plaskett: election to the Royal Society, the Gold Medal of the Royal Astronomical Society, the Bruce medal and the Rumford medal, and the RAS Darwin lecture. Clearly the bold vision that Plaskett had laid out had been fully realized through the telescopes, the efficient spectrographs that the staff developed, and the focused, collaborative scientific use of the assets of the observatory. The DAO maintained that high level of research, continuing to attract a stream of innovative astronomers. Those achievements model the effective manner in which scientific excellence, public and government support, and often *realpolitik* all combined to create Canadian astronomy.

The arrival of C.S. Beals at the DAO brought new research interests, in particular concerning early type stars that can be seen at large distances. The absorption lines in their spectra show the P-Cygni profiles attributable to stellar winds, as well as signatures of interstellar gas. Beals discovered that the interstellar lines could be resolved, thus indicating that the gas was distributed in a medium of discrete clouds. It is interesting to note that when Beals moved to Ottawa in 1946 he quickly became an expert on meteor craters and impacts, helping to establish an important research field in Canada that united geophysics and astronomy. The interstellar work also inspired Andrew McKellar, a UBC student who had studied at Lick and at Yale and had developed a strong interest in laboratory spectroscopy insofar as it relates to astrophysical problems. McKellar's work required a very-high-dispersion spectrograph to separate and identify the weak and narrow interstellar lines. In 1940 he published a truly remarkable paper that was a "pre-discovery" measurement of Cosmic Microwave Background radiation. McKellar first identified some weak spectral features as arising from the CN radical. His knowledge of the molecular rotational energy levels led him to deduce that the "rotational temperature" was about 2.7 K. Since in fact the relevant energy level is pumped almost entirely by CMB photons, his method yields a very accurate temperature of the CMB. Later refined with additional data by Herzberg, that temperature measurement was appreciated by Hoyle as an upper limit that (in his view) argued against the Big Bang hypothesis, particularly since Gamov's simple calculation from the helium abundance suggested a temperature of 10 K or higher. As a later echo of that result, in the early 1980s Gush (a Saskatoon undergraduate during Herzberg's years, later doing PDF work on Fourier transform spectroscopy at Haute Provence) built at UBC a beautiful rocket-borne Fourier transform spectrometer that measured the CMB spectrum nearly a decade before COBE, but unfortunately the rocket motor had a residual fuel burn that pushed it into the field of view. Although it was possible to subtract the relatively hot motor from the low-temperature CMB, such a large systematic inevitable increased the errors. Later Gush, Halpern, and Wishnow provided the most precise CMB temperature yet, slightly after COBE reported its results.

Andrew McKellar (1910-1960). RASC image.

As an aside, it is interesting to recall that, to this day, the DAO (now the Herzberg Institute for Astronomy (HIA) and part of the National Research Council (NRC)) offers summer research positions to undergraduates interested in astronomy. In 1953 Hubert Reeves worked as a summer student with McKellar on a binary-star orbit; later he went on to considerable note as a Big Bang theorist and science popularizer. While in Paris, Reeves is widely believed to have played a rôle in the creation of the Canada-France-Hawaii Telescope through his friendship with a former Montreal faculty colleague, then Prime Minister Pierre Elliot Trudeau.

Theorists and Observers

Black-hole astrophysics is a remarkable line of activity with a broader story that illustrates a wider picture of Canadian astronomy and the crucial importance of theoretical stimulus. Black holes were a theoretical invention that came to the fore in the early 1960s. In 1967 Werner Israel in Edmonton proved a celebrated theorem that black holes had to be remarkably simple objects, like elementary particles, described in the simplest case by their mass alone. In the early 1970s X-ray binaries were detected with rockets and the Uhuru satellite. One of those was Cygnus X-1, which Tom Bolton at the David Dunlap Observatory established as having the same X-ray periodicity as the radial-velocity variations of the star that orbited around an unseen companion. The study of X-ray binaries then burgeoned, with several of the DAO staff contributing to the concept of a mass flow from the visible star onto an accretion disk around a compact object, the latter ranging variously from white dwarf to neutron star to black hole. The super-massive black holes in galactic centres required powerful facilities to observe them and were frustratingly out of the reach of all but the Palomar 200-inch telescope for many years. Kormendy took advantage of the superb image quality at CFHT to provide the first observational proof that super-massive black holes were likely to be present in all galaxies.

With a neat complementarity, Hartwick and Sargent used the 200-inch telescope to measure the radial velocities of globular clusters and dwarf galaxies of the Milky Way, and established definitively that our own Galaxy is immersed in a heavy halo of dark matter. Purely theoretical research, however, continued in Canada alongside the observational work. Unruh came to UBC, where Matt Choptuik then became interested in numerical relativity and helped develop that field to a level of precision that would support numerical proofs. One of Choptuik's students, Frans Pretorius (now at Princeton), led the development of an essentially complete description of how two orbiting black holes spiral together and merge to create the new event horizon that Israel's theorem demanded. But scholarship in any form does not thrive without interaction; institutes are the theorist's observatories, creating exchange and debate of ideas and techniques. Theorists recognized that issue for years, but the tremendous success of Canada's observers at the DAO and the David Dunlap Observatory (DDO) and later CFHT created a community-wide call for a theory institute, which eventually materialized as CITA, the Canadian Institute for Theoretical Astrophysics. CITA's road to funding has much in common with telescopes. A bold scientific case, backed by prominent scientific promoters, was taken to the Natural Sciences and Engineering Research Council (NSERC) with strong country-wide university backing. The story is not yet fully told, but the route to success traversed quite a few committees that offered only lukewarm reviews before the proposal reached a level where the vision was fully appreciated and the budget had to accommodate its realization. As with other Canadian observatories, CITA has delivered on all aspects of its vision and mandate, repaying in full the confidence of its founders and backers.

Canadian Radio Astronomy's Rapid Rise

The field of radio astronomy largely grew from a community of physicists who had worked with high-frequency equipment during the Second World War, when the strong astronomical sources of radio waves first became visible, but their follow-up had to be set aside. In Canada this group largely worked in the National Research Council, led by Covington who specialized in solar radio emission, an important topic in a high-latitude country in the days of short-wave communications.

NRC, along with the Defence Research Board, built the Algonquin Radio Observatory in Ontario. Around the same time astronomers were pushing for a research telescope, and, in an outburst of telescope building comparable to the era before the DAO, this led to the founding of the Dominion Radio Astrophysical Observatory (DRAO) in Penticton. There was also a Defence Research Board antenna in Prince Albert, the home riding of Prime Minister John Diefenbaker. The antenna was inaugurated by a greeting from President Eisenhower, broadcast from MIT and bounced off the Moon. The astronomers and engineers quickly realized that having three substantial dishes under common ownership in a country the size of Canada could offer a unique technical and scientific opportunity. A team of NRC, Toronto, Queen's, and DRAO scientists seized that opportunity, creating the VLBI techniques that expanded the size of our radio array by a factor of about thirty in a single step. The team was awarded the Rumford medal for its work.

The Circuitous Routes to the Canada-France-Hawaii Telescope

Much of the history of the CFHT has yet to be written by those who were present at its development. The "CFHT21" celebration provided an occasion for many to reminisce on "what really happened." Astronomers everywhere realized that the mighty Palomar telescope completely eclipsed all others, particularly for the very exciting work on the nature of the expansion of the Universe and exotic new objects such as quasars. Canadian astronomers supported a proposal to participate in a British Commonwealth Telescope to be built in Australia. Perhaps unwisely, the proposal was presented to the Government of Canada by the Astronomer Royal and was rejected with the message that it was too large an offshore cost. The response was to search for a mountain site in western Canada, leading in turn to the "Mount Kobau" project, later renamed the "Queen Elizabeth II Telescope" project by Prime Minister Pearson.

Canadian optical astronomy had become oriented predominantly towards spectroscopic interests in the west and imaging interests in the east. Imaging and faint-object work require good "seeing," while an image slicer can mitigate poor seeing to some extent for point-source spectroscopy. Several Canadian astronomers already had some experience with the exceptional image quality of sites in the Chilean mountains, and contrary opinions led to a dispute that was eventually resolved in the Rose and Petch reports of the Science Council of Canada. The QE II project was cancelled, though some of the alt-az and enclosure design work was later featured in the Anglo-Australian telescope. The report recommended that Canada seek to own completely a telescope in Chile or to consider 50-50 participation in the Carnegie Southern Observatory (CARSO) project to build a 4- or 5-m telescope there. But the CARSO project had its own complex history in the politics of U.S. private and public observatories, and in fact neither side was able to move forward. Meanwhile, astronomers in France were proposing a telescope in the Pyrenees but were running into concerns about the relatively poor quality of the site for a front- line telescope. The Canary Islands were clearly scientifically attractive, but the Government of France was not disposed to work with General Franco's Government. Their search then moved to Baja peninsula of Mexico, but sites were only offered under a short-term lease. Meanwhile, John Jeffries had been promoting the benefits of Mauna Kea, to which both Canadian and French astronomers listened with great interest. Many of the technical elements for a combined large-telescope project were thus already nearly in place when General de Gaulle uttered his famous *"bon mots"* in Montreal (see Racine 1981 *JRASC* 75, 305), in the wake of which the authorization to implement the Canada-France-Hawaii Telescope followed quickly.

The Canada-France-Hawaii Telescope from below.

The telescope was commissioned with 2″ images, an over-abundance of instruments, an inadequate operating budget, and a somewhat suspicious astronomical community — a community, however, that shared a sense of excitement, accomplishment, and effective national commitments to help the new observatory succeed. The issue of image quality had been alive in Canada since the days of Plaskett. The new observatory undertook an analysis of the causes of the poor images and systematically addressed optical and thermal problems in the telescope, resulting in it becoming internationally known for its routine sub-arcsecond images such that it could do work that no other telescope could. The development of the "fast-guiding" HRCAM demonstrated that the site could offer yet more if true image diameters of ~0.3″ were realized. As detailed later in this *Journal,* DAO astronomers seized the scientific opportunity of the unparalleled CFHT image quality to demonstrate that practically all quasars are located at the centres of galaxies, a challenging observation that required separating the extended wings of the image of the bright central nuclear emission from the faint starlight of the extended galaxy. Those instrumental and scientific successes fuelled an interest shared by all of the CFHT partners to develop adaptive optics for the CFHT, foreseeing two significant scientific developments: the hunt for extra-solar planets and the search for strong gravitational lenses. Planet-searching had been inaugurated at the DAO by Gordon Walker and Bruce Campbell with their pioneering radial-velocity absorption-cell technique — a unique hydrogen fluoride implementation (that was also appropriate for the CFHT coudé spectrograph) to monitor drifts in the spectrograph.

What Canadian Observatories Are Next?

The 2000 *Canadian Long Range Plan* for astronomy provides the pathway for the development of future astronomical facilities. It remains true to the century-old goal of Canadian astronomy by demonstrating that our community is interested in participating at the forefront of astronomical science, which (as we have seen through the above examples) is very demanding. It requires bringing a very clear scientific vision to the development of observatories so that the appropriate instruments can be built in a timely fashion. In Canada funding has always required addressing the broader interests of national politicians, ultimately having some visibility at the very highest levels of government. With the possible exception of the far north of Canada, astronomers are no longer in a position to contribute to border measurements any more. Maintaining the health of our economy, particularly in areas that depend heavily on human capital, is clearly an overarching priority for our government and one in which astronomers can continue to play an important rôle. Big Science, expensive as it is, has a unique ability to draw together the most innovative people and industries to create completely new economic opportunities. The creation of new ideas and the discoveries that result will inspire and improve the lives of everyone, thereby fulfilling an important function of a nation that aspires to international leadership and stature.

A Half-Century of Astronomy Viewed from the Dominion Astrophysical Observatory

Alan H. Batten, National Research Council
Herzberg Institute of Astrophysics, Dominion Astrophysical Observatory

Having worked at the DAO since late in 1959, I draw on my memories of Canadian astronomy and the experience of working for the International Astronomical Union to reflect on some of the changes that have taken place in the ways we perform and report our researches.

Introduction

Compared with a human life, 90 years is a long time even in these days of greater longevity, and a 90th anniversary is something to celebrate, but compared with the billions of years we astronomers are used to thinking of, 90 years is a mere tick of a clock. Even compared with the millennia during which the human race has speculated about the nature of the stars, 90 years is not a long time. So, we might ask, what is special about a 90-year-old observatory? One possible answer is that modern astronomy can be said to have begun late in 1609, when Galileo first turned a telescope to the sky, which is why 2009 has been chosen as the International Year of Astronomy. From that point of view our 1.8-m telescope in Victoria has been contributing to the advancement of our science for nearly a quarter of the latter's modern history.

At a personal level, I am not sure how long I can claim to have been an astronomer, but I have been associated with the Dominion Astrophysical Observatory for more than half its lifetime. It is nearly 70 years since I became a schoolboy amateur, but 2008 is a significant anniversary for me, as well as for the DAO, in that it includes the 50th anniversary of my doctorate. A little more than a year after that graduation, I came to Canada and the DAO, little expecting that I would stay there for the rest of my life. My half-century as a professional astronomer, therefore, has been almost entirely based at the DAO, which has done much to form my own scientific attitudes. In this article I want to report on the changes that I have seen and experienced in Victoria, in Canadian astronomy, and in the international scene.

The Dominion Astrophysical Observatory

Perhaps the most obvious change in the DAO is in its size — both the physical size of the buildings and the size of the staff that has occupied them. When I arrived in 1959, the entire staff (including secretaries, machinists, grounds-staff, and caretakers) numbered about 25, of whom only about a half-dozen were astronomers, but there were also seismologists and geomagnetic researchers. A resident caretaker had an apartment on the top of the old building; the one I knew was the last of his line and left a few weeks after my arrival. What is now referred to as the "1950s wing" was simply the "new wing" or the "extension." Nearly all the astronomers had their offices in it, but there were still several large rooms available for storage, and (for lunchtime relaxation) even a ping-pong table, which provided an alternative to the 9-hole putting green that surrounded the office building. Now we have added two more wings to the office building, and there are still complaints that we do not have enough space (and lunch hours are full of meetings). There was only one telescope: the 1.8-m, now called the Plaskett Telescope; the 1.2-m arrived at the end of 1961. I am not sure how many people work there now, but I suspect that it is over 100. Some of the increase is the result of concentrating the Herzberg Institute of Astrophysics into Victoria — equivalent to combining the old Dominion Observatory in Ottawa with the DAO — but much of it reflects the greater need for professional support for the astronomers, such as the engineers involved in instrument design and the computer group. The DAO had no computer in 1959, and, indeed, the word "computer" without an adjective meant a human being — usually female. Our first electronic computer was not acquired until after Ken Wright became Director in 1966.

A less obvious, and to outsiders possibly less significant, change was from being part of a Government Department, as we were from our foundation, to becoming in 1970 a part of a Crown Corporation, the National Research Council of Canada. That change followed from a recommendation of the Glassco Commission that was set up to inquire into the organization of research in the Dominion Government (as it was then called). The Penticton radio astronomers wanted to be in the same organization as their colleagues in NRC. Optical astronomers were less keen for change, but there was no real choice. Oddly enough, in 1970 the Crown Corporation had more red tape than the Departments, which had evolved. Of course, NRC has evolved since then, and I do not know how it compares in that respect with the Departments now.

At about the same time, the DAO was declared to be a national facility, and our telescopes were to be available to all Canadian astronomers. Although this happened shortly after we joined NRC, I believe it would have happened anyway to satisfy the increasing number of Canadian astronomers (which I shall discuss in the next section). It was not really a change of policy, although those outside the DAO might have thought so. In principle the Plaskett Telescope had always been available to other astronomers. The limitation was not our unwillingness to share (most of us were quite glad to be freed, from time to time, of the obligation to observe!) but the time taken to travel to and from Victoria, with no assurance of good weather during the run. Trans-Canada Airlines, as Air Canada was then called, introduced passenger jets in 1960. A little later, government employees travelling on business found that, instead of seeking special permission to fly, they had to receive special permission not to. We tend to forget how much the present organization of observational astronomy around large multi-national facilities at exceedingly good sites has depended on the availability of rapid (and, until recently, relatively inexpensive) long-distance travel. It is perhaps sobering to contemplate the contribution of observing astronomers to global warming! The development of remote-control systems for major telescopes, however, is saving us from too much reproach on that score.

Canadian Astronomy

On the national scene, the most obvious differences between the 1950s and now are the size and diversity of the astronomical community. There were only somewhere between 20 and 30 astronomers in the whole country — and that was including a number of people, most prominently Gerhard Herzberg, whose work and interests bordered on astronomy, but who would not have described themselves as astronomers. Most of the astronomers were concentrated in three institutions, the DO, the DAO and the DDO (David Dunlap Observatory, Toronto). As already mentioned, there were radio astronomers in NRC (the Dominion Radio-Astrophysical Observatory in Penticton was opened shortly after my arrival). There were also upper-atmosphere researchers (including Peter Millman and his meteor group) in NRC, and small astronomy groups were beginning at Queen's University and the University of Western Ontario, but most of us at the three big observatories were observational astronomers (and spectroscopists). There were no francophone astronomers — unless you count Hubert Reeves who was, I believe, already spending most of his time in France. Today, almost every major university has an astronomy group, many with their own observatories, and the two most important universities in Québec have access to the observatory at Mont Mégantic. There is also at least one group of theoreticians, at CITA. The Canadian Astronomical Society (CASCA), which we thought when we founded it would be lucky to attract 200 members, now has well over 500.

Of course there was no CASCA in 1959. C.S. Beals had found funds to bring members of the Canadian National Committee of the IAU together once a year, and they took advantage of that to have some scientific sessions. I believe Beals always hoped that these meetings would develop into a national astronomical society, but the growth of the community had to come first. Even when CASCA was founded, some very prominent Canadian astronomers were reluctant to join immediately, fearing that attendance at CASCA meetings would jeopardize their funding for participation in US and international meetings, to which they attached more importance.

One of the spurs to the founding of CASCA was the cancellation of the Queen Elizabeth II telescope project, which is referred to in some depth elsewhere in this *Journal;* future historians will probably conclude that there were merits and faults on both sides of the argument. The episode had, however, two beneficial effects. First, it made clear the need for a forum in which astronomers (especially the younger ones) could speak their minds on the needs and priorities of Canadian astronomy without others assuming that they necessarily spoke for the institute in which they were employed — and that was one rôle that CASCA was designed to play. Secondly, the episode highlighted the need for Canadian astronomers to have access to much larger telescopes than the two 1.8-m instruments then available to them. Without the QE II initiative, which originated with the DAO, we might not have become partners in the Canada-France-Hawaii Telescope, Gemini, and now the Thirty-Metre Telescope. Cancellation of the QE II was a bitter disappointment to many at the DAO, especially to Ken Wright and Graham Odgers who, nevertheless, persisted in searching for ways to get access to large telescopes for Canadian astronomers, and did much that has never been fully recognized to get us into the CFHT project.

The founding of CASCA inevitably changed the rôle of The Royal Astronomical Society of Canada, which has become much more a purely amateur society than it was when I first came to Canada. I myself foresaw this consequence and hesitated about working with the new society, but the need for a professional body was evident and there were already signs of tension in the RASC as it tried to satisfy each of its two different kinds of members. Nevertheless, as one of the few people who have held the presidency of both Societies, I regret the tendency towards increasing separation of the amateur and professional communities.

