ASTRONOMY

Journal of the Royal Astronomical Society of Canada / Journal de la Société Royale D'Astronomie du Canada

Canada

Dedicated to the Advancement of Astronomy and Allied Sciences

A MESSAGE FROM THE PRESIDENT

Welcome to a prototype issue of a proposed new publication of the RASC, combining what we believe to have been the best features of the Journal and the Bulletin, and introducing several new features.

We hope that this publication will better serve the needs and aspirations of all members of the society, and do so for many decades. The 1992 membership survey revealed that, while only a minority of the members were very dissatisfied with the old publication, a clear majority desired some changes which would increase the appeal of the publications to a wider audience.

The society's members include both professional and amateur astronomers, active observers and armchair astronomers, men and women, young and old. .. in short, a *very* wide range of backgrounds, skills and interests. A single publication cannot satisfy everyone all the time, but it should always offer something for everyone.

This publication invites submissions of research papers; articles that describe advanced observing projects; discussions of new or improved observing techniques and computer-related articles. There will be sections devoted to reviews of books and commercial software packages.

There will be a section devoted to news from centres. We invite brief, regular contributions from all centres describing special events and concerns. This is a standing invitation to all ofyou! We welcome the submission of graphs and photographs to supplement written material, preferably submitted on floppy disk.

Letters to the editor and commentary will provide opportunities for both professional and amateur members to express opinions on all matters relevant to the society and to astronomy. We encourage commentaries from professionals in which they clearly describe the nature and significance of current research, particularly that being conducted in Canada or by Canadians working elsewhere.

The society is its members. This publication will be deemed a success if it serves its members well and if its members serve it well.

Dr. Doug Hube
President, RASC

A message from the Publications Revitalization Committee

What you are reading is the prototype publication, "Astronomy Canada" which is proposed, by the *Publications Revitalization Committee*, to replace the current *Journal* and *Bulletin*. The committee is grateful to the editor, Cliff Cunningham, who designed, edited and desktop published this issue. Also deserving of thanks are the authors, who prepared original material for this prototype issue, and the members of the committee (Peter Ceravolo, Doug George and Pat Kelly).

The focus of this publication is to highlight astronomy in Canada, amateur and professional. If adopted, it is expected to include the sections and topics contained in the current publications, as well as many new ones. It will continue to publish material in English and French and will contain commercial advertising.

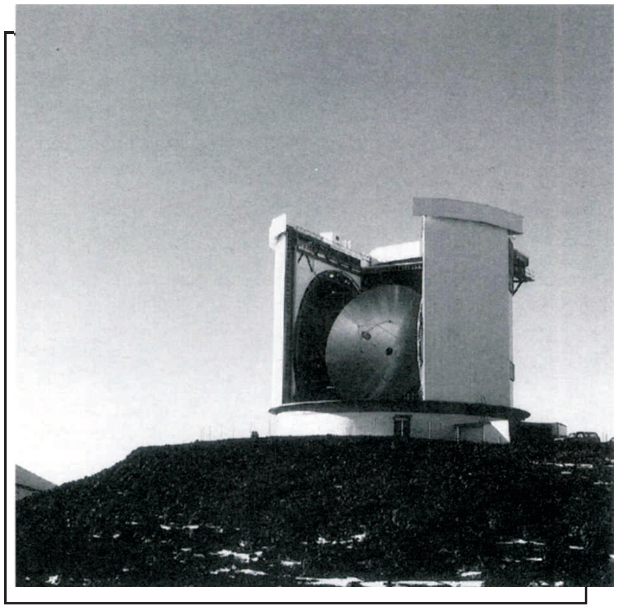
However, Astronomy Canada presents a more "popular" format heavily illustrated with photographs and figures. It will, however, still publish more formal peer-reviewed papers. This prototype represents the general content and style of the proposed publication, but should not be interpreted as a final product.

We hope you, the members of the RASC, will support our efforts to revitalize the Society's publications by filling out and mailing the **postage-paid questionnaire card** included with this issue.

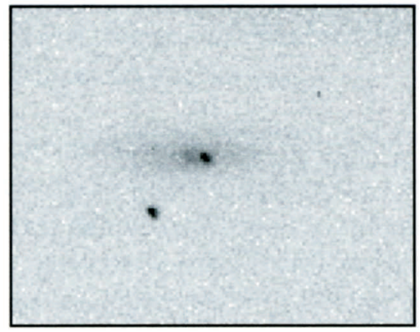
David J. Lane, Chair
Publications Revitalization Committee

In This Issue...

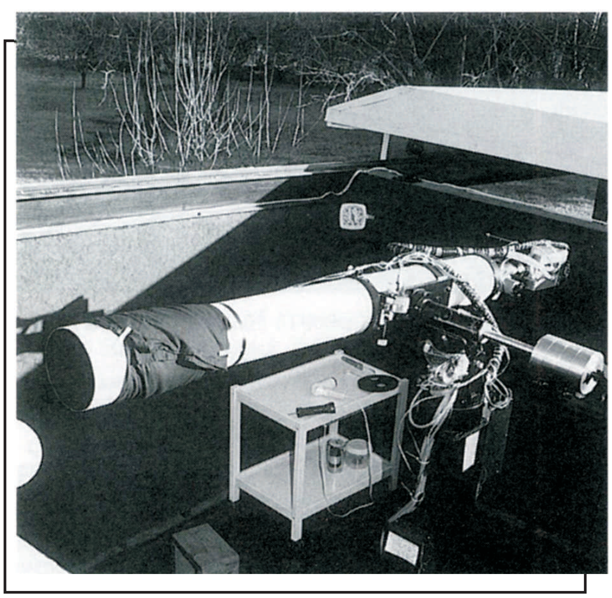
November-December, 1995



Feature: *The James Clerk Maxwell radio telescope in Hawaii is partially supported by Canada. An examination of the state of Canadian radio astronomy begins on page 11. Photo of the JCMT is by Dr. D. C. Morton.*



The discovery image of Canada's first supernova (centre). Details on page 2.



A close-up of the 7" apochromat refractor in Paul Boltwood's observatory in suburban Ottawa. Details on page 25.