When I first came to Canada I was favourably impressed to find that about a quarter of Canadian astronomers were women — a much higher proportion than was then to be found in the larger British astronomy community. They included Jean McDonald-Petrie and Anne Underhill at the DAO, Ruth Northcott and Helen Hogg at the DDO, Miriam Burland and Mary Grey at the DO, Ali Vibert Douglas at Queen's, and Amelia Wehlau at Western. While not all of them were fully active in research, they contributed importantly in one way or another to the astronomical community, which accepted them as full members. I was taken aback in the late 1960s or early 1970s to hear complaints that only one woman had a tenured position in Canadian astronomy. I am not sure that the complaint was justified, but I am inclined to think that if it was, the situation was the result of the vagaries of small-number statistics, rather than of some deep-laid male chauvinist plot! At any rate, the situation is much altered now.

In the 1960s, Canadian astronomers were not studying cosmology except for Sidney van den Bergh, then in Toronto — our instruments were inadequate to the task. Nevertheless, modern scientific cosmology is about the same age as the DAO, since its theoretical underpinning is, of course, Einstein's theory of general relativity, of 1915-16, and its observational foundation was Hubble's 1929 discovery of the recession of the spiral nebulae, as galaxies were then called. To the younger generation those dates may sound like ancient history, but they do not to me: 1929 happens to be the year in which my parents were married and my sister was born. Those who were senior Canadian astronomers when I first came to the DAO began their own careers at a time when it was not known whether or not the spiral nebulae were extragalactic objects. Reflecting on that fact makes me skeptical of present-day assurances that we know, even in outline, the entire history of the Universe.

The International Scene

On the international scene, we are once again struck by the growth of the astronomical community. When I was elected to membership of the IAU in 1961, there were fewer than 1300 members — and the older generation then was reminiscing about the "good old days" when there were only a few hundred members. The latest figure for the membership of the Union is 9666. The number of countries adhering to the Union has also increased; indeed, I am partly responsible for that since, for a decade, I chaired the IAU Working Group for the Worldwide Development of Astronomy, and it was part of my job to encourage countries to adhere to the Union. There has also been a spectacular growth of diversity in what can be observed. I was the equivalent of a high-school student when the 5-m Hale telescope began operation. At that time radio astronomy (mainly concerned with observing daytime meteor showers and the Sun) and X-ray astronomy (possible only in the few minutes afforded by V-2 rocket flights) were in their respective infancies. Now, many colleagues are using 8-m and 10-m telescopes and are planning much larger ones, while from above the Earth's atmosphere we can observe, in principle, the entire electromagnetic spectrum, and have thus learned much more about the Universe. New terms have had to be devised: "quasar," "pulsar," and "black hole" — all coined since I came to Canada. A less-welcome coinage is "light pollution" — a phenomenon that did not trouble Victoria 50 years ago. I can remember the first time I found a mercury-vapour line in emission on one of my spectrograms. For a few moments I thought that I had stumbled on something really exciting, but then the horrible truth dawned!

There is much to celebrate in all this growth and increasing scope for astronomical research. We can only rejoice that more people from more countries have the opportunity to enjoy the challenges of the sort of work that we have ourselves enjoyed. I do not share the "optimism" (if such it be) of those who believe that we will soon have a "theory of everything." This vast Universe in which we find ourselves presents enough problems to occupy the entire membership of the IAU for some time to come. Nevertheless, growth always brings its problems. One is the increased competitiveness of astronomy and of science in general. Competitiveness itself is not new: F.G.W. Struve and Bessel vied to be the first to measure a convincing parallax for a fixed star; Newton and Leibniz quarrelled like children over priority for the invention of the differential calculus; Galileo remained strangely silent about Kepler's laws of planetary motion, although they were better arguments in support of the heliocentric hypothesis than any of his own; Tycho Brahe was furious when, as he believed, his model of the Solar System was plagiarized by Reymers Ursus. In our own time, I can remember R.M. Petrie's annoyance when Otto

Struve "scooped" him in publishing the orbit of a spectroscopic binary that he had discussed with Struve when the latter visited Victoria. Nowadays, however, there are so many more astronomers, and direct competition is more likely. More importantly, we have so institutionalized peer review that we create more opportunities for competition. Of course, we are all working, directly or indirectly, on public money, or that of private foundations, and we must use those resources responsibly. Many astronomers, however, have to submit their research proposals to peer review to get them funded, their requests for telescope time to another committee of peers, and finally the finished paper must be reviewed by at least one, and often two or three referees. I think that it is legitimate to ask if we are overdoing peer review and if the model we have is the best possible. I doubt if many reviewers take advantage of privileged knowledge to further their own research (although such things have been alleged), but the more subtle danger of review committees imposing an orthodoxy in science is very real. Astronomers cannot be very proud of the way in which those of our colleagues who dissent from the hot big-bang in cosmology have been treated by peer review. I know that those colleagues are going against the overwhelming consensus in their field, but even an overwhelming consensus can be wrong. When the DAO opened its doors, the overwhelming consensus among astronomers was that stars could not be composed predominantly of hydrogen. The consensus in cosmology 90 years from now will, I suspect, be very different from today's.

The routine refereeing of papers is more recent than many realize, although some journals *(e.g. Physical Review)* were already doing it in the 1930s. Einstein was angry with that journal when they sent a paper of his to a referee in 1937 — not because he thought he should be above such treatment, but because he thought that the editor, by sending an unpublished paper to a colleague without the author's permission, had committed a gross breach of professional etiquette! As recently as 1953, the famous letter to *Nature* in which Watson and Crick announced the structure of DNA was not refereed; its truth was considered to be "self-evident," and it came from the Cavendish Laboratory with the imprimatur of Sir Lawrence Bragg. In those days, papers by any member of an institute or department were often "communicated" by the head, who thus accepted some measure of responsibility for its contents. For that very reason, several of my early papers were not refereed, except by the journal editor, who was expected to be competent to judge the papers submitted.

Many observatories also ran their own publications series and those were not subject to external review. The seventeen volumes of the *Publications of the DAO* are in that tradition. As I had the sometimes thankless task of editor from Volume 12 onwards, I know that only one or two papers were sent to external referees. When I took over, however, it was made quite clear that every astronomer on the staff was to be given an opportunity to read every paper, whether it was destined for the *Publications* or for a journal that would use its own referees, because all papers reflected the reputation of the whole observatory. Thus, papers in the *Publications* were probably scrutinized at least as carefully as those published in journals. Later, it was not always possible to give everyone a chance to read every paper. Newer members of staff were unwilling to submit to that discipline, and, to give them credit, they were so productive that there would not have been time. Moreover, increasing diversity of interests among the staff members meant that we were not always competent to assess each other's work. Nevertheless, I would certainly have consulted Ken Wright on any paper about which I had serious doubts, and I believe that our series of *Publications* is a worthy part of the DAO heritage.

During its 90 years the DAO has clearly weathered many changes, in its internal organization, in its rôle in the national and international communities, and in the way that these communities organize themselves to try to guarantee the integrity of our scientific endeavours. I think we can claim to have maintained, and possibly even to have enhanced, the reputation that J.S. Plaskett and his early colleagues earned for the observatory in its earliest years. We have good hopes that, ten years from now, we will be able to celebrate a full century of achievement. Beyond that, it is impossible to predict. If the three-century tradition (and more) of the Royal Greenwich Observatory could be ended by the stroke of a pen, we cannot count on the DAO completing a second century. But if it does, I hope it will show the same adaptability to changing conditions, both in science and society, that it has shown so far. If I could be there, I would not be surprised to see some of our older ways of doing things coming back into favour. Perhaps there may even be more volumes of the *Publications of the DAO*. After all, it is precisely in the realm of publication that big changes are being forced on us by the Internet. For some years, pre-prints were a very popular way of spreading news of recent discoveries while authors were waiting for the unavoidably slow process of printing. They quickly went out of favour when scientists discovered they could achieve the same end much more cheaply and quickly with electronic distribution. The problems of assuring both quality and permanence in this new form of publication still have not been fully solved, and one reason I have discussed publication at length is that I believe this is an area where several changes are still to come.

I am at once proud of, and humbled by, my association with the DAO over more than half its lifetime, and grateful that I knew personally many of the older generation who did so much to make the observatory the sort of place in which people of my own generation were happy to work.

Notable Enhancements to the Telescope and Spectrograph of the DAO 1.2-m Reflector

J. Murray Fletcher, National Research Council
Herzberg Institute of Astrophysics, Dominion Astrophysical Observatory

The DAO's 1.2-m (48-inch) telescope and coudé spectrograph were completed in 1962; the first spectrogram was taken in March of that year. The detector of the day was the photographic plate, and because of its inherently low quantum efficiency of a few percent and astronomers' persistent desire to push towards faint objects, we felt very acutely the need to modify the conventional telescope and spectrograph design to create a system that would maximize the photon throughput as far as possible.

To address those issues, three distinct enhancements to the telescope and spectrograph were initiated by Dr. Harvey Richardson in the late 1960s. They included (1) a mosaic grating, (2) image slicers, and (3) a small-mirror coudé train. While the first two modifications were not original in concept and were already in operation at other observatories (the Palomar 200-inch

The 48-inch telescope at the DAO.

coudé, for instance, was fitted with a mosaic grating, and the popular Bowen image slicer dates back to 1938), various specifics of the DAO system encouraged fresh R & D for an ensemble of enhancements that would be more effective overall than merely importing or copying individual devices from elsewhere.

Mosaic Grating

In place of the familiar single grating used in almost all grating spectrographs, we introduced four in a 2 × 2 mosaic array. It permitted the entrance slit of the spectrograph to be doubled but still achieve the same resolution, and resulted in an increase in speed of about 1.6. That gain was further raised by selecting gratings with blaze efficiencies as high as 85%.

Each grating measures about 150 mm high by 180 mm wide. Since each one will produce a spectrum, it is extremely critical to ensure that all four gratings are precisely aligned; a particularly fine adjustment is needed in the direction of dispersion. The precision of alignment that is required is challenging: a human hair placed under one edge of a grating tilts it by about 400 times more than can be tolerated. Each grating was therefore mounted so as to be individually adjustable in tip, tilt, and rotation.

The basic design was modelled on the one in operation at the Palomar 200-inch telescope's coudé spectrograph. The adjustment of the gratings is achieved by bending a thick mounting plate by using a thinner leaf spring; the leaf spring does most of the bending, while the mounting plate bends very little.

The alignment of the gratings is viewed with a periscope system that has a high magnification and a spectral source that gives bright emission lines. One of the gratings is chosen as the standard, and the rest are aligned to it; a system of masks allows one to switch between the standard grating and one of the other gratings. The test that is then performed employs the principle of the Hartmann test. A convenient emission line is viewed first as produced by the standard grating and then as seen by the one being aligned. If there is a misalignment of the two gratings the emission line will appear to move left or right. Adjustments are carried out until the "jumping" is annulled.

The mosaic grating in the DAO coudé spectrograph went into operation in October 1967 and is in use to this day. The grating alignment is checked at the start of every observing run.

Image Slicers

In almost all applications of ground-based slit spectroscopy the entrance slit of the spectrograph is narrower than the stellar image (largely as a result of atmospheric seeing), and the resulting loss of light that goes into the spectrograph can be quite substantial. The non-transmitted (wasted) light that was reflected from the polished slit jaws has usually been used to monitor visually the position of the star on the slit. An image slicer puts that wasted light to better use. With that in mind, Dr. Harvey Richardson invented the super-positioning image slicer. The optical layout is shown in Figure 1. The unit is small, and contains two lenses and two mirrors. The mirrors are about 20-mm square, concave, and face each other. Each is made of two segments, with a small shift of the segments in the plane of the mirrors. The first mirror is the aperture mirror, the second is the slit mirror. A detailed description of this image slicer has been given by Richardson (1968).

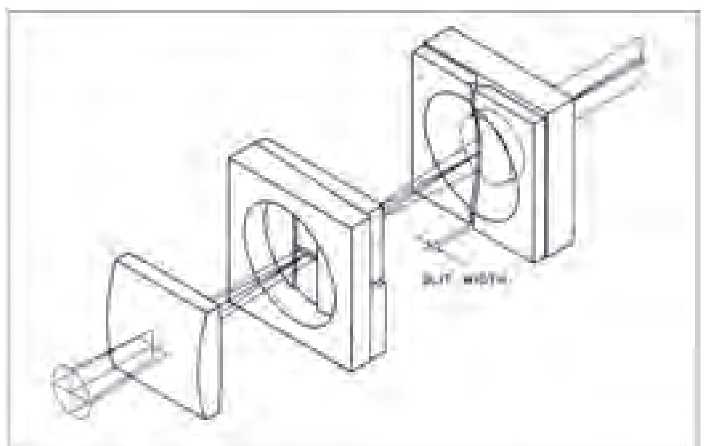


Figure 1 — Optical layout of an image slicer. Light from the telescope enters from the left. From left to right: cylindrical lens, aperture mirror, slit mirror, and field lens (dashed lines).

At the front of the slicer is a cylindrical lens; it forms a horizontal-line image of the star at a slot in the aperture mirror, and a vertical-line image at the slit that constitutes the exit end of the slicer. That slit is narrower than the stellar image, so some of the light is reflected back to the aperture mirror. When the two mirrors are correctly positioned relative to one another the reflected beam forms another image of the star on the slit. That light then enters the spectrograph. If some of the stellar image still misses the exit slit it is reflected back to the aperture mirror and again imaged onto the slit.

As viewed from the telescope, an image slicer presents a series of slit images side by side into which the star light is directed. In most applications the light that falls onto four of the slit images continues on through the single output slit and onto the collimator of the spectrograph. The image slicers give a gain of two to three times, and are in routine use at the DAO.

Small Mirror System

The 1.2-m coudé mirror train includes five mirrors. To accommodate the original f/30 beam they had to be quite large from the secondary (M2) onward. Each mirror was aluminized, so if a reflection of 90% (which is quite good) was achieved and maintained, the actual throughput was reduced to 0.90^5, or only 59%. However, the total central obstruction caused by the secondary and M3 was 45% in terms of diameter, or an added loss of $(1\text{-}0.45^2)$, so the total throughput by the telescope became $0.59 \times (1 - 0.45^2)$, *i.e.* 47%.

The solution adopted at the 1.2-m was to replace the large mirrors with smaller ones. In so doing we could place a turret of three mirrors at each mirror station (super-blue multi-layer dielectric, protected silver, and aluminum), thereby allowing a choice of three wavelength regions to be selected.

Simply replacing the mirrors from the original secondary (M2) to M5 with high-reflectance mirrors having an efficiency of 98% would give a throughput to the spectrograph of $0.90 \times 0.98^4 \times (1 - 0.45^2)$, or 66%. However, by employing smaller-diameter mirrors we could reduce the central obstruction to about 22%, gaining a throughput of 79%. The overall improvement was thus about 1.7 times greater than the original 47%.

Since the smaller secondary has to be mounted further from the primary, the resulting f/145 beam has to be converted to f/30 by a lens just after M5.

It is the nature of the image slicer that the central obstruction of the telescope affects the appearance of an observed spectrum by causing a strip of reduced intensity down the middle; the width and intensity of the strip are related to size of the central obstruction. With the original mirrors in place that was a serious drawback, but with the smaller mirrors it becomes only a minor cosmetic defect.

Harvey Richardson and his dog Duffy. Duffy was a frequent four-footed visitor to the 72-inch telescope, seen here in the background.

When combined, the three enhancements described above result in the 1.2-m telescope being roughly equivalent to a 3.2-m telescope. In theory the exposure times with the DAO 1.2-m telescope would be about 2.5 times those of the Palomar 200-inch coudé (for the same spectral dispersion). However, comparisons with actual Palomar exposure times demonstrate that those required by the 1.2-m range from about the same to one-half.

Harvey Richardson deserves substantial credit for the implementation of these modifications. Over the past 40 years numerous observers have benefitted from his achievements.

Digital Television and Precision Spectroscopy with the McKellar Spectrograph in the 1970s

Gordon A.H. Walker, University of British Columbia

The McKellar coudé spectrograph of the DAO 1.2-m telescope offered the perfect laboratory in which to develop the first Canadian digital TV system for astronomy. Later, the introduction of solid-state detectors produced a dramatically higher level of precision and signal-to-noise in the measurement of the line-profile variations in β *Cephei stars and, by using an HF absorption cell as the fiducial reference, in the measurement of the minute accelerations of other stars caused by planetary companions.*

Introduction

Nowadays, anyone can buy a sophisticated digital CCD camera, attach it to a telescope and feed images into a laptop computer. Such terms as "pixel" and "signal-to-noise" are today common parlance among optical astronomers — but not so 40 years ago. Then, the only panoramic detector was the photographic plate, occasionally coupled to an image intensifier. Unfortunately, photographic emulsions, even those especially prepared for astronomy, could detect but one incident photon in a hundred — a situation aggravated in spectroscopy by the considerable loss of starlight at the slit jaws (See, for instance, Argyle, 1955).

Photocathodes have a high photo-electron yield, making photomultipliers an order of magnitude more sensitive than photographic plates. In theory, an array of photomultipliers would have combined the multiplex advantage of the photographic plate and the sensitivity of a photocathode, but such a contraption with hundreds of photomultipliers would have been impracticably large and inordinately expensive. On the other hand, the spectacular success of television cameras in the lunar landing and Mars Mariner 9 programs in the late 1960s and early 1970s highlighted their potential for astronomy.

A TV camera generates, on a target, an electronic image corresponding to the incident light image. Before solid-state devices such as the CCD, the target was scanned by an electron beam to generate an electronic signal. The bulk of the camera was taken up with the generation and optics of the electron beam, and the magnetic or electrostatic beam-scanning system.

With a generous grant from NRC in 1969, I set up a laboratory at UBC with the specific purpose of developing a digital TV camera system for astronomical spectroscopy. I had huge help from colleagues, students, and others, and the availability of the McKellar spectrograph played a crucially important rôle in our success.

The McKellar Spectrograph

Andy McKellar had been a powerful influence on developments in spectroscopy. The DAO 1.2-m telescope, completed in 1961, was originally planned for photoelectric photometry to support the extensive stellar radial-velocity observations and luminosity calibrations being led by Petrie on the Plaskett telescope as part of his study of Galactic structure. McKellar had pointed out that one could include a coudé spectrograph in the design for the new 1.2-m that would enable spectroscopy of much higher resolution than was possible with the Plaskett's Cassegrain spectrograph. Such high resolution would indeed have served his interests in the molecular spectroscopy of cool stars and the interstellar medium much better. Unfortunately, I did not have the privilege of meeting McKellar as he had died two years before I arrived as at the DAO as a post-doctoral fellow in 1962.

Although a photometer had been built for the DAO in 1957 (Argyle 1957), by 1961 a considerable volume of photometry was coming from the then-new Kitt Peak National Observatory, and there was little incentive to duplicate a photometric program at the DAO. The emphasis for the new 1.2-m thus turned to coudé spectroscopy. A unique property of a coudé focus is that it remains immobile in space no matter where the telescope is pointing. In its simplest form it lies on the polar axis, but by introducing additional reflection and deflection to the light along the declination axis, the focus can be moved away from the telescope and the beam eventually sent horizontally into a laboratory — in the case of the 1.2-m telescope, to the McKellar spectrograph (Richardson 1968).

That spectrograph was the ideal laboratory in which to set up our clumsy camera, and we were allowed generous amounts of observing time. Harvey Richardson and Murray Fletcher also supported our work by contributing optical designs and improvements. Between 1971 and 1972, for example, exposure times were halved through the installation of the small-mirror system (described earlier in Fletcher's reminiscences), and by the enhanced-reflectivity coudé mirror system. Technical details of the UBC digital cameras that we developed in the 1970s can be read in Walker *(1977)*.