Contents

Cover story: CANADA'S FIRST SUPERNOVA

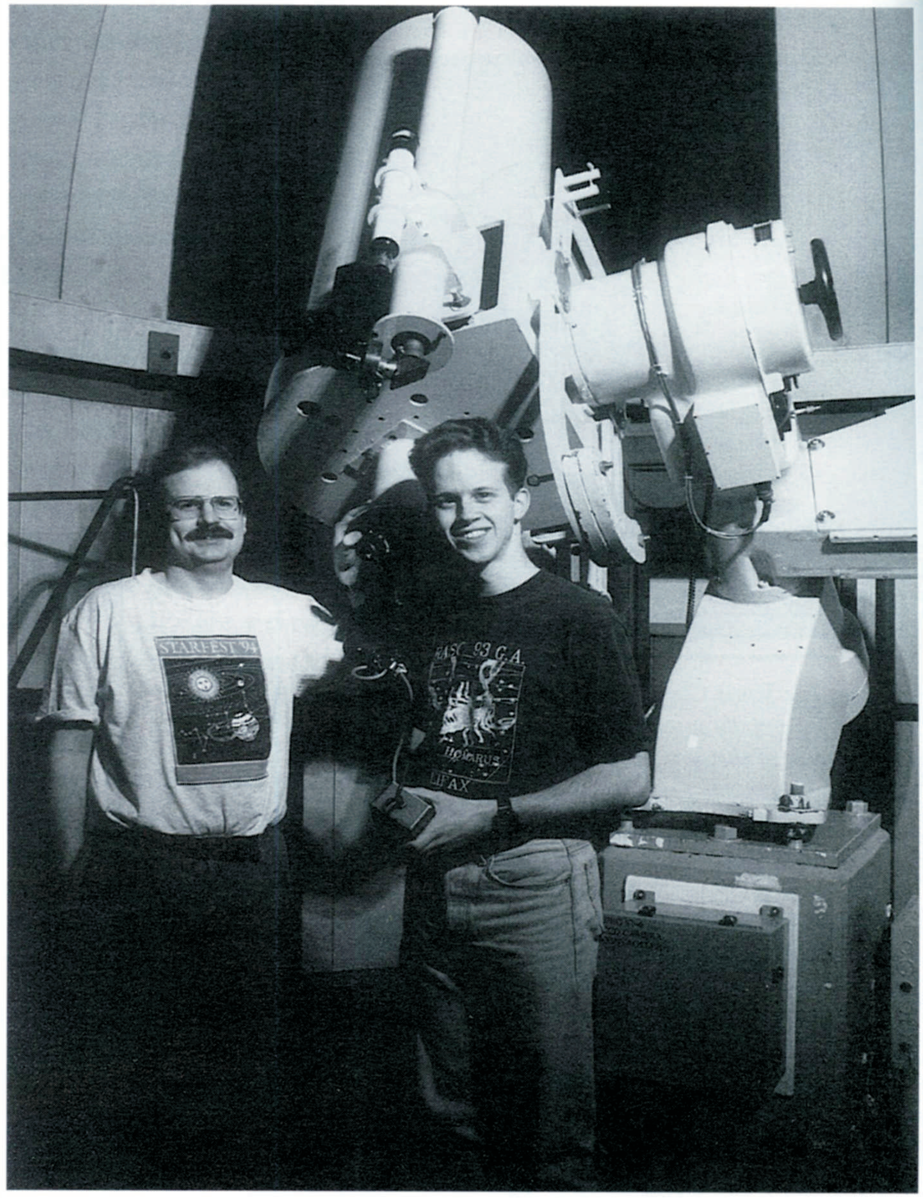
Dr. Gary Welch
Saint Mary's University

SEARCHING FOR SUPERNOVAS IN THE MARITIMES

Immediately after David Lane arrived at Saint Mary's University in 1992 as a technician in the department of astronomy and physics, we began plans to modernize the control of the Burke-Gaffney Observatory's 40-cm Ealing Cassegrain reflector. Although equipped with motors on both axes, the telescope had to be pointed the traditional way: the hour angle and declination circles were set manually and the target located in the finderscope.

The light pollution of surrounding Halifax made this process frustrating. Even if the sidereal clock was accurate and the hour angle correctly calculated, it was usually difficult to see almost anything except the moon, planets, and a few star clusters. This made slow work out of using the ST-6 CCD camera acquired in 1991. The camera could easily record images of faint galaxies and nebulas, but centreing them on the chip required patience. As observatory director I was keenly aware that we needed to automate the telescope pointing, but I had been hampered by the lack of electronic expertise in the astronomy and physics department and the lack of money to hire off-campus technical help.

Dave came with exactly the right experience to tackle the job. His first step was to install angular position encoders on both telescope axes. By the summer of 1994 these and the motors controlling telescope movement and focus were connected to a 486 clone in the adjoining warm room. Duplicate monitors now enable us to access the computer from either location - an especially useful capability during public tours. We now consistently put targets near the centre of the CCD without ever seeing them. A second 486 controls the ST-6 camera, and transfers images directly to the department's main computer network if extensive processing is to be carried out.



Dave Lane (left) and Paul Gray next to the 40-cm telescope in Halifax. The ST-6 camera used to discover Supernova 1995F can be seen at centre.

The telescope is pointed using the Earth Centered Universe software (reviewed in *Sky and Telescope*, September 1994) created by Dave for the amateur community. The ECU screen displays the sky using a variety of symbols for different kinds of objects. One can "point and click" on the screen, or enter the name or location of the target. The target data base incorporates the HST Guide Star Catalog and a selection of 10,000 deep sky objects including the entire NGC Catalog, plus an assortment of solar system members. The only required setup is to initialize the RA and DEC encoders at the start of each session by moving the telescope to a known location.

Possession of a largely automated telescope has stimulated plans for further improvements. During the summer of 1995 we began work on enabling the telescope position to control the rotation of the dome. Perhaps the day will arrive when a night's observations can be carried out by submitting a "batch" job to the controlling computer, but this is far in the future; observers at BGO should always have the option to carry on the ancient astronomical tradition of fighting off cold and lack of sleep to get their data.

Searching For Supernovas

On many occasions Dave and I had talked about what kind of research might be feasible for a small urban telescope. An active amateur astronomer and keen observer, Dave often expressed his willingness to get involved in a useful project. As work on telescope automation progressed we felt increasingly dissatisfied with the number of clear hours going unused.

Our commitment of three evenings per week to classes and public tours still left considerable time for other projects. Nonetheless, I was skeptical in the spring of 1994 when Dave broached the possibility of starting a supernova search project. He and Paul Gray, another member of the Halifax Centre of the RASC, had been kicking the idea around ever since Paul had first suggested trying it with a 35-mm camera. Like Dave, Paul had taken our introductory astronomy course during his undergraduate days at Saint Mary's. He was eager to get his hands on the telescope again.

The Search Begins

On August 16, just after the reinstallation of the newly aluminized primary mirror, the Team Supernova Scotia, led by Paul and Dave, obtained its first images - 17 galaxies in Draco (for more on Draco, see the article in this issue by Lucian Kemble). Over the coming months the team would be augmented on a "whoever is free" basis by other RASC members and our own graduate astronomy students - all unpaid volunteers. Everyone had daytime commitments - paying jobs or classes - which usually made very late nights impractical. Often it was necessary to wait for the end of class observing sessions or public tours before firing up the ST-6.

THE FASCINATION OF SUPERNOVAS

A supernova is an "exploding star". Huge explosions can occur on the surface of dense stellar remnants known as white dwarfs, as a result of gas transferred from a normal companion star. They are also believed to be the inevitable result of the chemical changes that take place in the centres of aging stars several times as massive as our sun.

In either case, the explosions are the most violent events known. During their first moments most of the chemical elements heavier than iron are created. These enrich the expanding debris, which gouge enormous cavities in surrounding interstellar gas, compressing it and possibly initiating the birth of new stars and attendant planets. We may well owe our existence to an ancient supernova.

Their connection with the life-cycles of stars and possibly with the origin of planets like the earth makes supernovas fascinating objects for study. Furthermore, it appears that they may provide distance estimates to remote galaxies and thereby help establish the scale and future of the universe. This is partly because for a few weeks a supernova is typically brighter than a hundred million stars like the sun.

During this time it becomes a brilliant point of light within its host galaxy and can be detected even at great distances by modest telescopes. With their high sensitivity and almost instant output (no darkroom processing required!) CCDs are the ideal detectors for supernova searches. With a CCD one can examine many galaxies per night, looking for star-like points which were not there before.

Supernovas are not common; a typical galaxy might experience one or two per century. The last Milky Way supernova near enough to be seen through our galaxy's interstellar dust clouds occurred before the invention of the telescope. Searching other galaxies improves the odds. Today several observatories conduct supernova searches - beneath clearer skies than ours. Some programs use automated telescopes capable of examining hundreds of galaxies per night without observers present.

As a result several dozen supernovas are discovered each year. It is essential to bring big telescopes into action as quickly as possible after the discovery. To cut down the response time the International Astronomical Union (IAU) operates an electronic circular service which broadcasts the news to observatories around the world. Could we really become a serious player in this process? I wondered if Dave and Paul were prepared to spend years trying to beat the "professionals" to a new discovery. On the other hand, what was there to lose? The project had at least potential scientific value. We just had to be looking at the right galaxy at the right time; maybe we would get lucky. -G.W

Various techniques for improving efficiency were gradually adopted. An early decision was to give high priority to circumpolar spiral and irregular galaxies; hopefully these would be neglected by more southerly search programs. Galaxies too large for a single image or fainter than about 14th magnitude were excluded. Each session was planned so that the current target list could be observed using minimum telescope motions. Exposures were kept short and unfiltered, sufficient to reach 16-17th magnitude. A standard filter set could be used later for photometric measurements of anything interesting. All first-time images had to be stored as comparisons for future re-observations. As the weeks rolled by, so continued the inevitable process of filling all available disk space.

Of course no one really believed that "lightning would strike". I suspect this was actually a secondary consideration for many team members, less important than the immediate fun of participating in a kind of high-tech game. I continued playing a minor role: examining the occasional "nice" image with Dave, listening sympathetically to stories of "false alarms" that turned out the next day to be unrelated foreground stars, providing opinions on the current search strategy - which constantly evolved during the fall of 1 994. The search gradually became just another part of the daily routine.

Interesting Images

One Monday morning in mid-February 1995 Dave asked me to take a look at a "first-time" image of NGC 2726 taken the previous Friday, February 10. A star-like feature was clearly visible close to the centre of the galaxy - almost a text-book example of what a supernova should look like. Without a comparison image, team members had checked the galaxy on our paper copy of the Palomar Observatory Sky Survey. Unfortunately, as is the case for most bright galaxies, the centre of the POSS image proved to be overexposed. No details could be seen.

Without feeling much excitement I agreed with Dave that the image was "very interesting", and that we really needed to find a comparison photo. The obvious question was, should we stick our necks out by contacting the IAU Circular Centre in Harvard, Massachusetts? If it was just another foreground star we would quickly be branded as "that amateur bunch from the boondocks who sees supernovas everywhere". Caution prevailed. We decided to try finding a comparison photo before doing anything rash. A quick search in my office failed to uncover one, and the press of other duties soon diverted my attention.