The Image Isocon

The Image Isocon had been developed by the English Electric Valve Co. as a low-light version of the Orthicon studio camera, in order to minimize the X-ray levels needed in medical imaging. It had already been put to use as a finder camera on the Isaac Newton Telescope at Herstmonceux (Gillingham 1969). The system that we developed has been described in Walker *et al. 1972*. Pictures of all the components and of the camera in the McKellar spectrograph are shown here in Figures 1 and 2.

Electrons released by light falling on the 70-mm diameter photo-cathode of the Isocon were accelerated and focused onto a very thin glass target, where they released secondary electrons that were removed by a mesh, thus leaving a positive-charge image in the target. The target was scanned normal to the spectrum by the electron-reading beam, which both neutralized the target charge and also produced scattered electrons in proportion to the amount of positive charge. The scattered electrons were collected and amplified in a dynode chain to produce the electronic output, which was then integrated and digitized each time the electron beam crossed the spectrum. If all that sounds complicated, it is nothing to the challenges we faced in getting it to work! In order to build up a charge image we exposed the camera for many seconds before reading it out, and that meant that we had to refrigerate the tube with a forced-air circulation system.

Figure 1 — The full Image Isocon digital camera system *c* 1970. The Isocon was a low-light-level version of a studio Orthocon having a 70-mm photocathode with magnetic scanning coils. It had 11 separate controls, many interactive! To avoid image spread during an integration, the tube was cooled to -10 °C by forced air circulating through a refrigerant. The Interdata computer had only 4K of memory and data were recorded on magnetic tape. The whole system had considerably less capability than the CCD camera in a modern cell phone.

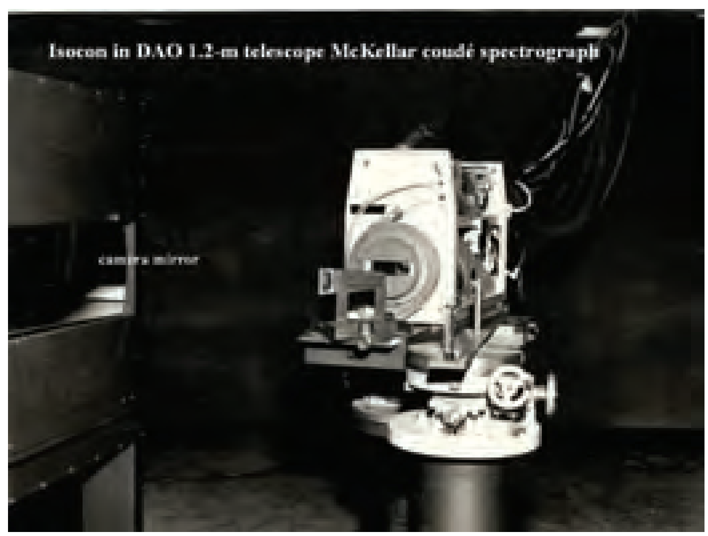


Figure 2 — The Image Isocon at the focus of the 32-inch camera of the McKellar spectrograph. The photocathode can be seen through the slot in the cooling mask on the front of the tube. Spectra were deflected by the diagonal mirror to the Isocon. In the foreground and to the right is the photographic plate holder mount.

The Isocon control and acquisition system had a myriad of analog controls, and required several people to keep it running properly. We had our first successful run in the McKellar spectrograph in December 1970. Computer memory was extremely limited in those days, and amounted to only 4K in our case. Parts of the program had to be written to tape while the data were downloaded from the camera, and then reloaded to display the spectra. The whole system of components filled a truck, and yet had considerably less capacity than Webcams or cell-phone cameras — but it was highly sensitive. We achieved a read-noise of only 17 electrons (photons) per pixel.

The nucleus of the Seyfert Galaxy NGC 1068 (Eilek 1973) — more than 100 times fainter than the stars of naked-eye brightness that had been observed photographically up to then — was among the first objects for which we acquired spectra. That is not a fair comparison, since the resolution of the Isocon of some 250 μm was an order of magnitude coarser than a fast photographic emulsion. The low spatial resolution allowed us to use a very wide spectrograph entrance slit; it passed all of the light in the star-like nucleus but

Figure 3 — NGC 1068. Image courtesy of David W. Hogg, Michael R. Blanton, and the Sloan Digital Sky Survey Collaboration

resulted in a correspondingly low spectral resolution.

Colleagues also exploited the linearity and large dynamic range of the Isocon in a number of innovative investigations. By isolating and tracking the emission line from singly ionized Helium associated with the black-hole secondary in the stellar binary Cyg X-1, Hutchings and collaborators (1973) made the first convincing case that the emission came from material close to, and streaming towards, the black hole. Goldberg and collaborators (1976) were able, for the first time, to resolve the complex pulsation phase of the βCephei star BW Vulpeculae at the "velocity stillstand" when both the stellar surface and the ejected atmosphere are simultaneously visible for a few minutes.

The Silicon-Diode Vidicon

Sensitive though it was, the Isocon's poor resolution, sheer bulk, and complexity forced us to try alternative cameras. In a silicon-diode vidicon the target and detector are one and the same, with an array of silicon diodes being read out by an electron-reading beam. We brought an RCA 4532A into operation in the McKellar spectrograph in 1972, using the data-acquisition system developed for the Isocon. The tube had a 12-mm diameter target and 30-μm resolution, and the filament was turned off during integrations. With no target gain and a high target source capacitance, the device was only suitable for brighter sources. However, the resulting high signal-to-noise level, quite beyond that possible with photographic emulsions, introduced us to a new realm of precision best illustrated by the work of John Glaspey on the radial velocity of Algol (AJ **78,** 681- 683, 1973; JRASC **71,** 139-151, 1977).

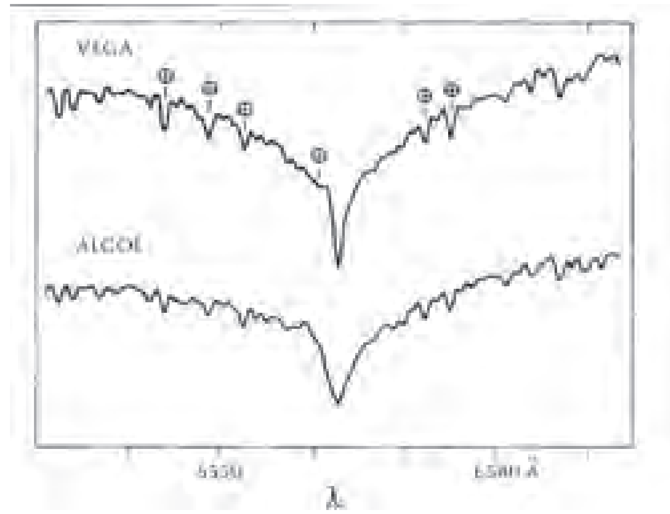


Figure 4 — A spectrum of Algol in the region of Hα taken in 1972 in the McKellar spectrograph with a silicon-diode vidicon (Walker *et al.* 1973). Several sharp telluric water-vapour lines are identified by circled crosses. The radial velocities shown were derived using these telluric features as fiducials, thereby eliminating the effects of guiding errors and electron-reading-beam jitter.

Figure 4 shows a spectrum of the well-known eclipsing binary Algol, observed with the vidicon in the region of Hα. The six circled crosses identify absorption lines caused by telluric water vapour. Applying a technique developed by Greg Fahlman, John Glaspey used those telluric lines as a fiducial reference to remove systematic shifts caused by jitter in the electron-reading beam and by guiding errors at the spectrograph slit, deriving Algol's short-term radial-velocity trend in a set of exposures taken over some three hours. The relative velocities are shown in Figure 5, where they are compared with

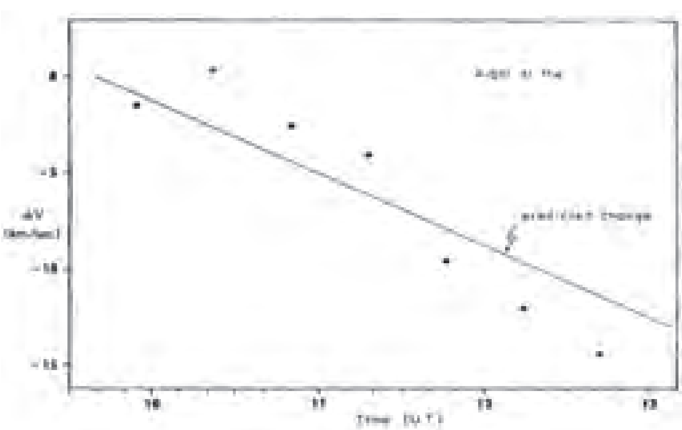


Figure 5. The relative radial velocities of the Hα line in Algol over a three-hour period relative to the telluric fiducials shown in Figure 3, together with the expected change. Reproduced from (Walker *et al.* 1973). See also Walker (1977).

the predicted change. By modern standards the precision is rather pathetic, but at the time it demonstrated how one could approach the radial-velocity precision inherent in the data by the use of such imposed fiducials. It was that diagram that made me think that the time might be at hand to try to detect planets on the basis of radial-velocity perturbations of their host stars. The idea of using telluric lines in that way was certainly not new, nor was it quite the first successful application (that success had been described in "Griffin & Griffin 1973).

Reticon Arrays

The Reticon Corporation began to produce push-broom print readers in the late 1960s and early 1970s based on linear arrays of self-scanned silicon diodes. The first arrays were only 256 diodes long, but ones with 1024 soon became available, eventually extending in the 1980s to arrays of 1872 diodes. We used all of them (Walker *et al.* 1985).

Figure 6 shows an early liquid-nitrogen-cooled housing that we used at DAO, with the clock and acquisition boxes on either side and a 1024 array visible through the window. These devices proved to have very high quantum efficiency and excellent photometric fidelity, and one could integrate for a very long time before reading them out. They soon completely superseded the TV systems.

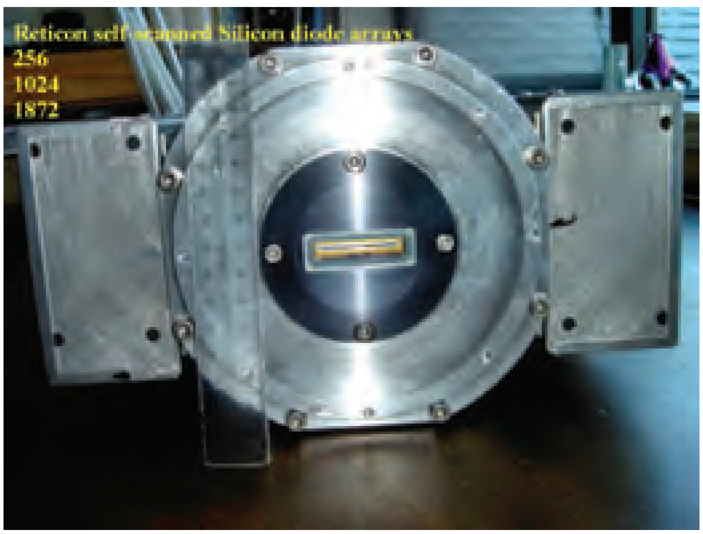
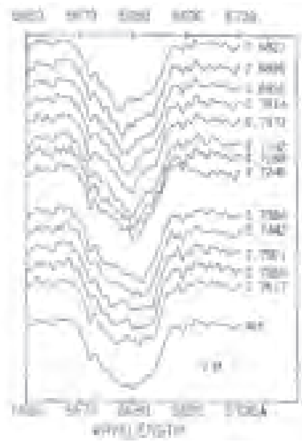


Figure 6. A 1024 Reticon self-scanned silicon-diode array in a liquid-nitrogen cold housing with electronics boxes on either side. This detector (replaced by an 1872 array in the 1980s) was highly stable and sensitive and superseded TV cameras with electron-reading beams.

Figures 7 and 8 show an example of an early success with the 1024 array in the McKellar spectrograph. The O-type star ζ Ophiuchi rotates very rapidly, with an equatorial speed of some 400 km/s. As a result, the lines in its spectrum are Doppler broadened, giving the observer a one-dimensional view of the star's surface. In the discovery series of spectra shown in Figure 7, we could detect what appeared to be ripples moving through the profile of the helium line, suggesting the presence of spots or waves travelling around the star. Not everyone was convinced — until we plotted residuals from a mean spectrum (Figure 8), when the ripples stood out in high contrast. We soon recognized that we were seeing the effects of non-



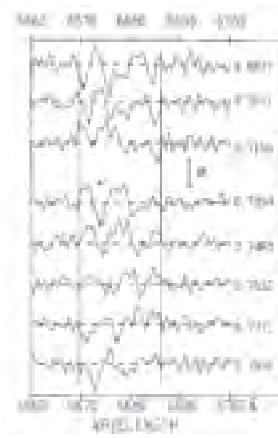


Figure 7 (left) — A 2-hour series of spectra of the rapidly rotating hot star ζ Ophiuchi taken in July 1978 with a 1024 Reticon array in the McKellar spectrograph. The helium absorption line is broadened by the star's rotation (~400 km s^{-1}), and is essentially a one-dimensional image of its surface. The eye can detect features systematically moving through the line profile, which show up in higher contrast in Figure 7, where residuals for the mean spectrum are plotted. The moving ripples correspond to nonradial pulsation distortions carried across the line of sight by the star's rotation. Figure taken from Walker (1979).

Figure 8 (right) — Residuals from the mean of the spectra shown in Figure 7. These residuals have the effect of showing up the moving features while suppressing those that do not change. Figure taken from Walker *et al.* (1979).

radial pulsations — previously unknown for this type of star. We went on to detect line-profile variations in a wide range of hot stars, founding a new branch of observational astronomy where the use of residual plots became invaluable.

Precision Radial Velocities

Bruce Campbell joined our group as a Killam Fellow in the late '70s. He had developed independently a Reticon camera while a Ph.D. student at the University of Toronto, and quickly absorbed the idea of using an imposed fiducial reference to eliminate instrumental line shifts in a spectrum, taking the idea a step further by suggesting a captive gas rather than telluric lines. On the suggestion of Douglas and Herzberg, hydrogen fluoride (HF) was chosen for that purpose since it has a well-spaced lattice of lines and is not confused by isotopic shifts. We were also provided with a suitable cell in which to contain the gas. HF for our experiment was provided by the UBC Chemistry Department.

Bruce and I set up the absorption cell just ahead of the McKellar spectrograph slit on 1978 December 27 to try the first observations. It was quite unsafe: HF is highly corrosive and toxic. The cell had to be heated to 100 °C to prevent the HF from polymerizing; the cell windows, which had to be made of Plexiglas because HF attacks glass, distorted with the heat. Nonetheless, we took a series of exposures of the Sun with the telescope mirror covers closed — enough light got through the gaps between the cover segments to give a good signal from the 1024 Reticon. One of those spectra is shown in Figure 9; the

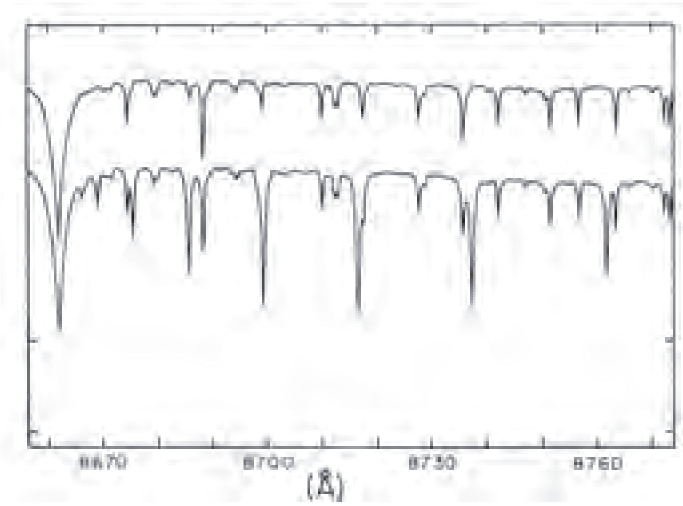


Figure 9 — Solar spectrum taken with the DAO 1.2-m telescope using a refrigerated 1024 Reticon self-scanning silicon-diode array. The mirror covers were closed so that the only sunlight reaching the coudé spectrograph came from the small gaps in the cover. The second spectrum shows the spectrum after passing through a cell filled with hydrogen fluoride (HF) gas that produces the evenly spaced comb of lines (figure from Campbell & Walker 1979). The HF lines provided fiducials that allowed measurement of a star's radial velocity freed from instrumental shifts and guiding errors. This was the basis for the 12-year program searching for extra-solar planets with the Canada-France-Hawaii Telescope.

imposed HF lines are obvious in the lower panel, while the upper spectrum was observed without the absorption cell in the beam.

It worked! Thanks to the small-spectral-shift program developed by Fahlman and Glaspey, we were able quickly to analyze the observations and to demonstrate from the solar spectra that indeed, in principle, we could use the HF fiducial lines to achieve radial-velocity errors almost an order of magnitude smaller than in conventional radial velocities measured photographically with the same instrument.

Bruce then became a staff astronomer at CFHT, where he built a safer version of the HF cell for use with the CFHT coudé spectrograph and, together with Stephenson Yang, we used the HF system at the CFHT in the 1980s and early 1990s in what eventually proved to be a successful 12-year extra-solar-planet search, although a full recognition that we had actually detected planetary signatures only came some time later. We had also built the original Reticon systems for the CFHT coudé spectrograph. There is no question that the early experiments in the McKellar spectrograph were crucial for the success of the precision radial-velocity and many other CFHT programs. The Reticon in its turn was superseded by that nearly perfect optical detector, the CCD, which seems likely to remain the detector of choice for a long time to come.

Thinking back to the heady days of getting the Image Isocon to work provides an excellent opportunity to acknowledge those who helped so much at the start. Vern Buchholz put the whole, largely analogue, system together and got the camera working; Jason Auman was heroic in writing the software; Ann Gower did a remarkable job in handling the masses of data and tapes; Bruce Goldberg designed and got the cooling system to work, while Barclay Isherwood, Rob Knight, and David Lane-Wright completed the team. My sincere thanks to them all.

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A Tale of Three Telescopes: The Commonwealth, the Queen Elizabeth II, and the Canada-France-Hawaii

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In the early fifties everyone had heard of the 200-inch telescope on Palomar Mountain, and many astronomers were beginning to visualize large telescopes for their own observatories. The Astronomer Royal (Dr. Woolley), representing Britain, visited the DAO to discuss a possible large telescope with a 4-m primary mirror, to be shared between Britain, Australia, and Canada. Dr. Woolley found considerable support, especially from Petrie and McKellar at the DAO. However, all funds had to come from Ottawa, and as they were not forthcoming, Canada withdrew its support.

A large Commonwealth telescope, the Anglo-Australian Telescope, was then successfully built in Australia. Although Canada did not join that project, the idea of a large telescope for Canada persisted, with Petrie and McKellar again being very enthusiastic. Up to that time they had worked with the venerable 1.8-m telescope built in 1916, and they worked very hard to convince their colleagues, but tragedy struck in 1960 when McKellar died, aged only 50. Many astronomers, both then and now and including Otto Struve, thought McKellar should have been given the Nobel Prize for his work on measuring the temperature of inter-stellar space as 2.7 K, 17 years ahead of Penzias and Wilson.

The work of McKellar and others at the DAO did however gain much attention, and an invitation was sent for an astronomer to address the Cabinet in Ottawa. Petrie was attending a conference in Germany and appointed me to attend a Cabinet meeting on the subject of a telescope named after Queen Elizabeth II on her visit to Canada. The Cabinet voted $10 million for a telescope in Canada, which surprised and pleased me very much. I met Petrie on his

[1] deceased 2008 June 15

return from Germany, and he said he still could not believe it. We made plans to appoint consultants and to activate the optical shop.

Then, one night in April 42 years ago, I was observing at the DAO. Normally the observatory is very quiet after office hours, but that night there was considerable traffic around the Director's house. In the morning the groundsman, Charlie Sainsbury, told me that Petrie had died. With Petrie and McKellar both gone, I became the signing authority for the telescope, and was told that it was now up to me.

Affairs began to deteriorate, and very severe problems arose. There was no criticism of the telescope, in whose design I had received very considerable help from the Pasadena astronomers, especially Bruce Rule and Ike Bowen. These distinguished men accepted no payment from us for their advice and accepted only travel expenses, but quarrels began amongst Canadian astronomers as to the site of the telescope. Their disagreements were so fierce that they came to the notice of the Cabinet Ministers, who appointed a committee (the Rose Committee, comprised of Drs. D.C. Rose, C.S. Beals, and W.H. Wehlau) to examine the source of the problems. Their report was given to the new Trudeau government first and not to the general public. On receiving the report the government cancelled the project, dismissed the opticians, and decided to sell the polishing machine. That was the end of the Queen Elizabeth II Telescope.

Harvey Richardson and I resigned. However, we had unknown friends in Ottawa who did not accept our resignations. We obtained funds for an optical shop for polishing large mirrors. Italy and Germany wanted their mirrors to be polished in our shop. The astronomers were still divided, and the large telescope project was greatly slowed down. Later I met Dr. Roger Cayrel at an IAU conference, and he told me that the French government also wanted to build a large telescope. He and I worked together on its design. The French telescope was not fully funded, and they were looking for a partner to share the costs. One evening Roger suggested to me that we approach our respective governments to build the telescope, the costs to be shared equally between France and Canada. It was proposed that the telescope be located on Mauna Kea. Some of Roger's colleagues had already been to that site and enthusiastically recommended it.

This idea gained much support in France, but there were some objections. In particular, French astronomers questioned sharply the ability of Canadians to polish a large mirror, something the latter had never done before. To overcome such objections a meeting was held in Paris, chaired by Henri Curien, the Minister of Science. It was the most important meeting we had ever attended. The French team left the room, returning several hours later. Curien stood up to deliver the French decision, and I still remember his exact words: "We have examined very closely Canada's claim to be able to polish a large mirror. Our conclusion is that Canada could do it." Curien took us all to lunch at "Le Doyen" (one of the best restaurants in Paris) — a very convivial lunch that I shall always remember.

The problem remained that Canadian astronomers still could not agree upon a site. Later, when at an astronomical conference in Hawaii, I went to see an old Australian friend from Cambridge, John Jeffries. John knew of our problems, and told me that we could have a site on Mauna Kea, the highest point in the Pacific, with no industry within 2000 miles, but that we should act quickly, and added that there might be a problem: the mountain top was owned by the Mafia. We might have to pay a bribe.

Mauna Kea was classified as a dormant volcano and of course we hoped it would remain so. The site on Mauna Kea was accepted by the astronomers and, at long last, the Canadian Cabinet decided to share the costs with France in the construction of a large telescope. We found out later that the Prime Minister himself was favourably disposed to a large scientific project shared between France and Canada, as was Jeanne Sauvé, the Minister of Science. There would be set up a corporation called (in French) "La Société du Télescope Canada-France-Hawaii," or CFHT. Canada would pay half, and supply half the high technology; the mirror would be polished in Victoria, the chief optician being Roy Dancey. The telescope was, in fact, built within budget, and on time. So the bribe was paid, and Canada got its new large telescope on one of the best sites on Earth.

First light — the first use of the telescope to see if and how it actually works — is always exciting. My eldest daughter, Kathy, who had studied at the Sorbonne for a year, was with me and Roger Cayrel that night. Roger had a bottle of champagne ready to celebrate the historic moment. When he started to take the wire off the cork Kathy cried, "Non, non, non, Dr. Cayrel!" At that altitude of 14,000 feet the champagne would have exploded into the air. "Vous avez raison (you are right), Mademoiselle!" answered Cayrel. We took it down to the mid-level at 10,000 feet, and celebrated there in the proper French style.

DAO Instruments at the Canada-France-Hawaii Telescope

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The DAO played a major rôle in the instrumentation for the CFHT, commencing well before the telescope was commissioned in 1979. Several of those instruments proved to be very popular workhorse instruments, and have contributed greatly to the overall success of the CFHT.

Early Instruments: Grenses, Coudé Spectrographs, and Spectrograph No. 1

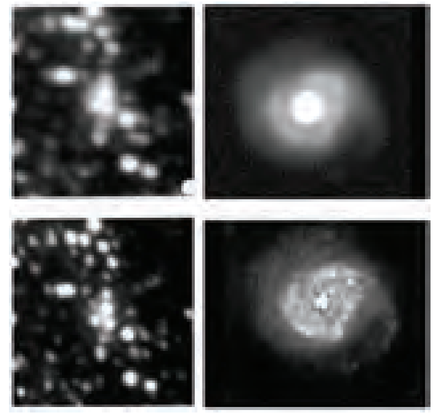
One of the most topical lines of research when the CFHT was being designed concerned quasars. Even though they had been discovered some 15 years previously, quasars remained enigmatic objects, and consequently several different techniques were being developed and tried in their study. Since quasars frequently exhibit very strong, broad emission lines and have very blue continua, it was recognized that they could be detected to very faint limits using low-resolution spectra. Harvey Richardson modified the design of the wide-field corrector for the CFHT prime focus (originally designed by Charles Wynne) so that one surface of the last lens was flat, enabling a transmission grating to be replicated on it. Harvey called this grating-lens combination a "grens." Two different grenses were produced that would deliver 1000 Å/mm and 2000 Å/mm spectra over the whole 51′ ×51′ field, and would be recorded on 10-inch square photographic plates. Changing from direct imaging to low-resolution spectroscopy was accomplished by switching the last lens element of the corrector during the day, in preparation for an observing run. Since there was considerable delay in commissioning the Cassegrain focus, the grenses were used quite extensively during the early years of the CFHT.

The very efficient coudé spectrograph system for the DAO 1.2-m that had been designed by Harvey Richardson became the model for the CFHT coudé. The same types of highly efficient small mirrors were used in the f/115 coudé train, and the same basic coudé spectrograph employing Richardson image slicers was adapted for CFHT. The initial spectrograph began operation in October 1980, with a mosaic grating and an f/8 camera that produced spectra with resolutions of ~50,000-100,000. A copy of the precision radial-velocity spectrometer requiring a hydrogen cell, as pioneered on the 1.2-m telescope by Gordon Walker and Bruce Campbell, was also commissioned on CFHT in 1980. Extra-solar planet searches and chemical-abundance studies constituted some of the more significant early contributions of the CFHT. "Gecko," a much more efficient coudé spectrograph, was commissioned in 1995. Also designed by Harvey Richardson, Gecko incorporated an echelette mode with a grism cross-disperser and an f/4 camera, yielding a resolving power of 120,000. It continued to produce excellent science until very recently.

Spectrograph No. 1 was a low-to-moderate-resolution Cassegrain spectrograph. Designed by Harvey Richardson and Walter Grundmann, it built upon the very successful spectrograph concepts of the DAO Plaskett Telescope so that optics and detectors could be easily exchanged to achieve the highest possible efficiency for the wavelength range of interest. The original spectrograph was shipped to Hawaii in July 1982 but was then literally dropped (!) at the airport in Honolulu and had to be rebuilt. The new version, now proudly named the Herzberg Spectrograph, was finally commissioned in mid-1985. One of the highlights emerging from data collected with that instrument were the initial indications, demonstrated by John Kormendy, of the presence of Supermassive Black Holes (SMBH) in the nuclei of galaxies.

The Quest for Higher Spatial Resolution: HRCAM and AOB, *a.k.a.* "PUEO"

Anyone who has looked through a telescope knows the importance of good "seeing," and is also aware that images tend to "dance around." The CFHT High Resolution Camera (HRCAM) attempted to capture the best images by closing a fast shutter when the image quality was poor, and also tried to stabilize the image by sensing the position of a reference star at 100 Hz and quickly moving a piezo-controlled mirror to compensate for any motion. René Racine and Robert McClure were the principal scientists behind that instrument; it was designed (by Harvey Richardson) for the bare CFHT prime focus, yielding a corrected field of ~2′. During commissioning in 1988 it was demonstrated that the fast tip/tilt compensation improved the images by at least 15%, but since significantly poorer images occurred so rarely, the fast shutter was in fact unnecessary. It was also discovered that images better than 0.4″ could not be obtained owing to residual polishing errors in the primary (it should be recalled that, prior to CFHT, images better than 1″ on large telescopes were practically unheard of!). The most spectacular science produced by HRCAM included the detection of Cepheid variables in the Virgo cluster of galaxies, and an accurate determination of the Hubble Constant (which had been in dispute by a factor of two for several years). One of the primary scientific drivers for the *Hubble Space Telescope (HST)* was to determine the Hubble Constant and the distance scale of the Universe by observing Cepheids in Virgo. HRCAM beat them to it (in September 1994) by a few months, although it could have been done a few years earlier had not the CFHT Time Allocation Committee believed that *HST* was going to do it better and consequently did not allocate telescope time until everyone became increasingly pessimistic about the *HST* launch date. (It was eventually launched in April 1990 and repaired in December 1993).



The left panels demonstrate the typical improvement in image quality delivered by HRCAM, for the globular cluster M15: 0.8″ natural seeing at top, 0.5″ HRCAM V-band image below. The right panels demonstrate the improvement realized with AOB for NGC 7469, a galaxy with an active nucleus harbouring a SMBH. At the top is a typical CFHT image; beneath is a K-band diffraction-limited AOB image.

The CFHT Adaptive Optics Bonnette (AOB, or PUEO) was fortunate in that it was jump-started by the fact that significant funds became available for it and had to be spent quickly. It thus managed to avoid the usual, often very significant, delays that most projects experience when starting up. A joint DAO-Paris Meudon project, the AOB was completed in March 1996 only five years after its initiation. Adaptive optics for astronomy, using very rapid (~1 kHz) compensations involving several actuators (19 sub-apertures in this case), was very much in its infancy. In actual fact, the performance of the AOB very significantly exceeded the specifications for the instrument (and certainly my expectations!). On my first night during commissioning, I was so excited to see diffraction rings round every star, and how easy and efficient the AOB was to operate, I stayed up at the summit all night instead of returning to Hale Pohaku (as was usual during altitude acclimatization).

But despite the fact that the AOB performed so spectacularly well and clearly had much potential, it did not produce a lot of science. That was largely due to three factors: (a) it was more technically motivated than science-driven, and consequently lacked a science team, (b) suitable cameras and integral field spectrographs were not available to take advantage of the images (typically characterized by an equivalent seeing of 0.12″ in the I-band right out to K), and (c) the fact that astronomers, being conservative, were afraid of this new technology that produced images that were both temporally and spatially variable. In fact, some skepticism still lingers in the community about the latter, despite the many excellent results from adaptive optics that are now in the literature. Sadly for CFHT, several opportunities to participate in leading science were thus missed. In particular, perhaps, the AOB could have easily produced a long sequence of diffraction-limited images of the galactic centre, permitting the measurement of the orbits of stars around the central black hole and thus establishing both the existence and the mass of the latter — as was subsequently carried out by other teams using larger telescopes.

The CFHT Multi-Object and Sub-arcsecond Imaging Spectrograph (MOS and SIS)

In 1986 the CFHT Scientific Advisory Council identified, as a very high priority, a spectrograph that could observe spectra of many objects simultaneously by using aperture masks to select the desired targets. Separate design teams from Victoria, Paris, and Marseille eventually decided to collaborate in the design of MOS/SIS. The "SIS" part was, in fact, a separate spectrograph that utilized the same image-motion sensor and fast-guiding technology as that developed for HRCAM, to both sharpen and stabilize the images so as to provide the best possible spatial resolution at visible wavelengths. Aspects of the technologies used in MOS and SIS eventually found their way into the designs for Gemini instruments, especially GMOS, the Gemini Multi-Object Spectrograph. In fact, all Gemini instruments have "wavefront sensors" that are based on the SIS image-motion sensor.

MOS/SIS was commissioned in July 1992, and immediately started producing spectra of about 100 objects simultaneously, representing a hundredfold gain in speed for many projects. It was also extremely robust and reliable, so that most calibrations could be carried out during the daytime, thereby conserving precious night-time hours for observations (in that regard, it built on the heritage of the extremely stable spectrographs on the DAO telescopes). The community was anxiously awaiting the MOS/SIS capability, holding workshops for more than a year in advance, and imaging surveys for target selection were already well underway. In stark contrast to the case of AOB, the MOS/SIS science teams quickly produced new science; the Canada-France-Redshift Survey (CFRS) gave results on the evolution of galaxies in the last 5 billion years of the Universe, and the first Canadian Network for Observational Cosmology (CNOC) yielded a measurement of the density of matter in the Universe — both results were believed by many to be only possible with the Keck 10-m telescopes. The importance of maintaining a strong synergy between technical and scientific teams just cannot be overstated.

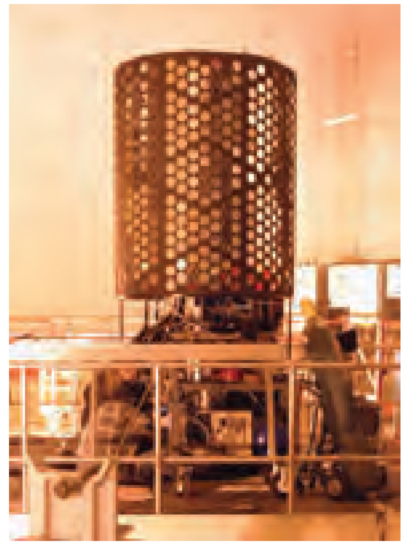
The SIS component of MOS/SIS also played an important rôle in establishing the legacy of CFHT. The improved image quality and automatic focusing enabled significantly better data to be obtained for the nuclei of external galaxies, firmly establishing the presence of SMBHs and providing estimates of their mass.

CFHT MegaPrime

In the mid 1990s it became increasingly obvious that it was difficult to compete with the light-gathering power of 8-10-m telescopes for spectroscopic observations, and that there was an opportunity for CFHT to exploit its excellent imaging capability for wide-field surveys. A new wide-field corrector was designed by Chris Morbey to have excellent transmission as far as possible into the ultraviolet (for U-band observing) and would incorporate a fast tip/tilt guiding system designed by Pierre Gigan (Meudon). For practical reasons the first element of the corrector was limited to a diameter of 820 mm, yielding a field of 1°.4″ in diameter. The guiding and automatic focus systems were all designed and built in Victoria. The detector, produced by CEA Saclay, is a mosaic of 36 CCDs each with 2K × 4K pixels, and produces 340 mega-pixels of data over its 1° square field. As might be anticipated, this huge camera is in great demand, and continues to produce excellent science through programs such as the CFHT Legacy Survey. Results from the supernovae element of that collaboration are directed towards measuring the equation of state of dark energy through the detection of very distant supernovae — a very exciting prospect!

The Impact of DAO Instruments

One of the ways of assessing the impact or value of an instrument is to measure how often it is actually used by astronomers at the telescope, and how long it lasts. Through such metrics, most of the instruments designed and built by the DAO fare very well, especially the coudé, prime focus cameras, and MOS/SIS. Another commonly used method is to count the number of papers that are based upon data from the various instruments, and the number of citations that those papers accrue. Statistics presented at the CFHT 21st anniversary celebrations in 2000 by Dennis Crabtree and Liz Bryson showed that the DAO instruments mentioned above were all in the top half (11/23) of CFHT instruments in terms of the numbers of published papers that they supported, and were amongst the most productive as measured by the citation index. In regard to the latter, the CFHT coudé, MOS, and the prime focus direct-imaging cameras outshone all the other instruments. Moreover, several studies have demonstrated that CFHT enjoys a scientific output that exceeds those of other 4-m-class telescopes, while its impact is comparable to some of the 8 to 10-m-class telescopes and *HST*.



The MegaPrime camera in 2008.

It can be fairly claimed that instruments that the DAO has helped to design and/or produce have had a tremendous impact on the scientific productivity of the CFHT. Several of the best can justifiably be attributed to the close collaboration with our superb French colleagues, and they have all benefited from strong interactions between the scientists and the teams of optical, mechanical, electronic, and control engineers.

Innovations in Data Management and Science Output

Elizabeth Griffin, National Research Council
Herzberg Institute of Astrophysics, Dominion Astrophysical Observatory

The foregoing describe some of the developments of unique instrumentation both for the two DAO telescopes and for their progeny (the CFHT and Gemini), using the local telescopes to gain essential experience if not as direct test beds. But when all is said and done, the whole purpose of these activities is to gather data, whether as images or spectra, from which science can be extracted. Thus although a focus on Data is left until last it is by no means least; rather, it is the converse.

Because astronomy is an observational science, the scope and quality of data management influences intricately the variety, potential, and integrity of scientific output. Astute management of observations has always been a forefront concern at the DAO, one product being an almost complete archive of photographic observations dating back to 1918 May 6, another being the user-friendly digital archive, the *Canadian Astronomy Data Centre* (CADC), which has world status and (many argue) world supremacy. Yet despite the modest mirrors of the DAO's two active research telescopes (once classified as "large," and now well below "modest" as world-class sizes go), the technological innovations described above plus an enduring team spirit have demonstrated the very real feasibility of small-telescope science, and have influenced very positively the DAO's research profile at the international level.

Managing Digital Data: the CADC

The CADC was created as an individual nucleus within the DAO in 1986, to serve as the Canadian centre for distributing data from the Hubble Space Telescope. Since then it has evolved into the national data hub for Canadian astronomy. It has a total staff of 19, and can claim to be the largest astronomy data centre of its kind in the world.

Today the CADC archives data from all major operations that involve Canadian participation, such as the CFHT, JCMT, *MOST,* radio, and sub-millimetre telescopes. In addition it mirrors other large-instrument archives, and leads Canada's official participation in the International Virtual Observatory Alliance (IVOA). It is difficult to measure its "usefulness" as an active asset for research, but in 2007 (for instance), it served data to about 2000 users, which is about 44% of its registered users and equivalent to some 20% of world professionals. In that year 90 refereed papers formally acknowledged use of CADC services — though undoubtedly there were considerably more, since many do not give the requested acknowledgement.

The CADC always places a strong emphasis on SCIENCE, which it considers its foremost driving force. Its official mandate includes serving the user community, developing IVOA standards and implementing them, designing and managing storage systems, and developing and enhancing pipeline processing systems. Of those, perhaps its most effective application is the help that its staff can supply at an individual level. In these times of megalithic instruments and organizations, the individual who is balked by a query of whatever nature can experience considerable difficulty in finding a listening ear and one-on-one advice; that is where the CADC excels, and is what earns its reputation as a unique organization rather than as a manager of robotic tools.

More recent, born-digital observations made at the DAO are also available unreduced, whether spectra or radial-velocity traces made with the RV scanner (now superseded), but not via the CADC as they are not in the public domain; they can be accessed on request.