That evening, February 13, the team was again at work. A confirming image of NGC 2726 showed the same suspicious star, proving that it wasn't a cosmic ray hit or other artifact. Several other galaxies were also observed. An image of NGC 2441 provoked some discussion when a faint condensation (star? fuzzy patch?) was noticed in the galaxy disk. This galaxy had been observed previously and the comparison image was immediately retrieved. As it filled the comparison window team members were surprised to see a completely different galaxy!

Apparently the original first-time image of NGC 2441 had been overwritten on some later night, probably by keying in an incorrect NGC number. Since nothing could be concluded without a comparison image the matter was temporarily laid aside, with the intention of returning to the galaxy during the next clear night. After closing up, the search for a comparison image of NGC 2726 resumed. Unfortunately, nothing could be found in the astronomy library collection.

By the following day we had to recognize that we weren't going to find a comparison image of NGC 2726. Screwing up his courage Dave sent an e-mail message to "novanet", an Internet mailing list used by observers of galactic novae and supernovae, describing our "possible supernova" and asking for help in locating another image of the galaxy. Two days later, on Thursday 16 February, we received a message from Peter Garnavich at Harvard requesting a copy of our image to compare with a photo of NGC 2726 in the Harvard plate collection. Dave quickly e-mailed a copy. Later that day, Peter sent the following message:

"*Good news! I've pulled over your image and compared it to the plates. We don't see a star that bright on the galaxy. You've probably found a supernova. The only question is what band pass was your image. The plates are blue sensitive, so we could have missed a very red star on our plates.*

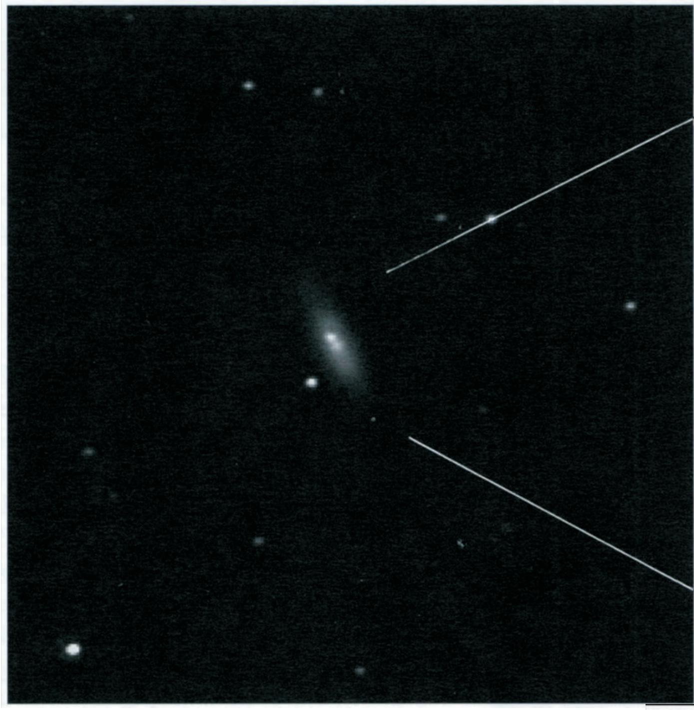
You should officially report it to Dan Green at the IAU Circulars. Be sure to mention Martha Hazen and the Harvard plate collection. We will try to get an image of the galaxy in the next few nights. But a spectrum won't be possible for another 5 days."

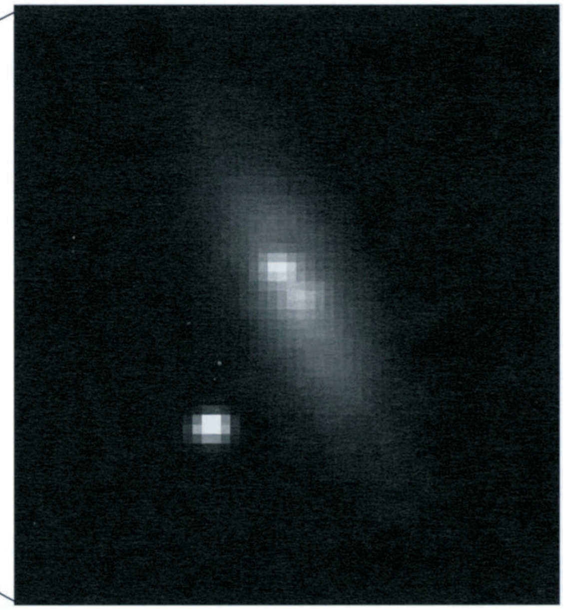
A report to the IAU went in late Thursday. All at once the "impossible" seemed ready to happen. Taken without a filter, our images were certainly much more red sensitive than the plates in the Harvard collection; it could still be a red foreground star. Several days of mounting tension followed. The evening of the 22nd witnessed a surge of regret when an IAU Circular arrived announcing the discovery of supernova SN1995E in NGC 2441, the Feb. 13th galaxy with the funny condensation.

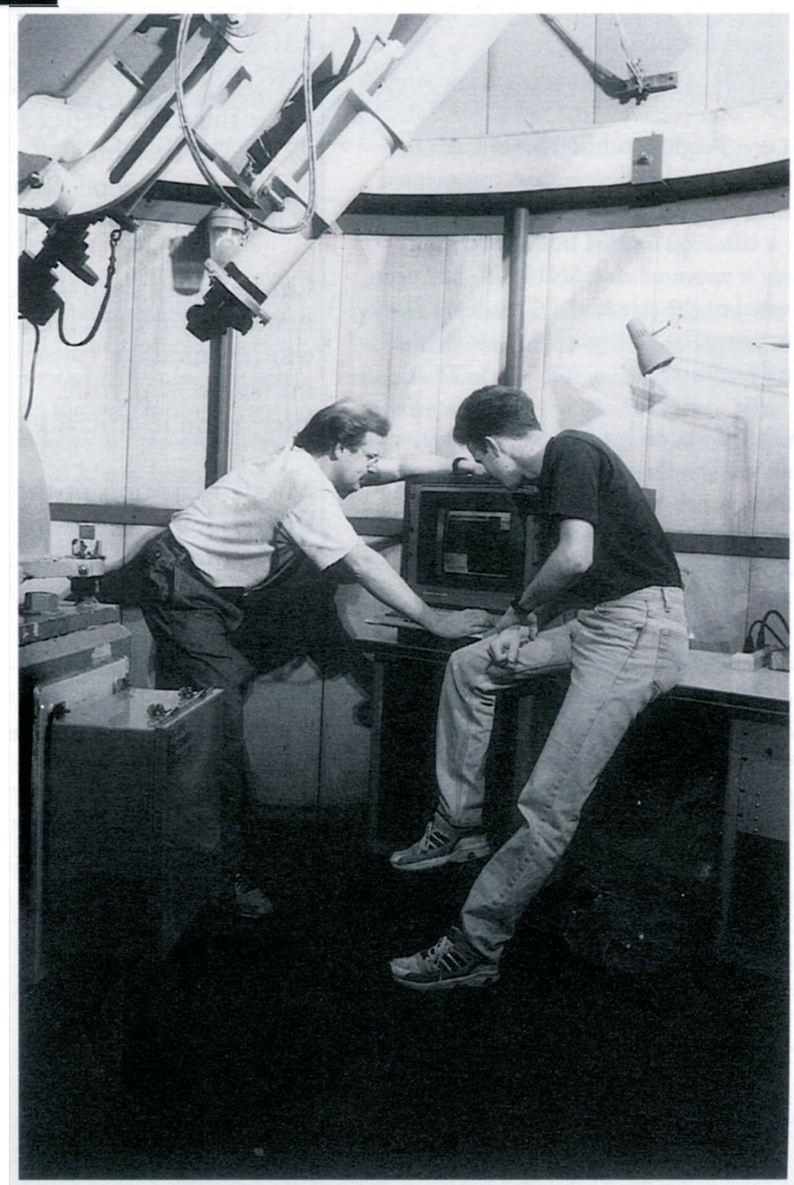
Measurement of our image showed that the condensation was located right at the reported position of the supernova; another image taken some days later indeed showed that the condensation had turned into an obvious star. It appears that the "condensation" was actually the supernova, which we had caught during the brief phase of rising brightness. So close to a discovery; if only the comparison image had not been accidentally overwritten!

This event did nothing to raise spirits, as we waited for word on the nature of the NGC 2726 star. In this case, however, there was a happy ending. On the 24th we received two messages. The first came from Lick Observatory in California: a spectrum taken with the Shane 3.05-m telescope clearly showed that we had discovered a supernova!

The second message, IAU Circular 6138, announced the discovery to the world as SN1995E In an ironic footnote, we later realized that this announcement came eight years to the day after the discovery of SN1987A, the last "Canadian supernova".







Upper left: Centred in this view is NGC 2726 and Supernova 1995E This CCD image was taken by Peter Ceravolo and Doug George in February 1995 with a 216 mm f/6 Maksutov-Newtonian and a HiSIS22 CCD camera. The five-minute exposure was image processed with Hidden Image.