Managing Heritage Data: an Under-Exploited Resource

Ninety years of active observational work with the 1.8-m telescope have resulted in over 90,000 spectra, all of which (save for a few persistent wanderers) are arranged in the DAO's plate-store in order of RA. All the spectra from the 1.2-m (some 16,000, dating back to 1962) are similarly stored. The few direct plates that were exposed at the 1.8-m (by Helen Sawyer Hogg, when Frank Hogg was on the DAO staff) are also archived there. To what purpose have they been kept all those years? Today's research is mostly geared towards faint objects that require large telescopes and modern detectors, and many researchers are unaware of the existence of astronomy's heritage archives, so naturally they do not opt for research projects that call for data older than the start of the digital era. But there are important exceptions, whose solutions can only be attempted by appeal to older observations. Understanding long-term variability in all its forms ("long" meaning 25+ years), the relatively rapid changes in spectra of AGB stars, period modulation indicating a third body in a binary, and investigating the history of the Earth's ozone are all problems that have been tackled productively because astronomers never threw away their photographic observations.

Were those heritage data available in the digital forms that modern research demands, tackling these types of problems would merely involve the familiar requests to a data archive and downloading the relevant files. But unfortunately very few of astronomy's heritage data are presently

The 1918 cover and first plate in the DAO archive — a spectrum of β Canum Venaticorum.

A scan along the first plate, showing the spectral lines in more detail.

accessible digitally. It is not a question of scanning plates with a flat-bed scanner; those were never designed to cope with the stringencies of astronomical plates, though they may suffice for objective-prism plates, classification spectra, and some types of images. Only a purpose-built machine will digitize astronomical plates faithfully. The DAO has an operating PDS (one of the few remaining in North America) and, given suitable resources, the DAO's own holdings, plus an impressive fraction of others imported for the purpose, could be digitized and placed in the public domain.

It is important to reflect however, that even with all our modern data-sharing technologies it is still by no means simple to cross the boundaries to different (even allied) sciences. The intricacies of handling raw data correctly are unquestionably best managed by experts in the field, and it is only when those data are converted into scientifically meaningful units that they can be considered fully robust for whatever application. It is only when we have reorganized our heritage data along those lines that we may reap the real scientific benefits from well-kept archives.

A view of the plate storage archive at the DAO.

Suggestions for further reading:

D.A. Bohlender, Celebrating 90 years of observational astronomy at the Dominion Astrophysical Observatory, in *400 Years of the Telescope*, `www.400years.org/newsletter` (May 2008).

CFHT Legacy Survey: www.cfht.hawaii.edu/Science/CFHLS/.

Richard Jarrell, *The Cold Light of Dawn: A History of Canadian Astronomy*, University of Toronto Press, 1988.

Crabtree, D.R & Bryson, E.P. 2003, *Library and Information Services in Astronomy (LISA IV), Emerging and Preserving: Providing Astronomical Information in the Digital Age* (Eds. B.G. Corbin, E.P. Bryson, and M. Wolf, US Naval Observatory, Washington, DC, p. 199.

Crampton, D. 1999, *JRASC*, 93, 168.

E.H. Richardson, 1968, JRASC, 62, 45.

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Pen & Pixel

Figure 1 — M35 and NGC 2158 from the MegaPrime camera at the CFHT. The large field of view of MegaPrime on CFHT allows astronomers to capture panoramic views of our own galaxy. Here, an interesting perspective captures two open clusters in the same image, Messier 35 on the upper left and NGC 2158 on the lower right. These two clusters have no relation to each other since detailed study shows that NGC 2158 is four times more distant from us than M35 and about ten times older. Canada-France-Hawaii Telescope / 2003. Used with permission.

Figure 2 — Unattached member Rick Stankiewicz captured this image of the evening sky on July 5 using a Canon XTi and a Sigma 17-70-mm lens set at 62 mm. In Rick's words: "It was a picture-perfect evening for the beautiful alignment of a thin crescent (with earthshine) Moon, (bluish) Regulus, (orangey) Mars, and (yellowish) Saturn from my backyard south of Peterborough, Ontario, Canada." Exposure was 1 s at ISO 800 and f/4.5.

Figure 3 — A very happy group of campers, the Calgary RASC eclipse group, at their site in China after a successful observation of the August 1 total eclipse. Don Hladiuk of the Calgary Centre reports "Well, we had to go to Plan B and move the whole group about 40 km north, away from the mountains, to avoid some cloud, but we saw it!"

Figure 4 — Don Hladiuk of the Calgary Centre took this image of the eclipsed Sun from northern China on August 1 using his Canon EOS 30D. Exposure 1/320 s at ISO 1000.

Astronomical Art and Artifact: The View from the RASC Archives

by R.A. Rosenfeld, RASC Archivist (randall.rosenfeld@utoronto.ca)

ABSTRACT: The holdings of the RASC National Archives testify to the importance of astronomical sketching as a scientific technique and scientific recreation from the early years of the Society, *i.e.* the late Victorian and Edwardian eras. This article traces the history of astronomical drawing in the RASC during that period, comparing it to similar activity in several analogous national astronomical cultures, and closes with a glance at astronomical sketching in the RASC today. This article is the first in a series devoted to making the contents of the Archives better known to members, as part of an initiative of the RASC History Committee.

Introduction

The recording of astronomical observations in graphic form pre-dates the invention of script, if not the advent of *homo sapiens sapiens.*[1] The basic impulse to depict astronomical objects, events, and ideas is seemingly common to many cultures, however much they may differ in their approaches to imaging the heavens. Perhaps we are "hard-wired" for this. Astronomical art has been a vital tool for making, mapping, and manipulating astronomical discoveries and theories from before the rise of Copernicanism. Galileo's epoch-making telescopic observations and analyses owed their quick achievement and telling impact to his mastery of two technologies: telescope design, and visual representation (Biagioli 2006; Bredekamp 2001). Skill in drawing enabled Galileo to enhance the textual presentation of his observations in support of his new theories. His depictions aided others in comprehending and eventually reproducing his results. The original "Galileo moment" would not have happened for Galileo's contemporaries had he not artfully rendered his observations.

The Archives of the RASC contain an intriguing paper trail of our post-Galilean astronomical activity. That trail-among-the-stars can be discontinuous and faint, but amidst its more vivid vestiges is the surviving graphic record of observations by RASC members. Drawings from the immediate prehistory and early days of the Society, roughly corresponding with our late-Victorian and early-Edwardian corporate existence, are particularly interesting, for at one and the same time they can be familiar in subject, yet alien in details. This article marks the beginning of a new column devoted to increasing accessibility to the RASC's National Archives. A different image, drawing, photograph, or astronomical artifact will be highlighted in future editions of the *Journal*. To introduce this series, something of the history of astronomical sketching in the RASC is outlined below. This outline will give a taste of what is to come.

The aim of this column is historical, but only in part. It is also practical. The better we know our history, the more we can learn from it. The more RASC members are encouraged through this column to venture on astronomical sketching, or to discover a graphic technique they can use today, or to see a celestial phenomenon from a different creative perspective, or to preserve a newly uncovered vintage or antique observational record book or instrument, then the more our collective activities will be enriched. Astronomical sketching, aside from its continued scientific utility,[2] provides a wonderful method for increasing observational prowess, and is a technique completely within the capabilities of all RASC members.[3] The tools are inexpensive and readily available, and there is but one cardinal rule: *attempt to draw only what you see, and be honest about what you record.* If you want to do something more creative with your results afterwards, there is nothing stopping you from doing so. And you have the advantage of basing what you then do on your own graphic record of a real observation.

[1] To our knowledge, no serious commentator has attributed extant astronomical imagery to extinct fossil hominid species *(i.e. Homo sapiens neanderthalensis/H. neanderthalensis),* yet serious claims for the creation of astronomical art at sites like Lascaux *ca.* 20,000-15,000 BC have been advanced on behalf of our upper-paleolithic ancestors (Rappenglück 1999). Such claims are best met with interested scepticism.

[2] *e.g.* the 150-Foot Solar Tower Current Sunspot Drawing (`http://astro.ucla.edu/~obs/cur_drw.html`), or the reports of the various observing sections of the British Astronomical Association, for which see the JBAA.

[3] For a modern instructional guide, see Handy *et al.* 2007 (*n.b.,* there are other effective technical approaches than those described in this book). For a collection of modern examples of astronomical sketching, see the Astronomy Sketch of the Day site (www.asod.info), and for an active web community, there is a dedicated Cloudy Nights forum (`www.cloudynights.com/ubbthreads/postlist.php/Cat/0/Board/Sketching`). Jeremy Perez maintains an excellent collection of web resources on all aspects of astronomical sketching (`www.perezmedia.net/beltofvenus/archives/000567.html`).

Training, techniques, and tools

As a rule, there were no formal procedures or courses specifically designed for the grounding of observers in the art of astronomical drawing from the 16th to the early 20th centuries. For most of that period, training in many aspects of observational astronomy was very much an informal affair (what we would now call "on-the-job" training), consisting of unequal measures of mentoring, autodidacticism, and most important of all, cumulative experience. What is truly surprising is the absolute dearth of instruction on astronomical drawing in the handbooks, amateur or professional, from the heyday of the hand-drawn astronomical record (*e.g.* Webb 1859; Herschel 1878; Young 1889).[4] This absence is in stark contrast to contemporary treatises on microscopical instruction, which regularly featured a detailed chapter devoted to sketching what one saw on the slide (*e.g.* Suffolk 1870). Occasionally, comments were offered in the astronomical literature on how drawings were done, but they were infrequent (notable and instructive exceptions are Rosse 1874; Weinek 1890; Morehouse 1922). A few papers expressly devoted to astronomical drawings and their reproduction were written, but enumerating them would hardly exhaust the fingers of one hand (Smyth 1843; Webb 1871; Huggins 1882). This lack of written instruction specifically aimed at astronomers seems less odd when one considers the position of artistic activities in 19th-century society. Painting in watercolours was a socially acceptable activity in polite circles; many handbooks were published, and many instructors found ready pupils among the gentry, not to mention the mercantile and mechanical classes with a bent for self-improvement. The training of numerous professions — surveyors, architects, engineers, and military and naval officers — involved instruction in design (Drayson 1865); those professions were the very ranks from which many astronomers were drawn. Diverse astronomers were also microscopists. Clearly there were ample opportunities to acquire drawing technique before one ventured near a telescope.

The media chiefly favoured for graphically recording astronomical phenomena were watercolour, pen and ink, graphite pencil, coloured crayon (Conté), charcoal, coloured chalks, and pastels (Figure 1). Many of the techniques acquired in landscape, still-life, and portrait work were put to use in astronomical drawing. The supports (lined and unlined, bound and unbound notebooks, watercolour papers, boards),

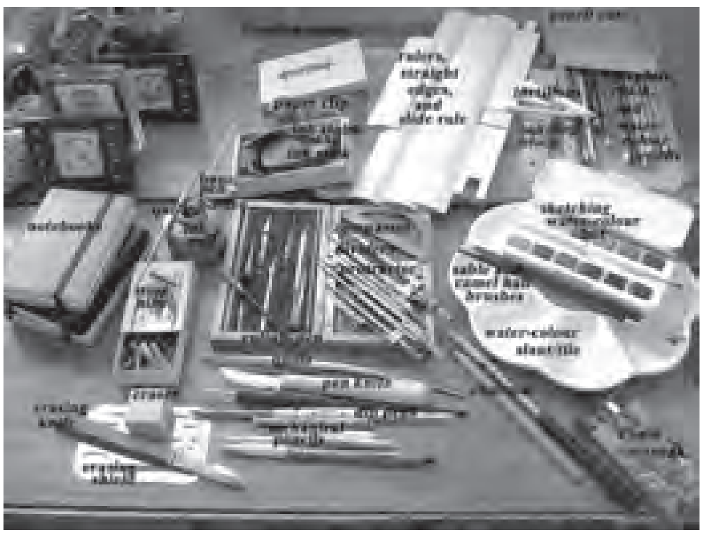

Figure 1 — Tools for astronomical drawing, *ca.* 1850-1950. Included here are notebooks, steel nibs, nib holders of bone and plastic, goose and crow quills, penknife, ruling pen, mechanical pencils of silver, bone, copper-alloy, and plastic, an erasing knife, erasing shield, and gum eraser, a fitted box of German-silver and copper-alloy drafting/mathematical instruments, compasses, dividers, protractor, rulers, and straight-edges, a Mannheim-type slide rule, a Japanese travelling Suzuribako with ink-stone and ink stick (some astronomers preferred to mix their own ink prior to a night's work), a paper clip and portable writing board, *tortillons* and sanding block, a pencil case with numerous graphite, chalk, and watercolour pencils, a travelling watercolour box, sable, and camel-hair watercolour brushes, a slant for mixing colours, charcoal, a porte-crayon, and Conté crayons. Image courtesy of the Specula astronomica minima.

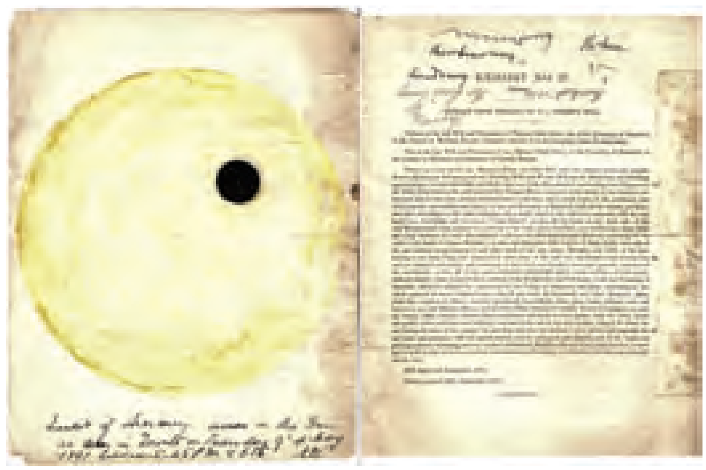

Figure 2 — The left image shows Sir Adam Wilson's attempt in watercolour to depict the transit of Mercury, 1891 May 9. The attempt cannot be characterized as successful, and has the dubious distinction of being scientifically and artistically the least competent drawing in the Archives. The right image shows why it is interesting; it is drawn on the back of a copy of a legal document of 1872 (the Cedar Island property mentioned here later belonged to Sir Harry Oakes). Sir Adam could easily have afforded a better support for his poor drawing. Peter Broughton has suggested to the author that the only way to salvage Sir Adam's competency would be to imagine that the yellow circle is not the entire solar disc, but merely a detail as framed by the field of a medium- to high-powered eyepiece.

[4] Nor has the historical study of astronomical drawing drawn much attention today. The best recent work has concentrated on the historical techniques used to translate astronomical sketches to media for mass dissemination, *e.g.* Hentschel 2002 (an excellent treatment).

the brushes and pens (quill and steel), and the pigments were the same. Mathematical drawing instruments (dividers, compasses, ruling pens, scales) were also deployed (Stanley 1878). In one amusing case from the RASC Archives, Sir Adam Wilson recorded a transit of Mercury (1891 May 9) in watercolour on the back of a printed probate of 1872 (Figure 2)! Perhaps the most unusual support for a drawing in the RASC Archives is a record of the solar eclipse of 1900 May 28, by A.E. Weatherbe, done neatly in ink in a booklet entirely of birch bark (Figure 3). The material of this artifact is probably unique among 19th-century Commonwealth eclipse records, and there is an innocent quality to the choice of such a quintessentially “Canadian” support. Weatherbe was a brave man; ink generally cannot be corrected when laid down on birch bark. The bark, however, is a reasonably long-lived material.

Figure 3 — A.E. Weatherbe, solar eclipse of 1900 May 28, compass, pen, and India ink on birch bark. The graphic depiction of the various stages of the eclipse is elegant, simple, and skilful. This is most likely a finished report of his timings, rather than Weatherbe’s actual observing log.

The major part of the Victorian and Edwardian images in the RASC Archives were done at the eyepieces of quality long-focal-length achromatic refractors with 3- to 4-inch objectives (Harvey 1904), the so-called “common” telescopes of the era (Figure 4).[5] The fortunate could afford instruments by the likes of Cooke, Wrey, and Brashear (the latter was an honorary member of the RASC, and a loyal supporter). The foremost exception is the suite of lunar watercolours done by the “ladies of Simcoe” with J.J. Wadsworth’s 12.5-inch reflector, an imposing instrument for its time and place.

The two chief differences in technique between 21st- and 19th-century astronomical drawings are the present neglect of watercolour, and the use of digital image processing.

Of course, differences in the general aspect of astronomical drawings executed between 1868 and 2008 are not just caused by technological change, or even principally caused by technological change. Alterations in human perceptions, conceptions, and expectations of astronomy are probably more important factors (Hockey 1999; Baum 2007). We do not

Figure 4 — RASC starparty *ca.* 1900. The Society’s long-focus achromatic 4-inch Cooke is in the foreground. Note the mixed genders; women were full members from the very beginning of the Society.

process what we observe with the eyes of 1868, 1908, or even 1998. To try to observe as our predecessors observed, however, would be a potentially useful, salutary, and difficult exercise. At the very least it may teach us that as they now appear to us, so shall we appear to RASC members a century from now.

Drawing and photography

Astronomers were quick to imagine the scientific possibilities of photography from the late 1830s, and many of them were innovators generally in photographic technology. These pioneer astrophotographers were frequently noted astronomical draughtsmen as well (*e.g.* William C. and George P. Bond, Charles Piazzi Smyth, Edward Emerson Barnard — this list could even start with Sir John Herschel, if we admit a first-rate astronomical draughtsman who was also a photographer, but not an astrophotographer). Inevitably, comparisons of the utility of the two techniques were made. By the 1890s, Edward S. Holden commented that what the keenest observer and gifted artist might accomplish through decades of examination and recording of a single object could be achieved by three or four hours work with an astrograph (Holden 1891). Note that photography did not triumph in results; it seemed to score rather in the area of efficiency. Astronomers were well aware that there were physical differences in the light processing systems (eye and hand *vs.* lens and plate) that could account for the dissimilarities in drawings and photographs of the same nebulae (Keeler 1895). For some work, such as coronal observations during total solar eclipses, drawing was definitely abandoned in favour of specialized photography in the most

[5] Hence the title of Webb’s celebrated handbook: Webb 1859. Some of his nebular sketches are in the Archives (Webb, Astronomical Index).

technologically progressive "professional" astronomy circles of the last quarter of the 19th century (Pang 2002). For other research, such as planetary observations, drawing played a dominant role till the 1960s (Hockey 1999). Some amateur selenography was of scientific value to the burgeoning space programmes of the late 1950s and early 1960s (one thinks in particular of the work of our honorary member, Sir Patrick Moore). The most impressive example of astronomical sketching surpassing photography in a scientific application is that of the superbly detailed high-resolution sunspot images drawn by Samuel Pierpont Langley during the last quarter of the 19th century; photography did not equal his results till the late 1990s (Wittmann 2000; Langley was also an honorary member of the RASC). The advent of astrophotography and its successive improvements never did effect the extinction of astronomical sketching; and it is unlikely to do so. The two technologies can now be seen to meet different needs, and should be viewed as complementary, rather than competing.

The RASC record of achievement in astronomical drawing

It is probable that most, if not all, of the active observers in the RASC from its foundation to the death of C.A. Chant (1865-1956),[6] the launch of Sputnik I and the International Geophysical Year (1957-1958), practised astronomical sketching to some degree. Evidence of that activity can be found throughout *Looking Up* (Broughton 1994). Nearly all of the images in the Archives from those years are of solar-system objects; it is indeed remarkable that it holds no sketches of deep-sky objects (DSOs) done by the Victorian and Edwardian members of the Society. All of the Messier list and more than a few of the NGC would have been visible in their telescopes. DSOs were certainly recognized as sporting telescopic quarries (Webb 1859; Proctor 1873); the brighter could even be bagged with opera glasses (Serviss 1900). RASC members read, respected, and referred to those observing guides. Granted that avocational observing in this period was heavily weighted towards Solar System objects, nevertheless a representative body of sketches could be expected to include some DSOs. Perhaps RASC members spent more time on the solar system than did their British, Continental, and American counterparts, or perhaps the sample in the Archives has been skewed by accidents of acquisition or survival. It is not till the 1950s that the Archives can show DSO sketches, namely the acrylic paintings of R. Broadfoot.