Upper right: This detail view shows the supernova to the upper right of the central condensation of the galaxy. To the lower left is a star in our own galaxy shining at magnitude 14.9.

Lower right: Dave Lane (left) and Paul Gray study information on the observatory's computer monitor.

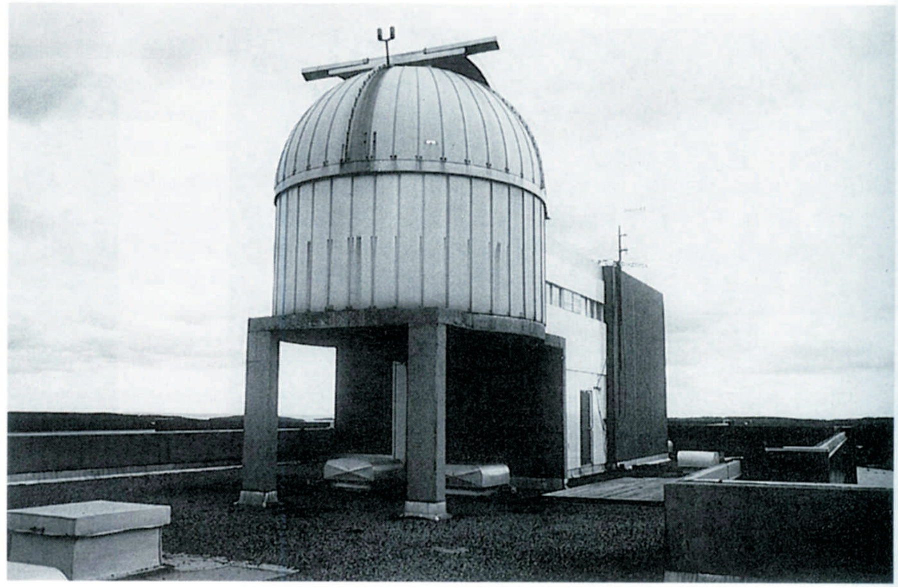
Postscript - Media Madness

Word of our discovery spread almost instantly among local RASC members; close contacts between many amateur and professional astronomers ensured that within a few hours the news had reached across the country. Meanwhile, with Dave's help I composed a short press release summarizing the discovery, before leaving for the weekend. I didn't expect the media to pay much attention - after all, who but astronomers would care about news of some faint burp in a distant galaxy? Even so, it seemed silly to throw away a chance for some publicity. I had no idea of how much I had misjudged the situation.

On Monday morning my e-mail contained a message from Terry Dickinson, who writes for the Toronto Star. Apparently Terry had learned of the press release over the weekend through his RASC connections. His message related an interesting story: after receiving the news, Dr. Sidney van den Bergh, a world-famous Canadian authority on supernovae, had commented that he couldn't recall a similar case involving a telescope located in Canada. Suddenly it appeared that SN1995F had been elevated to the status of a Canadian "first". This proved to be irresistible bait for the news media.

During the coming week everyone remotely connected to the discovery was besieged with interview requests from journalists across the country. There was one notable exception, however.

With almost supernatural prescience, Dave Lane had previously arranged to attend the annual Winter Star Party held in the Florida Keys during this week There he was effectively beyond the long reach of the media. Back at Saint Mary's the rest of us compiled a number of choice comments on this amazing coincidence, which Dave accepted good-naturedly after returning.



The Burke-Gaffney Observatory and adjoining warm room. The floors of the dome and warm room are one storey above the roof.

VIGNETTE: By David Lane

I was the most skeptical member of the team between the night that NGC 2726 was first imaged and when the official announcement came through. With no real good reference image, the evidence was mounting against it being a supernova.

On February 24th while I was putting the final touches on *Nova Notes*, the newsletter of the Halifax Centre, I decided to check my e-mail. The waiting message from Alex Filippenko at Lick Observatory marked a milestone in my life. The subsequent IAU circular which arrived an hour later made it official with the announcement of SN1995E

My participation in the local celebrations among the team members and the resultant media attention the week following were dampened by my preparations for subsequent departure to the Winter Star Party in Florida: a warm "week" under the winter stars.

I expected to have to wait much longer in order to "bag" one. The discovery has certainly provided plenty of encouragement for the team and confidence in our methodology. The search continues...

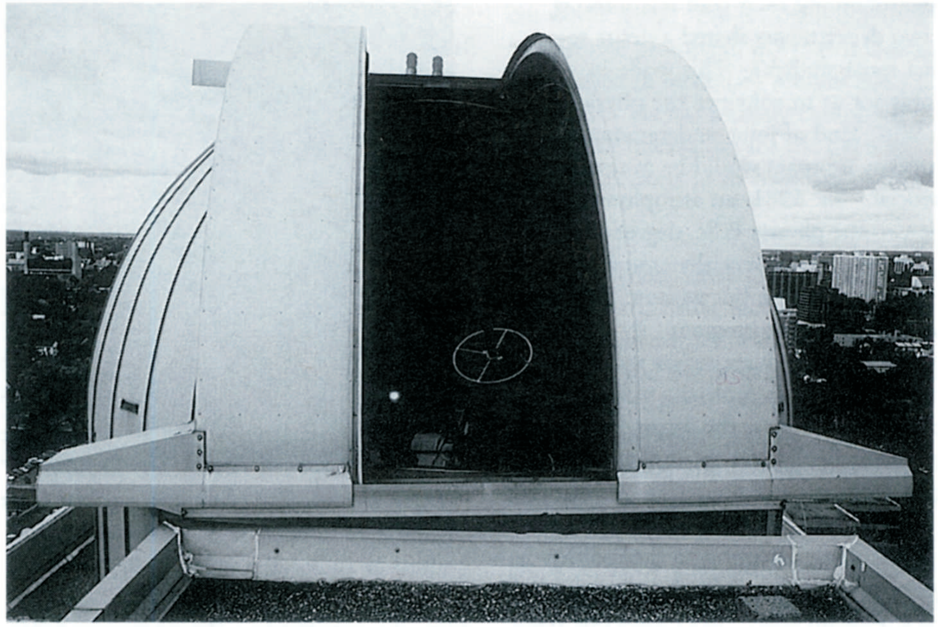
Properties of the Supernova and its Galaxy

Galaxy NGC 2726	Supernova 1995F
Position: 9h 5.0m +59 56'	9h 4m 57.4s +59 55' 58."7
Magnitude 12.5	14.7 at discovery
Size: 1.8' x 0.5'	
Type: Sa	Ic (possibly Ib)
Distance 56 Mly (Ho=87)	

ASTRONOMY AT SAINT MARY's

Dr. Gary Welch
Saint Mary's University

WHEN ASTRONOMY WAS ASTRONOMY AND PHYSICS WAS PHYSICS



The dome and 40-cm. telescope of the Burke-Gaffney Observatory. Halifax lies beyond to the north.

Even now, some 30 years after his retirement, I still occasionally meet older Haligonians who recall being introduced to the glories of the night sky by Father Burke-Gaffney. During his 25 years at the university the tireless Jesuit forged an indelible link between astronomy and the name Saint Mary's in the minds of Nova Scotians. This tradition played a large part in the decision to start a department of astronomy in 1974. There were other factors too: with enrolments on the rise since becoming a non-denominational public institution in 1970, there was a growing feeling that the time was right for Saint Mary's to expand.

A powerful pro-astronomy lobby coalesced within the university, centred around Father Burke-Gaffney and administrators including the Dean of Science Bill Bridgeo and Edmund Morris, future mayor of Halifax, who was acting president of Saint Mary's from 1970 to 1971 . Ties with the church were still strong, and the argument that astronomy provides a natural means of bridging the growing gap between modern science and traditional religious beliefs was persuasive. So persuasive in fact, that the new department was granted permission to offer the first graduate science degree at Saint Mary's, a Master's of Science in Astronomy.

I arrived at Saint Mary's in the summer of 1974 to join George Mitchell and David DuPuy, who were being transferred from the Physics Department into the new Department of Astronomy. George, whose interest at that time was in relativity theory, had "picked up the torch" passed by Father Burke-Gaffney several years earlier. David had come on board in 1972 with a mandate to use his observational expertise in activating the new Burke-Gaffney Observatory (BGO). David and I had become acquainted as graduate students when our paths crossed at a couple of astronomical meetings. He was chiefly responsible for my decision a few months earlier to leave my teaching job at Wheaton College in Massachusetts, where I was a lonesome astronomer in a small physics department. Like most Yanks I originally had little idea of Canadian geography; I vividly remember my wife and I studying an atlas of North America in the evening after David's fateful phone call in early April, to reassure ourselves that Nova Scotia was indeed connected to the rest of the continent. During a quick trip to Halifax I decided that I liked the idea of helping to start a new astronomical enterprise in the "far north".