The Archives' drawings are by and large of moderate to exceptional quality. The poorest drawing is Sir Adam's transit of Mercury mentioned above (Figure 2), the most exceptional, scientifically and artistically, is John Goldie's paraselene image (to be featured in an upcoming column). The RASC drawings are comparable to the work of members of the Royal Astronomical Society (RAS), the British Astronomical Society, and the Société astronomique de France (SAF), and to drawings published in the American journal *Popular Astronomy.* Some of the drawings by early RASC members are clearly superior to those by famous British men of science issued in the *Monthly Notices of the Royal Astronomical Society,* or *The Observatory* (Huggins 1882; Denning 1904; William Huggins was also an honorary member of the RASC). On the other hand, no member of the RASC was an astronomical illustrator equal to the RAS's John Brett, R.A., or the SAF's E.-M. Antoniadi (Brett 1878; Antoniadi 1930). The work of the prominent astronomical artist É.L. Trouvelot (1876, 1882) was known, admired, and copied by members of the Astronomical and Physical Society of Toronto (A&P, the kernel of the RASC). Intriguingly, the more mannered aspects of Trouvelot's style were not aped by our Society's members when they recorded their own observations graphically.[7]

Few of the early drawings in the RASC Archives were intended for publication. Most of those from the important Album of the A&P (Figure 5) were probably executed in the first instance for distribution and discussion at Society meetings, although a small handful subsequently appeared in the Society's Transactions (TA&P 1890-1891, 21 and frontispieces; TA&P, 1892, 45). The majority of the Victorian images in the Archives are drawn from that source. The genesis of the album goes back to a meeting of the A&P on 1892 October 18:

> On behalf of Mr. Charles Sparling, Mr. Elvins presented to the Society a large and handsomely bound album, suitably inscribed and intended to receive the Astronomical drawings, plates and views belonging to the Society. Mr. Elvins said he had inserted various plates and original sketches, and would be glad to receive from members others to be thus preserved. Mr. Sparling was heartily thanked for his timely and valuable gift [TA&P 1892, 68-69].

It would be interesting to know more about the history of this album; it seems clear from the back of some of the drawings that they were cut down from larger sheets. Most of the images appear to be second-generation astronomical art created from original observational drawings, but can any be shown to be original observational sketches cut down from bound or unbound log books? What were the criteria for inclusion, and did they undergo evolution? What was the active life of the project?

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[6] Published examples of Chant's drawings can be found in *JRASC;* Chant 1910 (Halley's Comet in its 1910 apparition).

[7] Trouvelot 1882, a set of fifteen chromolithographs of his astronomical sketches, was issued at that time for $125. As a measure of how affordable that would be for the average North American of today, the modern equivalent is above $16,000! Astronomers who are also gardeners can blame Trouvelot for the introduction of gypsy moths to North America. He was penitent about the moths, if not about the price of his chromolithographs. They apparently sold well.

Figure 5 — Detail of the cover of the Album of the A&P, 1892.

There are what appear to be chronological gaps in the Archives' holdings. It is difficult to say whether these reflect fallow periods in the art of astronomical depiction in Canada, or losses due to carelessness or worse with the RASC's documentary heritage during the 1950s or before.

The Archives contain drawings by some figures of renown in the late 19th- and early 20th-century astronomical world: the Rev. T.W. Webb, Richard Proctor's daughter, Mary, and Dr. John A. Brashear (Rosenfeld 2008).

Present and future practice

Astronomical drawing is alive and well in the RASC, although it has received less notice than CCD imaging.[8] There is no specific and regular RASC forum for discussing astronomical sketching, nor programmes for developing it, although its practice forms a necessary part of the certification for the Isabel K. Williamson Lunar programme, and the Messier and Finest NGC programmes, and it is strongly encouraged by the various RASC observing sections. Prominent current RASC members who have drawn at the eyepiece include Scott Young (Winnipeg Centre), Bill Weir (Victoria Centre), Carl Rousell (Hamilton Centre), Barry Matthews (Ottawa Centre), Gilbert St-Onge (La Société d'astronomie de Montréal et du Centre francophone de Montréal de la Société royale d'astronomie du Canada), and Dr. David H. Levy (Kingston & Montréal Centres). The late Fr. Lucian Kemble (Regina Centre), a prominent deep-sky observer, has left a valuable archive of thousands of his DSO drawings to the Regina Centre of the RASC. The latest edition of *Nightwatch* (2006) by Terrence Dickinson (Toronto Centre), a spectacularly successful introductory text inside and outside the RASC, includes some excellent examples of observational drawings.

In the sphere of amateur astronomy it seems that the hand-drawn astronomical image is enjoying something of a renaissance, although ironically that may be due to a very untraditional technology: web-based communication (see the sources in note 3 above). The major change in astronomical drawing that can be foreseen is the increasing melding of 19th-century art methods with modern image processing. This melding has led in many instances to astronomical drawings that seek more and more to take on the appearance of astronomical photographs. How far this fusion is desirable is certainly open to debate. Those who have thought deeply about the history of astronomical observation, who themselves are modern observers, and have attempted to understand the work of their predecessors by doing it the way they did, will continue to use both CCD cameras and graphite pencil and paper, drawing rigorously and creatively on all the observing styles, techniques, and technologies available to them (Figure 6). We could do worse than follow in the footsteps of Dr. William Sheehan and Stephen J. O'Meara.

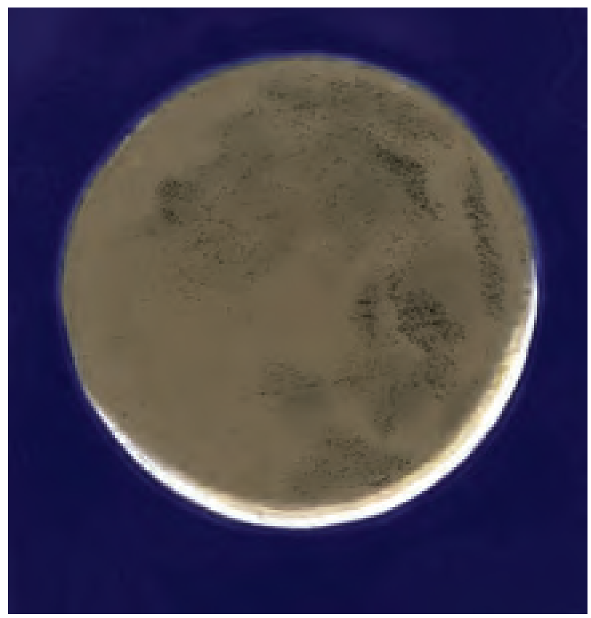

Figure 6 — R.A. Rosenfeld, crescent Moon and earthshine, 2008 April 7, as seen through 7x42 binoculars. Graphite, crayon, Conté chalk, and image processing. Is this a legitimate path for astronomical sketching to travel? What is the point of an image such as this?

R.A. Rosenfeld was trained in doing stuff with and to old manuscripts. He won the second prize in the 2008 Griffith Observer Boeing Astronomical Writing Contest. He'll look at anything through an old telescope provided it doesn't bite.

[8] Centre newsletters and the National Bulletin are a prime resource for anyone considering a full history of astronomical drawing in the modern RASC.

Acknowledgements

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Abbreviations

TA&P=Transactions of the Astronomical and Physical Society of Toronto

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A Moment With…

Dr. Robin Kingsburgh

by Phil Mozel, Toronto and Mississauga Centres (phil.mozel@sympatico.ca)

As even a cursory glance at any number of astronomical photographs will attest, art and science are simply two sides of the same coin. One can enjoy one, the other or, increasing our enjoyment to the maximum, both. With a foot in both camps, Dr. Robin Kingsburgh works to draw people of both sides together.

Dr. Kingsburgh's interest in astronomy is of long standing; she decided to be an astronomer while in grade seven. Nudging her in this direction was an influence felt by so many who go into this field, either as an amateur or professional: a dark sky at the cottage, especially during the Perseid meteor shower. A small telescope was acquired early in her budding career as well as an astronomy book from her uncle who also assisted with school science projects. She also took astronomy courses at the McLaughlin Planetarium as a teenager. While Dr. Kingsburgh is not particularly interested in science fiction, both her uncle and aunt, Garfield and Judith Reeves-Stevens, are: they have penned sci-fi novels with William Shatner, written episodes of *Star Trek: Voyager* and scripted the television miniseries *Race to Mars* for the Discovery Channel. Dr. Kingsburgh is currently working with her uncle and aunt on another Discovery Channel documentary dealing with the red planet.

More formally, Dr. Kingsburgh completed an undergraduate degree at the University of Toronto and a Ph.D. in astronomy at University College, London. As a post-doctoral fellow at the University of Mexico, she studied planetary nebulae and Wolf-Rayet stars.

Planetary nebulae are glowing shells of gas and dust ejected from stars near the end of their lives. (Interestingly, her faculty advisor, Dr. Mike Barlow, at University College, studies planetary nebulae because they are aesthetically pleasing. The "art" of the Universe again). Wolf-Rayet stars are massive, luminous stars with stellar winds that are more akin to gales. The accompanying mass loss is so tremendous that the stars' lifetimes are significantly shortened before ending as supernovae.

Wolf-Rayet stars and planetary nebulae are means to an end for Dr. Kingsburgh, *i.e.* she has studied the interplay between stars' masses and the nucleosynthetic reactions in their cores to gain insights into stellar evolution. Wolf-Rayet stars are important because their winds directly reveal elements manufactured earlier in their lives which, in turn, informs us about what processes occur in the hidden depths of the star.

Dr. Robin Kingsburgh

She is particularly interested in planetary nebulae because their chemical makeup reflects both the conditions existing in interstellar space during their formation and the subsequent nucleosynthesis and mixing processes of the resulting star. Studies of their chemical abundances allow us to constrain stellar evolutionary models. The dumping of all these newly refined chemicals into space also has an effect on the chemical evolution of galaxies.

Going hand-in-hand with her attention to astronomy has been Dr. Kingsburgh's interest in art. Taking art classes in high school, she subsequently studied the subject at the University of Toronto, in Aix-en-Provence and, while working on her Ph.D., during night classes at London's Slade School. She has exhibited in group shows in London and participated in Toronto's 2007 Nuit Blanche, the "all-night contemporary art thing," at St. Thomas's Anglican Church, and is currently curating the visual art component of their 2008 contribution.

Art is an increasing focus for Dr. Kingsburgh these days. She primarily creates abstract art and recently presented her first solo show. "Circles and squares" is her current artistic period in which she uses "rhythmic geometries with strong colour." Dr. Kingsburgh's painting of a comet hangs in her church and she is working on a scale model of the Solar System, in cooperation with the RASC, to be displayed on the York University campus in Toronto. Each depiction of a planet will be accompanied by

This image shows one of a series of four paintings by Dr. Kingsburgh based on T.S. Eliot' s *Four Quartets,* and inspired by the phrase "In my beginning is my end... in my end is my beginning." She notes "In my process of painting, layers of strong colour are built up, containing elements of both structure and randomness, which together create engaging textural and rhythmic geometries. Paradoxically, in this complexity of colour and rhythm, the possibility for stillness exists. The process of making and experiencing art presents transformative and transcendent possibilities. By deeply engaging in the present moment, we are able to transcend the everyday."

the latest information.

Dr. Kingsburgh takes this role of visualization in science very seriously as she invokes none other than Galileo, whom she describes as a master of combining text and image. A classic example is his *Siderius Nuncius,* or *The Starry Messenger.* "He had," she says, "a good sense of space and rhythm, and effectively integrated image and text to provide visual evidence that ultimately changed the scientific worldview." Following his lead, she wishes to see to the extensive public dissemination of astronomical images; images that will be wide-ranging and have elements of good design and colour, combined effectively with explanatory text. She wants to communicate science effectively without clutter, and to this end is on the curatorial team charged with obtaining suitable astronomical images from Canadian astronomers, both amateur and professional, and making them easily accessible to the public in an informatively scientific and artistic format.

For a number of years Dr. Kingsburgh has been teaching various natural-science courses at York University including *Understanding Colour* and *Science and Creativity.* While doing so, she contacted the Ontario College of Art and Design, who subsequently introduced courses for the first time on the *Science of Colour, Astronomy,* and *Modern Physics,* all taught by her. The latter course emphasizes physical observations and visualizations of nature from the microscopic to the macroscopic. Cosmology, relativity, and quantum mechanics are all covered, along with the relationship between art and science. Recently, the major assignment involved students researching a phenomenon involving light (*e.g.* polarization, fluorescence), writing an essay, and then creating a work of art involving this phenomenon, either literally or metaphorically, as a response to the knowledge gained. This might be a painting, a lamp, jewellery, a dance, *etc.* Student work was displayed at the annual *Subtle Technologies Festival of Art* in May 2007. Dr. Kingsburgh is thus engaging both the artistic and scientific parts of student brains. Feedback from students in these courses has been quite positive.

So, flip the coin. Heads or tails. Art or science. Or, as Dr. Kingsburgh has amply demonstrated, we can have both.

Phil Mozel is a past librarian of the Society and was the Producer/Educator at the former McLaughlin Planetarium. He is currently an educator at the Ontario Science Centre.

Second Light

A Common Mass Scale for Small Galaxies

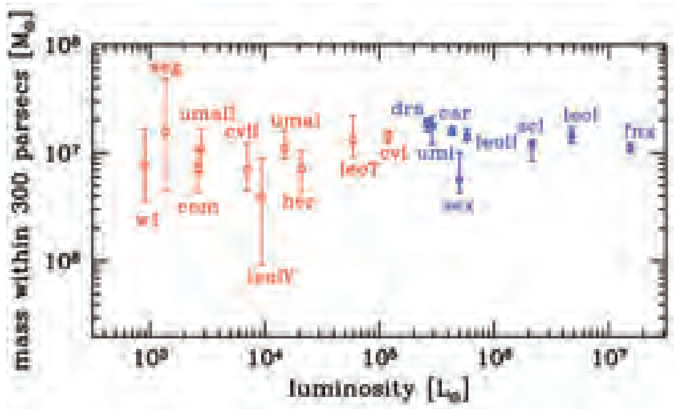
by Leslie J. Sage (l.sage@naturedc.com)

The Milky Way galaxy is surrounded by a cloud of satellite galaxies (23 are known so far) with optical luminosities ranging from a very dim 1000 solar luminosities ($L_\odot$) — less than a globular cluster — to more than 10^8 $L_\odot$. Small galaxies are of considerable interest to astronomers because their properties can be used to test formation models, which struggle to produce the right numbers relative to larger galaxies. The simulations all use a generic form of dark matter (since that dominates the mass of the Universe), and some earlier observations have suggested that the dwarf galaxies are the most dark-matter-dominated types. Louis Strigari of the Center for Cosmology at the University of California at Irvine and his colleagues may have found another clue about dark matter, in that nearly all of the satellite galaxies have the same mass within their inner 300 parsecs, despite huge differences in optical luminosity (see the August 28 issue of *Nature*).

Simulations of galaxy formation tend to predict that large galaxies like the Milky Way should be surrounded by thousands of small ones, rather than the observed 23, though it is unlikely that we have discovered all that exist. About half of the known 23 have actually been discovered within the last few years, based upon observations in the Sloan Digital Sky Survey (`www.sdss.org`). The least luminous ones are known to be strongly dominated by dark matter, through measurements of the motions of the stars in them.

On their orbits within the Galaxy, some of the stars are moving towards us and some are moving away. These motions give rise to blueshifted and redshifted lines, respectively, in the spectra of the stars. Since the motions of the stars are controlled by gravity, the total mass in the galaxy can be calculated by determining the maxima of the blue and redshifts.

For many years, actually going back to the 1930s with work by Fritz Zwicky, there has been evidence that the mass of the Universe is dominated by dark matter. These mysterious particles apparently do not interact with normal matter, except through gravity. There are lots of theories about what they might be, but no evidence. "Cold dark matter" refers to a class of models where the particles respond to gravity like standard matter. This class of models, with modifications arising from "dark energy" (an even more mysterious and dominant component of the Universe), seems best at explaining the fluctuations of the microwave background radiation and the large-scale structure of the Universe, namely the sheets and filaments of clusters of galaxies. In "warm dark matter" models, the particles are moving fast enough, because of how they formed, to slow down the growth of small structures. Hence these models do a better job of predicting the number of satellite galaxies.



The calculated mass inside a radius of 300 pc for 18 satellite galaxies spanning a factor of 10,000 in luminosity. The red symbols indicate the recently discovered SDSS satellites. Credit: Figure courtesy of Louis Strigari and *Nature*.

Strigari and his colleagues have compiled data on the stellar motions in 18 out of the 23 known satellite galaxies, and determined their masses within their optical extent, which averages a radius of 300 pc (see the figure above). All 18 galaxies have a dynamical mass of ~10^7 solar masses ($M_\odot$), with a central density of ~0.1 $M_\odot/pc^3$. There had been earlier indications that the larger satellite galaxies had similar masses, but this is the first demonstration that it applies to all of them.

The finding might indicate that dark-matter clumps smaller than this simply do not form, contrary to what is predicted by most simulations. Within the framework of the warm-dark-matter models, this result would exclude many models including those with low-mass particles. It isn't clear what it means for cold dark matter, as the models predict that smaller clumps should exist! So the result presents us with a puzzle. More work will be needed to determine the broader implications, but it's good to constrain models with actual data. The cold-dark-matter people need to get to work.

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

A Triple Cluster

by Warren Finlay (warren.finlay@interbahn.com) and Doug Hube (jdhube@telus.net), Edmonton Centre

Most amateur astronomers who focus on the deep sky encounter times when they lack the gumption to go out observing. While there may be different reasons for such astronomical malaise, a common reason is the lack of an observing program. If you've already logged all the Messiers, all the RASC Finest NGCs, and have revisited most of these objects several times, what point is there in heading out and looking at these same objects one more time? Forlorn telescopes lying in the closet are evidence that some never find an answer to this question. However, for many observers, one answer lies in taking deep-sky observing to the next level, using one of several excellent lists of deep-sky objects that go beyond the Messiers and RASC Finest NGCs. While there are many such lists, only a few are entirely observable from Canada. One such list is David Levy's "Deep-Sky Gems," consisting of 155 different objects, and given in the *Observer's Handbook*. It has no overlap with the Messier and RASC Finest NGCs, making it a fine list to snap you out of your armchair ennui.

Alternatively, the Astronomical League, an American amateur organization, has long offered the Hershel 400 list, consisting of 400 out of the roughly 2500 deep-sky objects originally found by Sir William Herschel. A significant fraction of these objects overlap with the 110 objects on the RASC Finest NGC list and the Messier list, but there are still hundreds of new objects to satisfy the appetite of even the most discerning observer. Moreover, you don't need a light bucket to log the Herschel 400 objects: Jay Reynolds Freeman has seen them all in a 55-mm scope, although a 150-mm scope is recommended for us mere mortals. If you're still bored, then take on the Herschel

Figure 1 — The arrow points to the position of the triple cluster (NGC 189, NGC 225, and Stock 24) in the night sky.

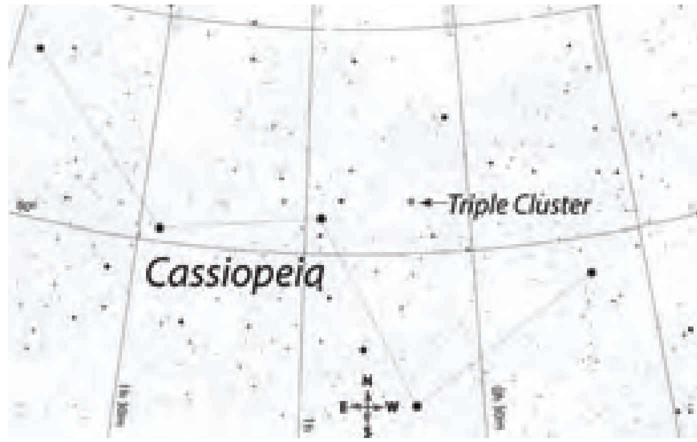


Figure 2 — Finder chart for the triple cluster.

II list, which takes you out to 800 of Herschel's best objects, for which a 250-mm scope is recommended. If you tackle either Herschel list, you had better like galaxies, since these make up 231 objects on the Herschel 400 list and 323 objects of the additional 400 objects on the Herschel II list.

The above lists require dark skies, so for those nights when you can't find the time to drive out of town to observe, why not chip away at a double-star list, such as the 100 double stars listed in the Astronomical League's Double Star Club?

The above lists contain more than a thousand different objects. Seeing them takes many years, and it's not a race. These are the best deep-sky objects you can see in our northern latitudes, so enjoy your views of them because going beyond them takes you deep into the realm of the dim fuzzies. However, if you've seen all of the above and are still nonplussed, try tackling the 45 objects on the RASC Deep-Sky Challenge list from the *Observer's Handbook*. And for something completely different, the 38 objects on the RASC's Dark Nebulae List will have you looking at dim patches of black, instead of dim patches of light. There are many other deep-sky lists out there, so there are no excuses for not having a list to work on!

With thousands of dim deep-sky objects that are readily observable, you don't have to stick to a well-known list. Observing software, such as AstroPlanner or SkyTools, makes it easy to create personalized lists from various databases. Indeed, one of us (WHF) stumbled on the beautiful triple cluster of NGC 189, NGC 225, and Stock 24 from a subset list compiled using the Saguaro Astronomy Club's database of more than 10,000 deep-sky objects. While this little grouping

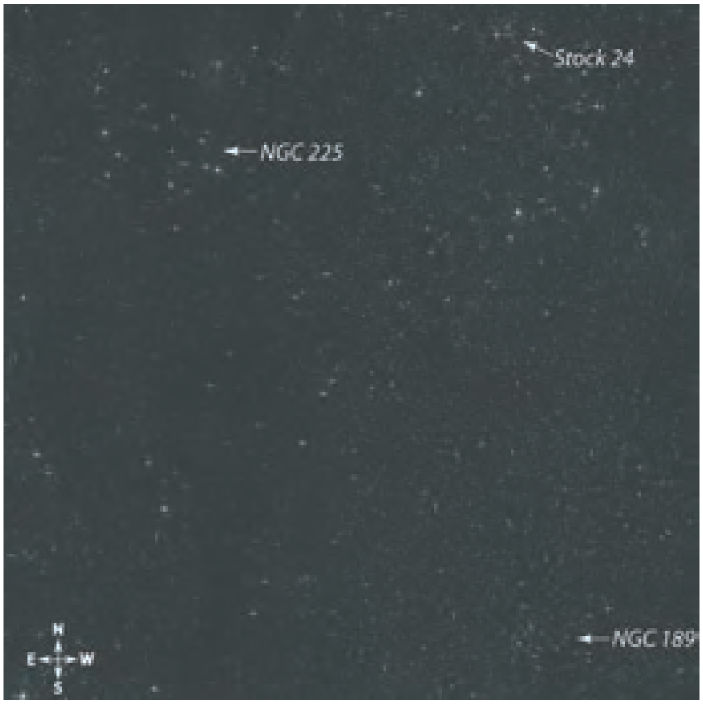


Figure 3. 60′x60′ POSS image centred on the triple cluster.

looks like a triple cluster, in fact only NGC 189 [mag. 8.8, RA = 00^h 39.6^m, DEC = +61° 04′] and NGC 225 [mag. 7.0, RA = 00^h 43.4^m, DEC = +61° 47′] are physically close together, at a distance of about 700 parsecs. Both were first discovered by Sir William Herschel's sister, Caroline. The third member, Stock 24 [mag. 8.8, RA = 00^h 39.7^m, DEC = +61° 57′] is about four times as distant. Despite being close together physically and apparently, NGC 189 is much younger than NGC 225, with NGC 225 being about 130 million years old and NGC 189 being just a baby, at 10 million years old. Stock 24 is similar in age to the middle-aged NGC 225. Open clusters lose members due to tidal interactions as they age, so, being the youngest, NGC 189 has the most stars, with two or three dozen being visible depending on the size of your scope. The two older clusters appear to have 10-20 stars, depending on your telescope's aperture, while professional telescopes find NGC 225 has about 30 members.

Finally, if you don't like lists, take your favourite star atlas, pick a constellation and try observing every deep-sky object shown on your atlas in that constellation. Or buy one of the many books about the deep sky, open it up to the pages where tonight's objects are culminating, and observe those objects.

Whatever your deep-sky observing preferences, there is an observing program out there that will fit your interest. So pick a program, grab that scope, and go observing!

Acknowledgements. Figure 3 is a Digital Sky Survey image produced at the Space Science Institute under U.S. Government grant NAG W-2166.

Having completed most of the above deep-sky lists, Warren Finlay is currently keeping astronomical apathy at bay by working on David Levy's Deep-Sky Gems. Doug Hube is a professional astronomer actively retired from the University of Alberta, and Associate Editor of this Journal.

Through My Eyepiece

Some EnChanted Evening

by Geoff Gaherty, Toronto Centre (geoff@foxmead.ca)

When I think of Chant Medalists, I think of Grandmasters of the astronomical arts, the medal being a kind of lifetime achievement award. In the last issue, I described the first two Chant Medal recipients who influenced my young observing life, both with decades of observing behind them. Much to my surprise, the next Chant Medalist I met was only five years older than I was, Earl Milton of the Edmonton Centre.

Earl joined the Montreal Centre as a teenager, and, like both David Levy after him and myself, was inspired by Isabel Williamson to become a diversified observational astronomer. When his family moved to Edmonton, he transferred to the Edmonton Centre and brought the Montreal Centre's observing program with him. He soon became leader of their observing team and eventually the first national observing committee

Figure 1 — East meets west: Geoff Gaherty (Chant 2008) and Earl Milton (Chant 1959) in front of Queen Elizabeth II Planetarium, 1960 (Photo by Ian McLennan)

chairman. Earl was only 23 when he received his Chant, the youngest recipient in the Medal's history.

It was eight years before the Chant Medal was presented again, this time to my friend Ray Thompson of the Toronto Centre.

Figure 2 — Ray Thompson (Chant 1967) with son David, 1963 (Photo by Toronto Telegram)

Ray was a music teacher (now retired to Halifax) who observed many objects, but whose special love was variable stars. He's pictured in Figure 2 in his backyard observatory in Maple, Ontario, with his son David. My visit to his observatory was a double thrill: first, that an amateur astronomer could have his own domed observatory, and second, that a real person could actually own a Unitron refractor, the Astro-Physics of its day. Ray's personality was wonderfully summed up by the plaque on his observatory wall that read: "The heavens do *not* declare the glory of God; they declare the insignificance of Man, *and* his gods!" Ray became a pioneer in the photoelectric photometric observation of variable stars.

If it was eight years between Earl's and Ray's Chant Medals, it was a further twelve years before the Chant was presented again, this time to the Ottawa Centre's Rolf Meier in 1979. I'm not clear on why the Chant seemed to have been almost forgotten for two decades. Since Rolf's award, the Chant Medal has been presented quite regularly, and the recipients read like a Who's Who of contemporary amateur astronomy. I'd like to single out one man who has been a strong mentor and good friend to me, Richard Huziak.

Rick is a typical Chant Jack-of-all-trades, but, like Ray Thompson, his special love is variable stars. In 2002 he issued a challenge to Canadian observers to observe at least one variable star during the coming year: http://homepage.usask.ca/~ges125/rasc/The_Great_Canadian_Observing_Challenge.html

I had always found variable-star observing to be something

Figure 3 — Richard Huziak, pictured here with his Chant Medal (Chant 2001)

of a bore, but Rick made it sound intriguing. Soon I was hooked: variable-star observing is now my principal observing activity.

As many of you know, I recently underwent major abdominal surgery. This has slowed me down a bit, but I soon expect to be back out observing here at Foxmead Observatory. Once again, I thank the Society for honouring me with the Chant Medal.

Thanks also to Peter Broughton for his history of the RASC, *Looking Up;* to the London Centre for inviting me to give the talk on which this column and August's were based; and to Peter Jedicke and David Levy for nominating me for the Chant Medal.

Figure 4 - The Chant medal

Geoff Gaherty is the recipient of the Society's Chant Medal for 2008. Despite cold in the winter and mosquitoes in the summer, he still manages to pursue a variety of observations, particularly of Jupiter and variable stars. Though technically retired as a computer consultant, he is now getting paid to do astronomy, providing content and technical support for Starry Night software.

A Clamp for All Seasons

by Don Van Akker, Victoria Centre (don@knappett.com)

Elizabeth and I share this hobby, and that being so we also share the hobby budget, so I was not concerned a year or two ago when she came home with a jar full of small spring clamps and announced that these would be used for astronomy.

Fine. Even though this money could certainly have been better put towards a new piece of equipment, I would humour her and help her find uses for these things so that she wouldn't feel bad.

The first was obvious and was actually her idea. They were just the thing for securing the reflective blankets around the scopes at star parties. The next was also her idea. Spring clamps could be used to secure the red Plexiglas in front of the computer screen so that it no longer falls over onto the keyboard and blitzes everyone in sight...and I see she has them holding down the pages of the star atlas in the breeze...and the observing log.

And she was right there when I was arranging a mess of wires between the mount and the computer. A few spring clips round the wires and onto the edge of the table, and it was all organized.

But for anything really astronomy related, of course, they are actually quite useless.

In spite of expenditures on spring clamps we recently acquired a fine old refractor with glass the equal of anything being made today, but with a rack-and-pinion focuser (top of the line in '88) that just doesn't compare with the silky smooth two-speed wonders that are now almost standard equipment.

Fortunately the scope can be upgraded. Unfortunately the price is so high that there will be no silky smooth two-speed wonders in our immediate future. So off I scurried for another solution.

Simple problem. The focuser works beautifully and racks in and out an impressive distance with a respectable load. It's great for visual. But, with a camera, that last tiny tweak, that final whisper of movement, just wasn't happening for someone as ham-handed as me. What I needed was something to give me just a little more sensitivity. Something like a focus lever maybe, which would clip on easily and be removed easily so it wouldn't get in the way.

This time I just went ahead and asked her.

Don Van Akker and his observing partner, Elizabeth, focus on the stars from Salt Spring Island, B.C. Don will help with this or any other Gizmos project if you email don@knappett.com.

Quick Picks for Observing

by Kim Hay, Kingston Centre (cdnspooky@persona.ca)

December 2008	Event
Monday, Dec. 1 00:00 UT 15:00 UT 16:00 UT	Venus 2° S of Jupiter (42° E) Jupiter 1.3° N of the Moon Venus 0.8° S of the Moon
Thursday, Dec. 11 8:00 UT	Moon 0.7° N of Pleiades (M45)
This is a great time to start your Winter Messier Observations. See `www.rasc.ca/messier/index.shtml` to work on your Messier Certificate.	
Friday, Dec. 12 16:37 UT	Full Moon (largest in 2008) Other moon names Oak Moon, Moon of Long Nights For more information on Moon Lore `www.geocities.com/RainForest/4893/lore.html`
Saturday, Dec. 13 23:00 UT	Geminid meteor peak * (Dec. 7 to Dec. 17)
Friday, Dec. 19 3:00 UT	Saturn 6° N of Moon
Sunday, Dec. 21 12:04 UT	Winter Solstice – shortest day of the year
Monday, Dec. 22 8:00 UT	Ursid meteor peak*
Thursday, Dec. 25 7:00 UT	Antares 0.1° S of Moon
Saturday, Dec.27 1:00 UT	Venus 1.5° S of Neptune (46° E)
Monday, Dec.29 4:00 UT 9:00 UT	Mercury 0.7° S of Moon Jupiter 0.6° N of Moon
Wednesday, Dec. 31 5:00 UT	Mercury 1.3° S of Jupiter (18° E)
January 2009	**Event**
Monday, Jan. 3 12:50 UT	Quadrantid meteor peak* (Jan. 1 to Jan. 6) (sol = 283°16)
Sunday, Jan. 11 3:00 UT 7:00 UT	Largest Moon in 2009 Wolf Moon - Lore Pollux 5.6° N of the Moon
Thursday, Jan. 15 12:00 UT	Saturn 6.0° N of the Moon
Wednesday, Jan. 21 13:00 UT	Antares 0.2° S of the Moon **Challenge daylight object**
Friday, Jan. 23 15:00 UT	Venus 1.4° N of Uranus
Friday, Jan. 30 12:00 UT	Venus 2.5° S of the Moon

* Meteor Showers for December and January
`www.imo.net/calendar/2009`

January and February is a great time for Double Shadow Transits on Jupiter. Check out the 2009 *Observer's Handbook* for all the times and dates on the transits.

February 2009	Event
Wednesday, Feb. 4 3:00 UT	Moon 0.9° N of Pleiades (M45)
Sunday, Feb. 8 17:00 UT	Moon 1.5° N of Beehive (M44)
Monday, Feb. 9 1:49 UT	Penumbral lunar eclipse
Thursday, Feb. 12	Zodiacal Light is visible in the Northern Latitudes in the west for the next two weeks
Friday, Feb. 13 21:00 UT	Mercury at greatest elongation W (26°)
Friday, Feb. 17 9:00 UT 21:00 UT	Mars 0.6° S of Jupiter Antares 0.04° S of the Moon
Sunday, Feb. 22 22:00 UT	Mercury 1.1° S of the Moon
Monday, Feb. 23 1:00 UT 8:00 UT	Jupiter 0.7° S of the Moon Mars 1.7° S of the Moon
Tuesday, Feb. 24 3:00 UT	Mercury 0.6° S of Jupiter
Friday, Feb. 27 23:00 UT	Venus 1.3° N of the Moon

2009 International Year of Astronomy

This is a global celebration of astronomy. Since the first view that Galileo looked through the telescope and discovered the moons of Jupiter, to the cutting-edge missions to space, we can all be a part of knowing and learning about astronomy. Be a part of the excitement of 2009 with celebrations across the world and Canada as we bring astronomy to the young and old.

The International Group has Cornerstone Projects, such as 100 hours of Astronomy, Dark-Sky Awareness, and the Galileo Telescope. Go to `www.astronomy2009.org` for more information. The Canadian node of the IYA has many projects such as the "Galileo Moment," Canadian First Nations and Intuit Peoples historical knowledge of the heavens, and many more. Visit the Web site for more information, or to volunteer.

The RASC is funding five major projects, Astronomy Trading Cards, Star Finder, Sidewalk Astronomer, Mary Lou's New Telescope, and LPA Campaign. Many Centres are planning local events and need volunteers to help. If you want to be involved, contact your local Centre, or visit `www.rasc.ca/education/iya`

Society News

Our Bird Leaves the Nest

After 11 years as the RASC's Executive Secretary, Bonnie Bird attended her final General Assembly in July. Her indefatigable good nature, knowledge of the internal workings of the RASC, and willingness to help will be long-remembered and acutely missed. Here are a few comments from those who knew her well:

My, the years have passed by. I remember when Bonnie first started with the RASC, and now the time has come that she is leaving the RASC, but not our hearts.

Bonnie, you have always been delightful, helpful, willing to help in any situation, and with always a kind word. But most of all, Bonnie, you have been my friend.

Happy retirement, Bonnie, enjoy life to the fullest, the cats to the purrrfectness, and time with Andreas, with his many projects.

May the next chapter in your life be filled with excitement, enjoyment and love.

I will miss you, but don't be surprised if I show up on your new doorstep :)

Your friend
Kim Hay

We have always been most fortunate in our choice of Executive Secretary for the RASC. Bonnie, in her many years in the position, exemplified the great spirit of dedication and enthusiasm that our members and visitors alike appreciated when dealing with the National. She will be missed.

While it may sound strange upon hearing this, I personally often thought of Bonnie while hunting moose in the Edmonton area, knowing full well that she would very much appreciate the delicious garlic sausage that would ensue from this recycling activity.

Thank you, Bonnie, for being the warm, down-to-earth person that you are.

Franklin Loehde

I had the pleasure of working closely with Bonnie from 1996 - 2000 as First V-P and then President of the Society.

We had some pretty interesting challenges — the membership handling had been outsourced and was not going very well. Bonnie was deluged by members phoning the National Office complaining. Around the same time we started to send out SkyNews, *which had its own set of difficulties. Once we brought the membership handling system in as a custom-built software package, it had its own set of teething problems.*

All through this Bonnie remained positive and was convinced things would get better. And they did — eventually. I often thought that anyone else would have had enough and left! But not Bonnie.

I would like to thank Bonnie very much for her professionalism and dedication to the Society during her tenure as Executive Secretary and I wish her all the best in her retirement.

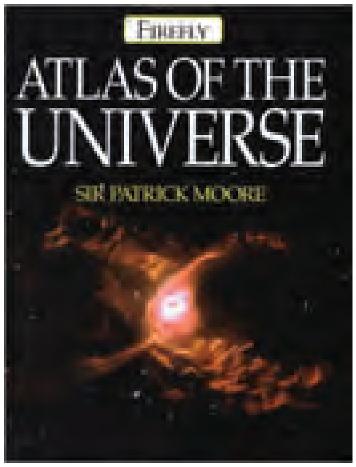
Randy Attwood
National President 1998 - 2000

Good luck Bonnie!!!! Whoever tries to fill your shoes will really have a momentous task ahead of them! We will miss you.

Barry Matthews

Reviews
Critiques

Firefly Atlas of the Universe, Third Edition, by Sir Patrick Moore, pages 288; 23.5 cm × 31 cm, Firefly Books, 2005. Price $49.95 hardcover (ISBN 1-55407-071-6).



"Canis Major, Orion's senior dog, is graced by the presence of Sirius, which shines as much the brightest star in the sky even though it is only 26 times as luminous as the Sun; it is a mere 8.6 light-years away, and is the closest of all the brilliant stars apart from α Centauri." If you can read that sentence without cringing, then Sir Patrick Moore's overuse of semi-colons and mundane modifiers will not interfere with your enjoyment of this book.

Moore's longevity as a popularizer of astronomy is remarkable. For half a century he has hosted a monthly television program on the BBC, and it is rare now to find a bookstore without one of his works. He was knighted for his services to our passion in 2001, an accolade that he must treasure at least as much as his honorary membership in the RASC.

Atlas of the Universe is ambitious, covering most aspects of popular astronomy in varying levels of detail. I particularly like the format where each topic is covered in a stand-alone two-page spread. If your reading time is limited to five- or ten-minute snippets — and we all have such intervals daily - this book provides an opportunity for satisfaction at each sitting. The format also facilitates its use as a reference book.