As observatory director, David laid plans to incorporate the newly installed 40-cm Ealing reflector as part of introductory and advanced classes, and to open the observatory to the public on a weekly basis. Although he also hoped to conduct variable star research with the telescope, the unreliable Maritime weather proved a formidable barrier. David decided to return to his native south in 1981, leaving me as the new director. Two years later his position was filled by David Turner (the second of several "David's" connected with astronomy at Saint Mary's), who left a rather uncertain astronomical climate at Laurentian University in Sudbury.

Throughout these years relations with the larger physics department were strained. This was especially awkward for the astronomers, because of the irony that we offered only a graduate degree. Thus, we needed to attract undergraduates from elsewhere, and our own physics department was the obvious place. To me the cause of the difficulty seemed to boil down to resentment of the fact that a separate department of astronomy had been created instead of attaching the astronomers to the existing physics department. I do not know the reason for this decision. Perhaps university administrators recognized that the physics department had become so Focused on teaching that not much research was going on. It might then have been concluded that the astronomy program, which was to have a strong research emphasis, would fare better on its own, than as a minor part of an expanded physics department.

Notwithstanding their cool relationship the two departments shared a desire to attract more students. This made it possible for us to convince the physicists that some kind of joint undergraduate astronomy program would be mutually beneficial. In 1981 an astrophysics option to the physics B.Sc. degree was introduced. This essentially amounted to a minor in astronomy, but without the status of an official degree program. By 1990, however, undergraduate major and honours programs in astrophysics were on the books. After 16 years the astronomy department finally had an undergraduate degree program.

Dave Turner, first chairperson of the Dept. of Astronomy and Physics

An outstanding exception to the indifference or hostility shown by the physicists was Fr. William Lonc. Bill retires this year as Professor Emeritus, the last Jesuit member of the science faculty. He supported astronomy from the start, and helped supervise our first M.Sc. thesis with David DuPuy. This involved constructing a 2-dish solar radio interferometer on the (conveniently flat) roof of the administration building. Prior to getting his Ph.D. Bill had become interested in electronics as a TV serviceman in Montreal. Over the years, his unquenchable urge to acquire and tinker with all things mechanical and electrical led to the establishment of what must rightly be called the "Lonc Antenna Farm" on the admin. roof. Impossible to miss from street level, the various converted microwave dishes are an eloquent statement of the continuing presence of astronomy at Saint Mary's.

Changing Times

Beginning in 1992 an improbable combination of retirements and resignations led to four vacancies in the physics department within a period of 2 years. The current Dean of Science David Richardson used this opportunity, with our enthusiastic support, to push successfully for a merger of the two departments. Dave Turner, the last chairperson of the Astronomy Department, became the first chairperson of the new Department of Astronomy and Physics. Note the "unusual" ordering of disciplines in the title. This probably has nothing to do with the fact that astronomers outnumbered physicists at Saint Mary's for the first time!

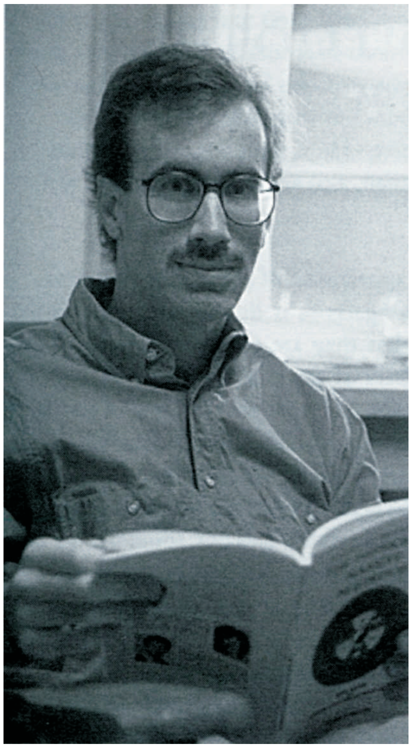
It was certainly no coincidence that one of our two present technicians Dave Lane was also hired during this period. Richard Ives, who had been the physics technician, effectively continued on in the same capacity The position of astronomy technician was vacated by Laurie Reed, a graduate of our M.Sc. Program. Laurie had recently married Cameron Reed, a new member of the physics department with interests in stellar photometry. (Interesting fact: there have been two other marriages involving people connected with our department; in each case *both* persons were former astronomy graduate students. I would like to know how unusual this is.)

Dave Lane, a gung-ho amateur astronomer, is currently president of the Halifax Centre of the RASC. As an undergraduate at Saint Mary's he had taken the introductory astronomy course and learned first-hand the joys and frustrations of observing with the 40-cm telescope. After later obtaining a strong background in computer technology, Dave dreamed about "computerizing" operations at BGO. His chance came with the departure of Laurie in 1992.

The new department came into existence in a climate of growing political pressure to reduce duplication in Nova Scotia universities. Under the circumstances it seemed wise to reconstitute physics at Saint Mary's with a unique character. It was obvious what to emphasize; Saint Mary's already had the only astronomy group in Atlantic Canada, and the only undergraduate astrophysics major and astronomy M.Sc. programs in the region. In the fall of 1993 we were joined by Malcolm Butler, David Clarke, and David Guenther. During the following months the new department jokingly debated the merits of adopting a "Davids need not apply" policy for making the final hiring! All were relieved when Mike West accepted the position in the spring of 1994.

The New Department: Astronomers In Action

As the astronomy program at Saint Mary's enters its third decade the future remains clouded by the external pressures bearing on all provincial universities. But there are important reasons for optimism. Our



Malcolm Butler studies solar neutrinos.

new members have brought seemingly unbounded energy and enthusiasm. Our undergraduate programs in physics and astrophysics have been extensively revised and improved. We are working to increase the awareness of astronomy in the community.

Research in astronomy is flourishing at Saint Mary's; our Canadian colleagues readily acknowledge that we have grown into one of the country's major research centres. The following summaries illustrate the wide range of exciting activities in progress.

Malcolm Butler's research focuses on one of the great scientific puzzles of the past 25 years: the case of the missing solar neutrinos. These elementary particles are a by-product of solar energy generation, in which nuclear fusion creates helium from hydrogen in the sun's core. Several experiments have now confirmed that far fewer solar neutrinos are detected on earth than predicted by our best models of the sun's interior. The solution probably lies in the domain of particle physics. There are 3 known types of neutrinos. The favourite explanation at present is that neutrinos are capable of "oscillating" between different types, thereby eluding detection by present equipment. Malcolm is interested in explaining how such oscillations could occur.

The largest and most powerful single entities in the universe are found among radio galaxies and radio quasars, so-named because they contain enormous reservoirs of hot plasma which radiates in the radio waveband. These reservoirs can be as large as 3 million light years, extending far beyond the visible parts of their host galaxy David Clarke's area of research is aimed at understanding the origin and behaviour of these huge plasma clouds, including their role in creating cosmic rays. He gathers observations using the Very Large Array radio telescope in New Mexico and interprets them with the help of theoretical simulations carried out on super-computers.

David Guenther is interested in exploiting the new field of stellar seismology to probe

David Clarke is a radio astronomer who studies plasma clouds

conditions within the sun and other stars. Seismology, the study of vibrations in the earth, has provided most of what is known about the internal nature of our planet. Although not solid like the earth, stars oscillate in response to energy flowing outward from their centres. With collaborators elsewhere, David uses computers to simulate stellar oscillations, showing how their observed behaviour can improve our understanding of the age, chemical composition and energy flow mechanism in stars. He is in the forefront of efforts to extend the work to include other nearby stars.

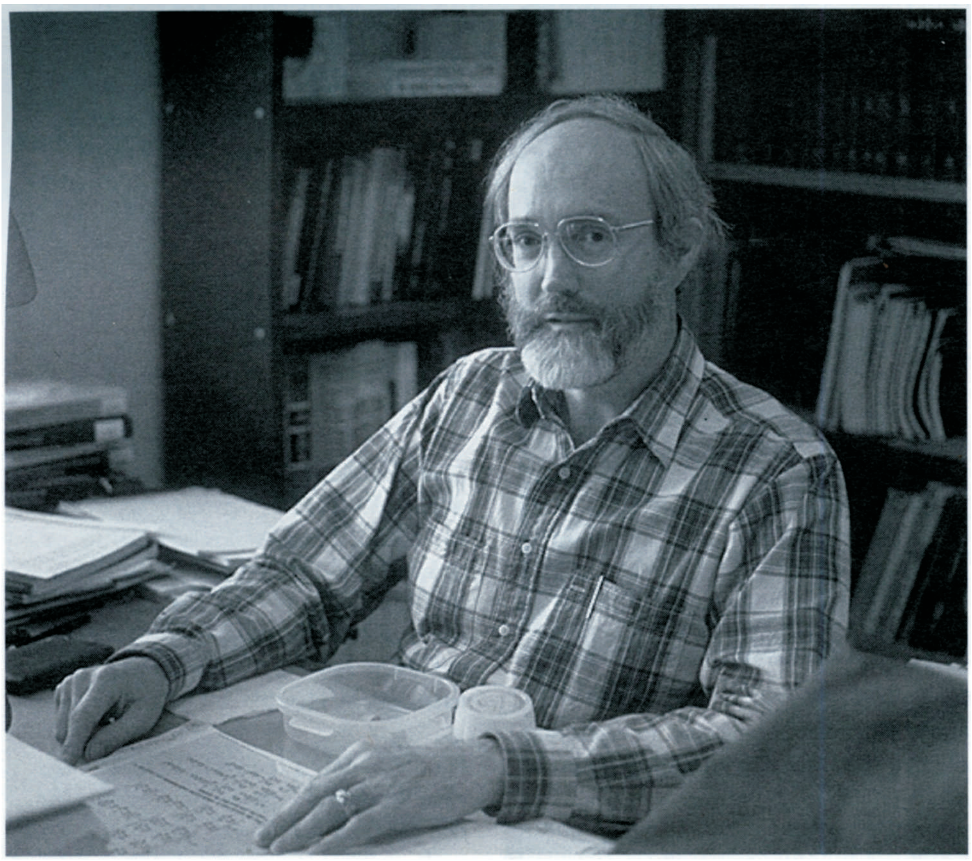
As the Department's first Professor Emeritus William Lonc intends to remain active in using radio astronomy to stimulate the interest of students in scientific careers. Our extensive "antenna farm" features interferometers operating at 3, 7.5, and 21 cm wavelengths. Bill is developing these as inexpensive prototypes of systems that can be installed in secondary schools and museums. He has recently completed a single-dish installation for the town of Stafford, Arizona in its Museum of Discovery.

George Mitchell carries out research on two closely related fields, namely the physical and chemical nature of interstellar molecular clouds, and the process of star formation within the cores of these clouds. He employs observational techniques in the millimetre radio and infrared several large telescopes in Hawaii.

He is currently attempting to understand what causes the large outflows of molecule-rich gas from very young stars. A related study aims to uncover the process which triggers the formation of massive stars within molecular clouds. George is planning to use the Swedish ODEN space mission, scheduled for launch in 1997, to conduct the first survey of submillimeter radiation emitted by oxygen and water molecules in interstellar clouds.

David Turner specializes in the observational study of galactic star clusters and Cepheid variable stars. He is especially interested in clusters which may contain Cepheids, because they provide a way to estimate the Cepheid's luminosity. Together with the established correlation

David Guenther probes the conditions within stars



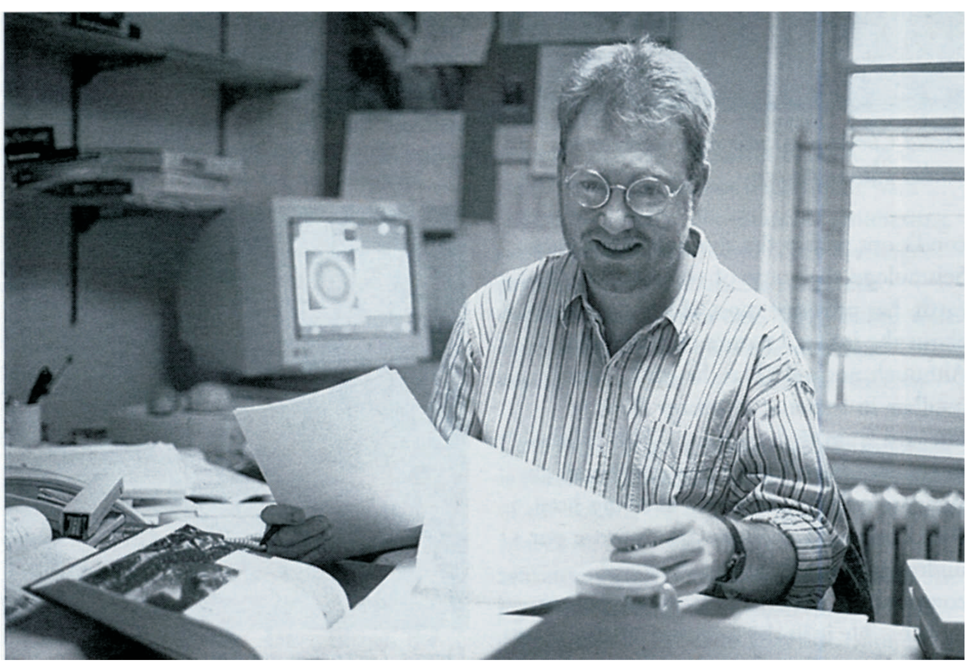
between brightness and pulsation period, this information makes Cepheids the most accurate tools for finding galaxy distances, and hence of mapping the scale of the universe. He is the current department chairman, and also edits the *Journal of the RASC*.

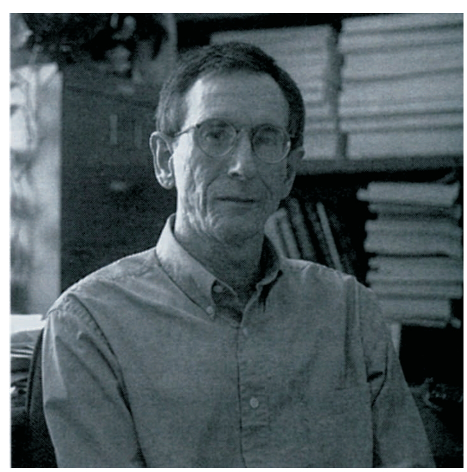
The appearance of our Milky Way and similar galaxies is due in large part to the fact that they are presently forming large numbers of stars. Many other galaxies, however, are now making few if any stars. These are the elliptical (E) and SO galaxies. Gary Welch is interested in understanding how the star formation process in these galaxies compares to that operating in the familiar environment near our sun.

He uses the James Clerk Maxwell radio telescope in Hawaii to probe conditions in the dense gas from which stars can potentially form in nearby E and S0 galaxies. With the 1 .6-metre reflector at Mont Megantic P.Q. he locates the sites of star formation and estimates the number of young stars by recording the emission from hydrogen clouds heated by stellar ultraviolet radiation.

Gary Welch (above) uses the JCMT (pictured on pg. 20) to study star formation regions in nearby galaxies. Michael West (below) studies cosmology and the formation of globular star clusters.

Michael West divides his research between observational and theoretical aspects of cosmology, clusters of galaxies, galaxy formation, and the large-scale structure of the universe. In addition, a good deal of his efforts at present are devoted to understanding the formation of globular star clusters, the most ancient members of our Milky Way.





George Mitchell examines star formation processes.

THE POLITICS OF SCIENCE ON A SMALL BUDGET: THE FUTURE OF CANADIAN RADIO AASTRONOMY

By RICHARD JARRELL

York University

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1. INTRODUCTION

Canadians have actively pursued radio astronomy for nearly fifty years. Radio astronomers have a well-established place in the Canadian scientific community and have built an enviable international reputation. Do they have another fifty years ahead of them? In the summer of 1994, the National Research Council of Canada (NRC) sponsored a four-day workshop on “Radio Astronomy: Visions for the 21st Century.” While several foreign radio astronomers participated, the workshop was essentially an internal affair to review the status and future aspirations of Canadian radio astronomers. I attended in the guise of a scientific anthropologist, to discern the tribal rites of this field, particularly how they would negotiate their future.

The conference announcement argued that “Canada has a strong tradition of excellence in radio astronomy and is well positioned to play a leadership role in the next generation of science and instrumentation,” and asked which are the likely directions of greatest scientific promise and what instruments could be built “to turn that promise into work for a generation of young astronomers?” Put this way, the issue is one of strategic planning. However, there are larger issues at stake and I shall argue that the very nature of Canada’s participation in Big Science may be changing dramatically, and that Canadian radio astronomy is a bellwether science.

By way of personal disclaimer, I offer no advice on the decisions to be made. I am an observer, not a participant. This discussion flags the salient features of this ongoing debate and describes the nature of the field. Such decisions have not been, and will not be, predicated upon purely technical grounds. Social, political and economic factors are as important for decision-making in Big Science as whether a particular project will produce “good science.”

2. THE PARAMETERS OF PLANNING

Several assumptions—not always voiced directly at the conference—underlie the planning process for Canadian radio astronomy:

(1) Canadian radio astronomers believe that they must plan now for the next generation of instrumentation and software, given new observing techniques and technological advances. Most of the conference programme focussed upon emerging techniques, and the most attractive scientific problems in the coming decades.