Moore begins his atlas with brief overviews on the history of astronomy, telescopes, and space flight. He then spends nearly half the book on the Solar System, covering details of the planets, their satellites, and the results of space missions to each. Comets, asteroids, and meteors all receive their due, but trans-Neptunian objects deserve more than a bit of text and a few discovery photos. Of particular use would be an illustration of their orbits with respect to Neptune and Pluto. The best chapter — as one would expect from Sir Patrick — is that of the Moon. It includes four full-page quadrant maps by John Murray, with accompanying tables that list the larger craters, their size, and latitude and longitude (which you require to locate their position on the map). Of less use and interest were the sketchy maps of other satellites and some planets. Mars was the exception, as the sketch of its surface details are beyond the capabilities of visual observers and do not meet the author's intent to concentrate "upon things which can actually be seen by an observer who is adequately equipped," as stated in his Introduction.

The Sun has its own brief section, which acts as an introduction to the chapter on stars. Here, Moore includes topics on stellar evolution, doubles, variables, clusters, and nebulae. Moving outward, he then tackles the Universe with sections on galaxies, the Local Group, cosmology, and life. At this stage, three quarters of the way through, the book lives up to its title of atlas.

The Star Maps chapter (which, oddly, is mislabelled as The Stars) highlights all of the constellations in groups of one to eleven. Each group includes a black-on-blue star map; tables of the brightest stars (above magnitude 4.3), doubles, variables, and deep-sky objects, along with the occasional photograph and plenty of descriptive text. Paul Doherty's maps are clean, with constellation lines and stars sized by magnitude. The stars are labelled with their Bayer or Flamsteed designations, except for significant variable stars. Most Messier objects are included, as well as more than a third of the Caldwell objects and several NGC objects. The text focuses on the doubles and variables found within each constellation, but it grows tedious with data on luminosities and distances that should be in the tables.

The final chapter, entitled The Practical Astronomer, is surprisingly brief. It comprises a useful section on binoculars, but less-than-useful information on amateur telescopes and home observatories. It is followed by a ten-page glossary with a haphazard selection of terms. Why include definitions of cybernetics and Hohmann orbit, when neither is mentioned in the book? Why include Steady State theory but not the Big Bang?

The strength of *Atlas of the Universe* is in its photographs and particularly its illustrations. Each two-page section contains a handful of splendid pictures from professional telescopes or taken by advanced amateurs. There are a few photos of the Moon and constellations, taken years ago by Sir Patrick himself, that are of such poor quality by today's standards as to appear out of place. Nevertheless, the illustrations are superb in helping the reader picture orbital subtleties and relative sizes of planets and satellites.

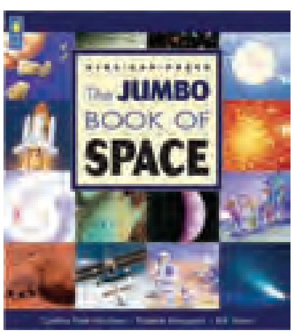
Atlas of the Universe was first published in 1970, with the most recent previous edition dating from 2003. Although this is the third edition from Firefly (who hold the rights in Canada and the USA), the 2003 Philip's version was advertised as the sixth revised edition. Apart from the addition of a section on the Mars rovers *Spirit and Opportunity,* and some data updates, there appears to be little reason to have released a new edition so soon. Any fact-filled book of this nature is bound to contain errors (pun not intended, but I'll take credit) and *Atlas* has its share. Among the more glaring are those resulting from sections not being updated for the revision. In the Introduction, the author hopes "we are now up to date to May 2005." On page 62 we find that the next transit of Venus will be in 2004, and that of Mercury in 1999. Even worse, an entry in the Glossary states that the next one for Mercury will be in 1986! Having seen that, I suspected the Index would be out of date, as well, so I ran a quick check. It took fewer than ten searches to find an error.

Firefly Atlas of the Universe deserves a spot on the coffee table of every amateur astronomer and in every school library. If there is to be another revision, I dearly hope it receives a thorough proofreading before being released.

Curt Nason

Curt Nason (nasonc@nbnet.nb.ca) is a member of the New Brunswick Centre and is employed as the Senior Health Physicist at Point Lepreau Nuclear Generating Station. Although such employment allows the purchase of, in another person's opinion, "too many astronomy books," it takes a serious bite out of the available time to read them all.

The Jumbo Book of Space, by Cynthia Pratt Nicolson and Paulette Bourgeois, pages 208; 21.5 cm × 24 cm, Kids Can Press Ltd., 2007. Price $18.95 softcover (ISBN-13: 978-1-55453-020-5).



Kids Can Press publishing company has released an impressive beginner's guide to astronomy. With a compilation of seven earlier publications as its core (*Exploring Space, Comets, Asteroids and Meteorites, The Planets, The Stars, The Earth, The Moon,* and *The Sun*), *The Jumbo Book of Space* places itself at the top of a list of books that belong in every young scientist's reference library. RASC members should consider the book when choosing birthday or Christmas gifts for their child or grandchild. If they are so inclined, they might at the same time purchase a few extra copies and donate them to science-fair participants or junior RASC members who display special interest in astronomy and space science. When RASC members at an Astronomy Day table in the local farmers' market or at a sidewalk astronomy presentation are asked for their recommendations regarding resources appropriate for children, there should be no problem. Show them your copy of *The Jumbo Book of Space.*

Why does *The Jumbo Book of Space* deserve such stellar praise?

I grew up on special astronomy articles from *National Geographic* and the Golden Guide books *Stars* and *The Sky Observer's Guide.* Through them I visited Mars, learned of Edmond Halley and his Comet, discovered when meteor showers occurred, and explored the surface of the Moon. Like those publications, *The Jumbo Book of Space* has the power to capture a child's imagination. It offers a well-organized presentation of astronomy and space-science themes. Eighteen chapters are outlined in a six-page Table of Contents. The outline introduces 280 short yet engaging topics arranged within 191 pages of text. These topics are distributed in the following themes: Earth, energy, space travel, Moon, Sun, planets, the Solar System, stars, galaxies, and discovering the Universe.

I was initially disappointed to see in the media release for the book that the proper nouns Sun and Earth were spelled with lower-case letters. In the book, however, authors Paulette Bourgeois and Cynthia Pratt Nicolson present them in their "proper" status.

Illustrations are plentiful and effective, numbering at least one and as many as seven on every page from 3 to 206. Bill Slavin's illustrations and diagrams form a natural balance with the photographs. His use of animated characters such as planets, comets, observatories, and rockets offer pertinent explanations and insights. Professor Moon informs the reader of the use and meaning of the Latin word "luna." A talking observatory describes the difference between natural and artificial satellites. A rocket ship tells the reader it is methane gas that makes the planet Neptune appear blue.

One of the strongest features of *The Jumbo Book of Space* is its use of 39 activities appearing under the heading "Try It!" Each is presented step by step and begins with a list entitled "You will need...." As a former junior high and elementary school science teacher, I enjoyed trying many of them to see if an 8- to 12-year-old (grades 3-7) would be able to handle the challenge. I loved them. Children will have a blast launching two-stage balloon rockets. "Moon Strength" is a fun and effective way to demonstrate lunar gravity. Five drops of milk in a transparent bowl of water really do make impressive sunsets and sunrises. Other sure-fire winners include Moon craters, See satellites in the night sky, Look at the Sun safely, Make a rainbow, Watch a meteor shower, and Split a star's light.

Topics are introduced in the form of a question, challenging readers to answer or think of what they know or understand about it. The answer following each question may be in the form of a definition, mythology, historical information, or theoretical possibilities. The history of astronomy and space exploration appears throughout the book. Entries include the race to the Moon and the first person to walk on the Moon, the discovery of the first asteroid, how and when rockets were invented, the *Hubble Space Telescope,* dwarf planets, and the new eight-planet Solar System. Most chapters contain myths, legends, and early stories that pertain to the chapter's theme. They include Earth creation stories, Icarus and Daedalus, the Man in the Moon, and Tcakabesh and the Sun's energy, to name a few.

Disappointments are rare and might properly be filed under the heading "Petty." However, a number of my concerns are demonstrated here to allow readers to judge for themselves.

On page 51, under the heading "Does the Moon move?", it is claimed that "You can only see one side of the Moon from Earth" and "The far side is always hidden from Earth." The statements come across as being final and rigid. There is no mention of the possibility that the Moon librates. I would have preferred to see a line added to inform children that the Moon wobbles and at times we can see a bit around one side or the other. The reader should know that we can see more than 50% and more like 59% of the Moon's surface from Earth.

On page 57 an eclipse of the Moon shows an Earth shadow slightly smaller than the Moon. The plastic lid needs to be larger, replaced by a plate or Frisbee positioned closer to the Moon, or a smaller replica of the Moon placed on the black paper. When I tried the activity with three different flashlights, including one with a halogen bulb, I could not get an effective yellow circle of light on the black paper to simulate the Moon. A yellow circle of paper one-quarter the diameter of the plastic lid (or substitute) and attached to the black paper makes a more realistic eclipse.

On page 99, aurorae are referred to as "a weird wind."

On page 113, "neighbors in the solar system" is spelled for the benefit of Kids Can Press customers south of the border. "Colors" bothered me until I discovered The Canadian Oxford Dictionary recognizes both "colour" and "color" as acceptable spellings and does not designate one as "especially British" and the other as "particularly American."

On page 179, the star Denebola is illustrated as a brighter star than Regulus. There are other more subtle deviations from reality that catch the astute astronomer's eye, such as the depiction of lunar mare and craters. It is unlikely, however, that such minor inconsistencies will pose a problem for junior readers.

At $18.95 Canadian, *The Jumbo Book of Space* is money well spent. It is not unrealistic that the publication will encourage many young people to become RASC members in the years ahead. Even if it does not, the thrill of experiencing astronomical phenomena will help them appreciate the power of life-long learning. Good for you, KCP!

Don Kelly

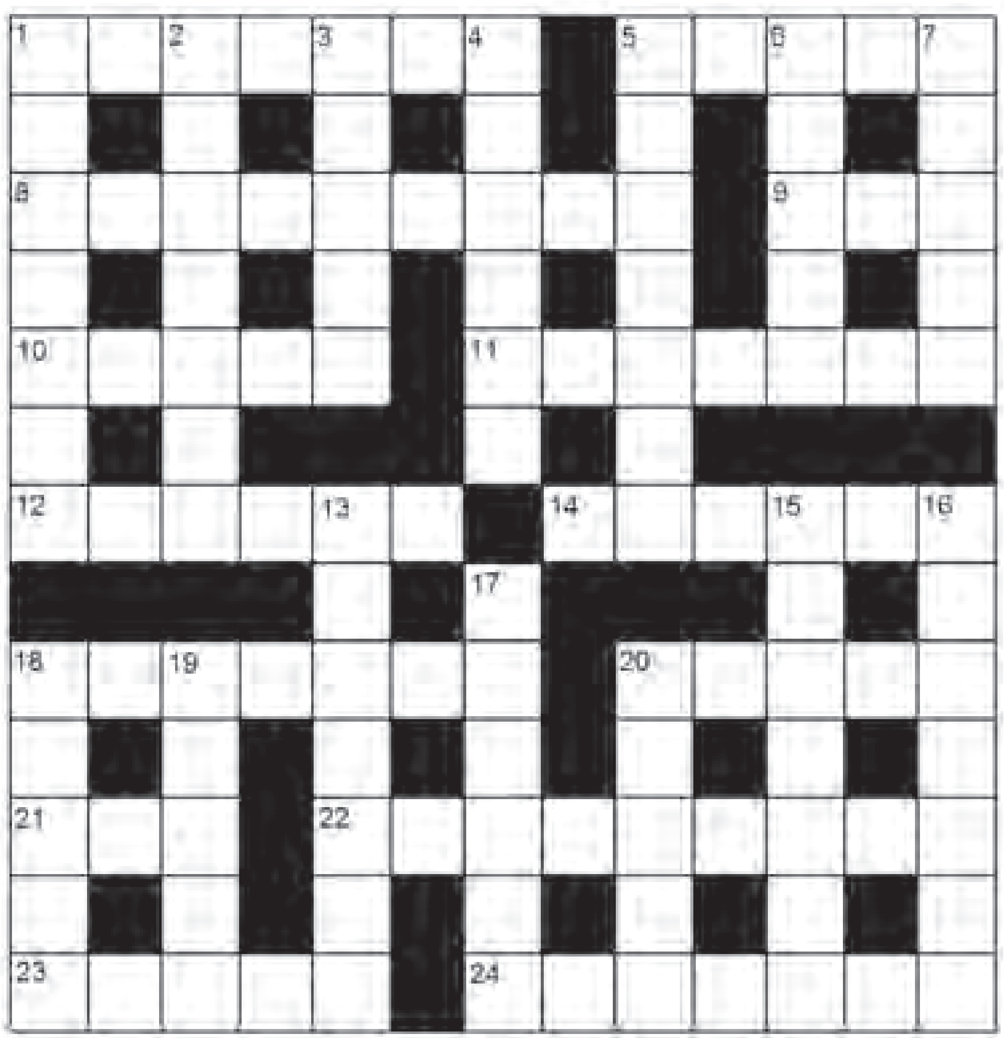
Don Kelly is immediate Past-President of the William Brydone Jack Astronomy Club, Fredericton, New Brunswick. He is Education Committee Chair of the RASC New Brunswick Centre, and serves as consultant/advisor to the national RASC's Education Committee. He can be reached at donald.kelly@rogers.com.

M42, by Kevin Black of the Winnipeg Centre on 2007 March 23, was obtained using his Canon 20Da camera at ISO 800; two 6-minute shots through an 8-inch f/5 Newtonian astrograph, combined as a panorama using Adobe Photoshop CS3.

Astrocryptic

ACROSS

1. Nail rocketeer Willy with starlight aberration discoverer (7)
5. Jovian satellite found within some of the belts (5)
8. Little bear roams ruin in confusion (4,5)
9. I'm leaving Maria at the altar (3)
10. Pace around before tomorrow starts a lunar age (5)
11. Equuleus starts by Aquila's claws as seen through interference filters (7)
12. Shattered Io pens in a more distant satellite (6)
14. Coin flipped about research and development for a La Palma telescope (6)
18. Barbie or Ken on Diamond Head with the developer of achromatic lenses (7)
20. Old Martian feature drawn in American almanac (5)
21. Number nine around Pluto (3)
22. Playful Titan tees up a rare chondrite (9)
23. Cookbook Camera man often in a jam (5)
24. Focus on sodium's legend (7)



DOWN

1. Browse around Ukraine capital for Dutch Mak maker (7)
2. Eagle's second brightest has lain oddly about (7)
3. Roche reached back in Alpha Ceti Milky Way region (5)
4. Rodney scrambled his jet in the wild blue (6)
5. Kansas storm ripped a dome, losing half of it (7)
6. Urania's sister was found in a caldera top (5)
7. Tests the leading solar max energy return (5)
13. Pole around head of Tigris with my copy of his Almagest (7)
15. Nova Scuti collapses in goddess, increasing its compactness (7)
16. Teach 150 about Palomar's owner (7)
17. Light pollution instigator involved in side-on collision (6)
18. Bird's beak follows half-dead swan's tail (5)
19. Illumination unit or the most light polluted hotel (5)
20. Libra's brightest couple once heard of Santa (5)

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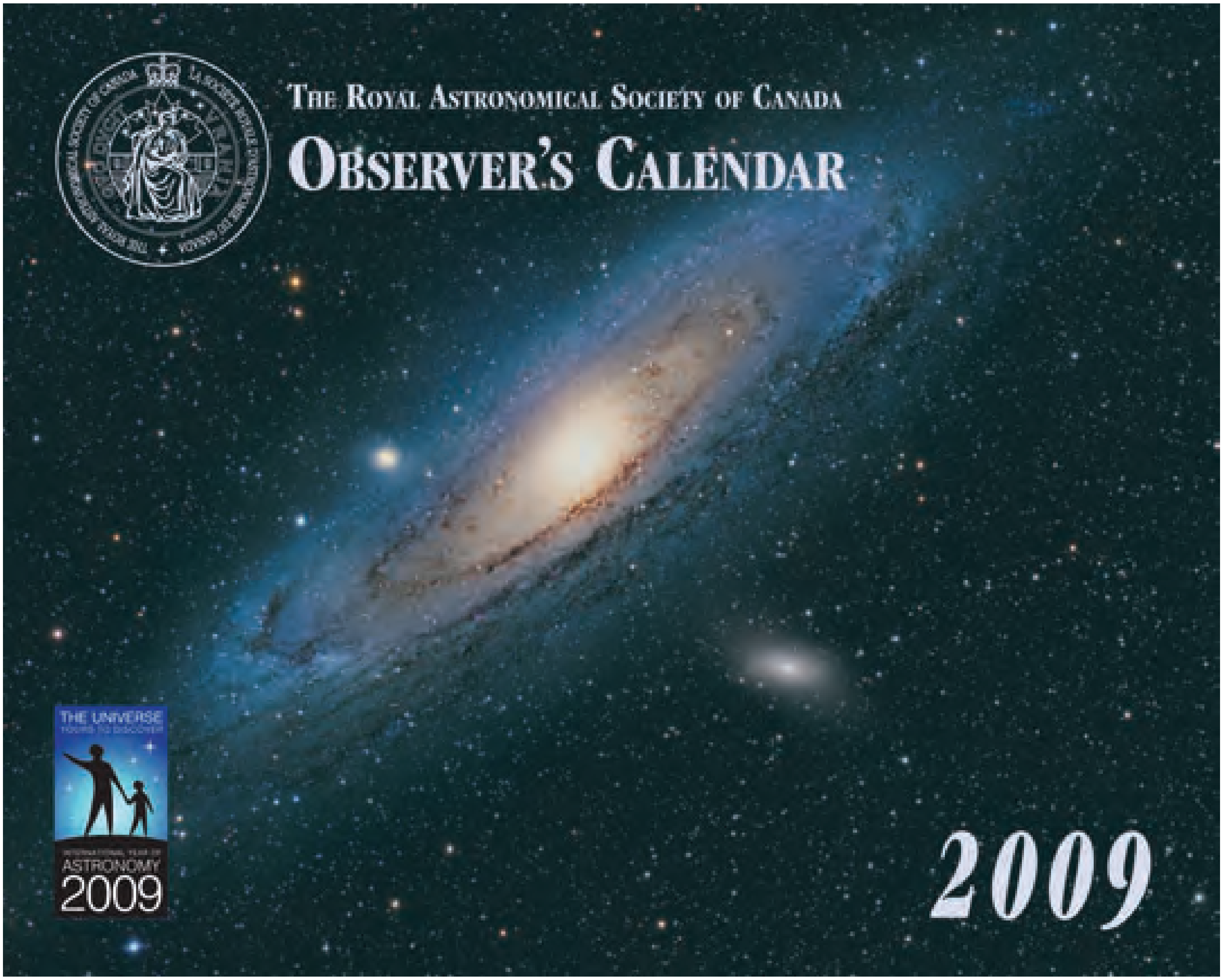

The RASC 2009 *Observer's Calendar* presents a treasury of astronomical information and lore complemented by stunning astronomical photographs. All photos in this unique Calendar were taken by members of the Royal Astronomical Society of Canada who are amateur astronomers using readily available telescopes and cameras. It was produced by volunteer members of the Royal Astronomical Society of Canada. This Calendar includes comprehensive listings of astronomical data such as lunar and planetary conjunctions, Sun and Moon rise and set times, eclipses, meteor showers, and Moon phases.

- Monthly grids include a host of astronomical information such as planetary conjunctions, eclipses, major meteor showers, Sun rise/set times, and daily Moon phases and rise/set times
- Daily lunar graphics showing phase and libration
- Rise/set times and other astronomical predictions are applicable to all of North America
- Canadian and U.S. holidays included
- Colour wall calendar, opens to 50 cm x 32 cm
- Photos taken by amateur astronomers, using the latest digital techniques
- Photographic-quality, high-resolution printing on top-grade paper
- Informative caption with each photo
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