(2) The amount of money likely to be available is limited;

(3) Radio astronomers want to realize the greatest scientific advantages within this budget for the largest segment of the community;

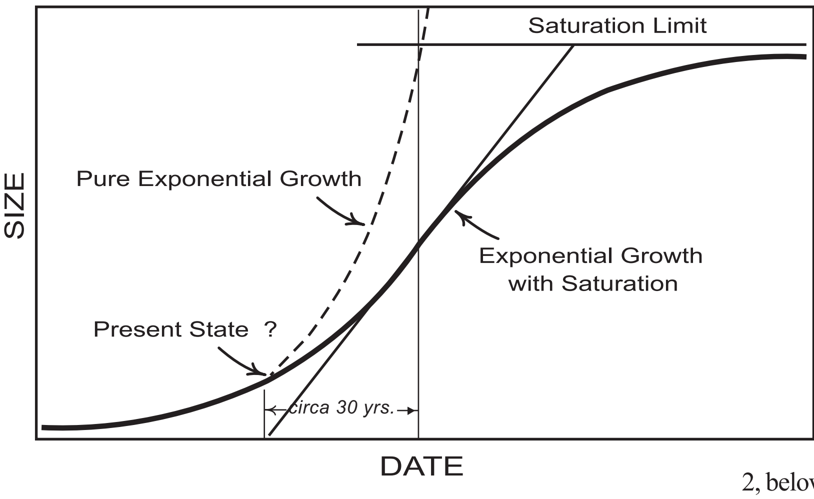
(4) Radio astronomers want to continue to be identified as *Canadian* radio astronomers.

The decision-making process will take some time. The Scientific Organizing Committee of the Penticton workshop identified two decimetric/centimetric and two millimetric/submillimetric projects for further scrutiny. Peter Dewdney of the DRAO will coordinate project planning for the NRC's Herzberg Institute of Astrophysics. As we will see, this is not going to be an easy task.

3. RADIO ASTRONOMY AS BIG SCIENCE

As an overarching idea let us first note that radio astronomy is Big Science. Big Science, first analyzed in the 1 960s by Alvin Weinberg (1961), Derek deSolla Price (1961, 1963) and others, is a form of science characterized by large teams, complex sets of interrelated objectives, centralized management and capital-intensiveequipment needs. Above all, Big Science costs Big Bucks. Although some features of Big Science had already emerged earlier in this century, World War II saw its first full-blown realization. The Manhattan Project was the quintessential Big Science programme, costing some $2 billion, large even by today’s standards, but colossal in the 1940s. No single national scientific undertaking had ever brought together so much brainpower and resulted in so much infrastructure.

On a smaller scale, the contemporary Montreal and Chalk River nuclear laboratories were the harbingers of Big Science in Canada. A feature of Big Science is that once you get started, it is difficult to stop. Thus, in the United States, Britain, the Soviet Union and Canada, the nuclear programmes continued to grow in size, cost and complexity, and exist to this day. The Americans offer us the best examples of Big Science, with the various programmes in high energy physics, aviation, energy, weapons and medical research and, currently, the Human Genome Initiative. The greatest of all was undoubtedly space research and development. Large organizations have a life of their own and a strong resistance to being terminated. One lesson that the history of Big Science during the past two decades teaches is that such programmes are vulnerable. The controversy over the role of science in the



Vietnam War was surely the political turning point for more than one programme. Later, the raucous debate over the Strategic Defence Initiative ("Star Wars") reflected public unease over seriously escalating costs, especially when the government had not decisively proved the need for such an extensive programme. The recent cancellations of the American Superconducting Super Collider and the Canadian KAON Factory, although they were not military enterprises, are signs of a continuing loss of public support for mega-projects.

One may object that this has little to do with Canadian astronomy. But Canadian astronomy is Big Science and has been for a long time. Given the cost of observatories, Canadian astronomy was an embryonic Big Science before 1920. By 1935, few countries in the world had optical facilities as good as Canada; by the mid-i 960s, only eight countries had radio facilities as good as Canada. In that sense, astronomy is a competitor for Big Science funds and must scramble for its share alongside other costly programmes in physics, environmental science, biology and medicine. Big Science represents international cooperation, but also competition. This means that although Canadian radio astronomy cannot match American facilities, budgets or staffs, it has to "keep up with the Joneses" if it wants to remain a player.

4. HEALTH AND DISEASE IN BIG SCIENCE

From World War II to the present, most research areas in Big Science have grown and prospered. However, Price argues that science has been expanding at an exponential rate since the late 17th century and that natural limits to such explosive growth must exist. A biological analogy to this growth would be the S-shaped logistic curve for expanding populations. Initial growth is very rapid—essentially exponential—but slows in time and approaches a "saturaiion" level. At this point, the curve flattens (Graph 1, above).

Exponential growth in anything cannot be sustained, and although science still exhibited exponential growth when Price wrote in the early 1960s, he predicted that the growth curve would have to deflect in the coming decades. As we approach saturation, the very nature of science must change: the limits of people and resources entail having to make hard choices about what and whom to support. This is the ultimate "disease" of science, though it is not so much a disease as it is the normal outcome of growth.

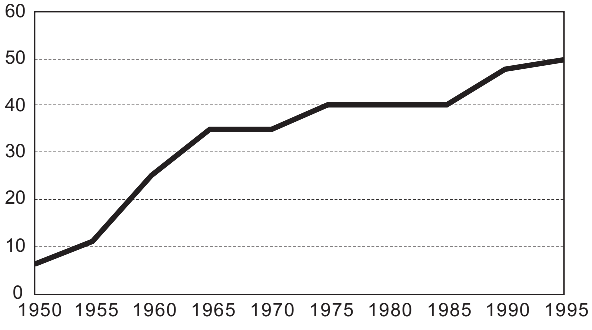
Price's original analysis seems to work for science-in-general and for disciplines like physics. It also seems to apply to national science, at least for some countries. No one has analyzed Canadian science in this way but a variety of indicators suggest that during the 20th century, and especially since World War II, Canadian science expanded exponentially, but has now slowed. Can we apply this analysis to specific fields of research?

Let us examine the growth of Canadian radio astronomy. If we chart the growth of the field (Graph 2, below) by plotting numbers of astronomers against time (at five-year intervals), we do obtain an S-shaped curve.2 The curve has two inflection points (though they are not sharp), located in the late 1950s and possibly in the late 1960s.

We might term the left-hand part of the curve the "String and Sealing Wax Era," a period of small-scale programmes (such as Covington's solar work, radar astronomy, scintillation studies, etc.). The second part—during the rapid rise phase—is the "Institution Building Era" when the Dominion Radio Astrophysical Observatory and Algonquin Radio Observatory came into existence. We would note accelerating budgets, staff and, simultaneously, the growth of a university-based clientele. The right-hand end is the "Era of Maturity," with no significant changes in either budget or population of researchers. One notable characteristic of the third period is the increase in publication rate. With slight fluctuations, Canadian radio astronomy appears to have maintained a steady state over the past decade or so.

What does steady-state imply? It could mean stable levels of expenditure, of publications, or average annual number of discoveries or technological advances, or at least no net change in the number of practitioners. With small fluctuations, such a steady state might last for years or even decades. For radio astronomy, on an international scale, we do not even know whether we have reached the saturation point. World-wide, the field might continue

RADIO ASTRONOMERS IN CANADA



Does not include students

its growth for some time. Big Science requires more, better and bigger instruments. In radio astronomy, many groups propose large-scale, sophisticated and costly projects. Like any Big Science, it has an Achilles Heel: it costs a *lot* of money, and that money is not generated by the scientific community but provided by the state or by large institutions and corporations. If we are approaching saturation in scientific growth, either internationally (likely) or in Canada (almost certainly), then a Big Science field will continue growing only at the expense of other scientific fields or non-scientific endeavours.

A micro-analysis of a field in steady state may turn up some disquieting features. Publication levels might remain constant, but with fewer interesting results. The number of graduate students attracted may begin to decline slowly but steadily. Administrative and maintenance costs, rather than new instrumentation, might increasingly absorb static expenditures. The growth curve may turn downwards and slowly subside, or the field might dramatically collapse. Alternatively, unforseen theoretical or technological break-throughs could lead to renewed exponential growth, but perhaps only for a brief period.

It may be more useful to analyze the nature and growth of a scientific field as a system: all parts of the system are connected with one another, but some subsystems may grow, while others decay. Thus, on an international scale, a field or discipline may be growing healthily, but a national field—which is but one subsystem—may be in serious trouble. A biological analogy could be useful on the local level to describe the relative health ofa field. On the international scale (as Price analyzed it), the curve masks local differences. However, we need not take the biological analogy too seriously; its value is more likely heuristic than explanatory. From an international perspective, radio astronomy's prospects are very bright, with such projects as the Green Bank Telescope, RadioAstron, VSOP, ODIN and several millimetric array proposals. The local Canadian prospects may be very different.

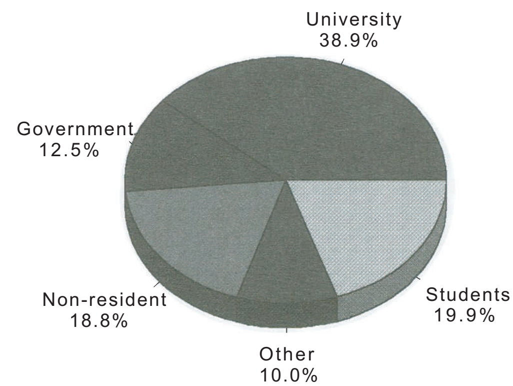
5. SOME CHARACTERISTICS OF CANADIAN RADIO ASTRONOMY IN HISTORICAL CONTEXT

The simple graphical depiction of the growth of Canadian radio astronomy differs little from graphs we could draw for other countries. They only portray the general pattern; they do not inform us about subtler national social and institutional differences. I will note seven historical constraints upon the growth of Canadian radio astronomy. This is not an exhaustive list, but will serve to show some limitations placed upon any planning exercise. Although they seem obvious, one rarely sees them mentioned explicitly.

A. Compared with the United States, Radio Astronomers Form a Larger Contingent in the Canadian Astronomical Community

It would be difficult to obtain a precise figure for American astronomy. We can approximate it, very crudely, by noting the percentage of astronomers reading papers or exhibiting posters at the meetings of the American Astronomical Society (AAS). At the summer 1994 meeting, for example, 50 papers and posters focussed upon radio astronomy. This accounted for 8% of the 632 presentations. Keeping in mind that the summer meetings attract fewer papers than the winter meetings, and that not all astronomers belong to the AAS, and not all read papers at every meeting, not all are Americans and that many contemporary astronomers work in several wavelength regions, we might assume that radio astronomers account for 10% of the astronomical community. It may be larger.

CASCA MEMBERSHIP 1994

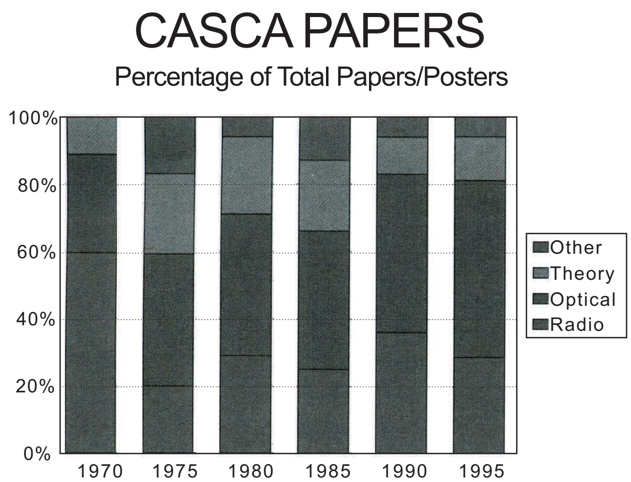


Graph 3, (above), shows the professional membership of the Canadian Astronomical Society (CASCA) in 1994. I have reorganized the classification of members into university astronomers, government astronomers, nonresidents, students and “others,” who include honourary, corporate or retired members, along with those not directly involved in research. Subtracting nonresidents, students and others, the membership amounts to 222 active research people in astronomy and related subjects. There is no master list of Canadian radio astronomers. From data given by Morton (1992), from the CASCA directory and other sources, I can identify about fifty people directly involved in radio astronomy. They would then make up 23% of the active astronomers. Based upon the number of papers presented at the annual meetings of CASCA, radio astronomers have maintained a consistent presence over two and one-half decades (Graph 4, top of next page). In this graph, I have divided the papers roughly into four categories: optical astronomy, radio astronomy, theoretical papers and other (which includes history and education). Radio astronomers typically provide about one quarter of the presentations at meetings.

The population of Canadian astronomers continues to grow, but so does the general population, suggesting that, as a discipline, astronomy has likely reached its limits. Any further growth of radio astronomy would be at the expense of other specialties.

B. The Number of Radio Astronomers Employed by Government is Probably Greater Than in Many Countries

Of radio astronomers I can identify, 54% are government employees. If we generalize to all active researchers in CASCA, we find that nearly one-quarter work for the government. This is likely also the case in Australia. It is unlikely to be true of the United States, nor probably of Britain. France is a middling case, though the importance of the national scientific organization, the CNRS, derives from different historical circumstances than Canada's concentration of government scientists.



C. Almost all Government Radio Astronomers are Employees of a Single Agency, the National Research Council

While the concentration of government science made economic and administrative sense in 1970, when the Observatories Branch of Energy, Mines and Resources amalgamated with the NRC astronomy groups, it now means that any threat to the nature and funding of the NRC threatens the existence of a significant proportion of Canadian astronomy. The shift towards technological, corporate-oriented research since 1980, lately accelerated, makes any "pure science" field like astronomy, with relatively limited industrial payoff, extremely vulnerable. Australian radio astronomers, many of them employees of the CSIRO, are in a similar position.

D. Radio Astronomy has not Taken Root in Many Canadian Universities

There are many historical reasons why astronomy developed in so few universities in Canada. In the Atlantic provinces, only St Mary's has a department of astronomy. Memorial developed as a university quite late. The many small universities in the Maritimes could never concentrate sufficient scientific talent to become major players and the provinces, none with populations of even one million, with far from robust economies, could not and cannot support a scientific field easily categorized as a luxury. Research-based departments in francophone universities in Québec date only from the 1920s and McGill, the leading scientific school in Canada at the turn of this century, never pursued astronomy systematically.

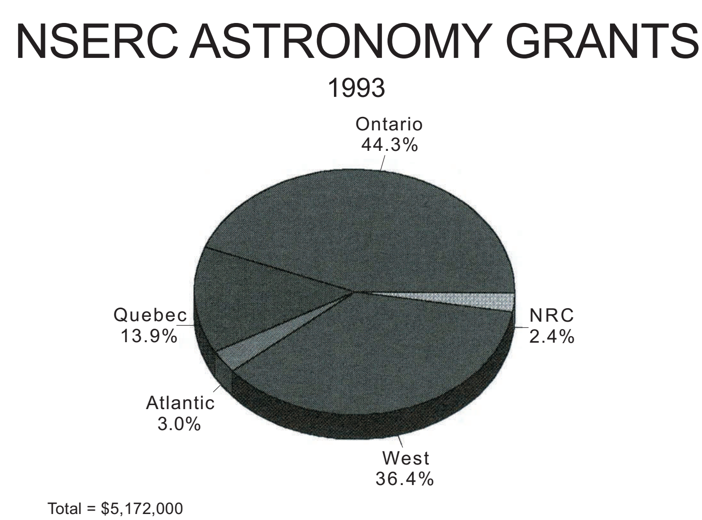
Before the 1960s, only two universities in Canada, Toronto and UBC, had active astronomy departments or subdepartments. Toronto was, in the early 20th century, the largest university in the British Empire and the farseeing vision of C.A. Chant and his successors ensured that Toronto would eventually possess a comprehensive department on a par with the major American universities. At UBC, the strength of the physics department was central to the emergence of astronomy. Astronomy in the Prairie universities has had a more chequered history, but the focus upon pure and applied science from the beginning laid the groundwork for the eventual emergence of vigorous astronomy programmes.

NSERC INDIVIDUAL & INFRASTRUCTURE GRANTS 1993

Institution	Researchers	Amount
Toronto	23	$939,200
Montréal	10	$558,800
British Columbia	12	$554,000
Western Ontario	14	$407,000
Calgary	12	$400,500
York	13	$372,000
Alberta	9	$338,500
Saskatchewan	5	$291,000
Victoria	8	$219,000
Waterloo	8	$194,000
Queen's	7	$185,000
McMaster	5	$174,200
Laval	5	$144,000
NRC (HJA)	--	$125,000
St Mary's	3	$ 64,600
Memorial	2	$ 47,000
Brandon	3	$ 27,200
Manitoba	1	$ 24,000
Lethbridge	1	$ 17,000
Bishop's	1	$ 16,000
New Brunswick	1	$ 15,000
Mount Allison	1	$ 15,000
Dalhousie	1	$ 15,000
Trent	1	$ 14,000
Regina	1	$ 9,000
Windsor	1	$ 6,000

The table, which shows the NSERC grants for astronomy and space science for the 1993 competition, echoes this historical development. Graph 5 (below), the division of "spoils" among the regions of Canada, showing that historical trends persist. The total disbursed to (mostly) university-based astronomers in that year was $5.2 million, which might seem a great deal to expend upon curiosity-oriented science. However, to keep that figure in perspective, the federal deficit increased by that amount during the conference banquet at Penticton. The radio astronomy projects received close to $620,000 that year, or about 12% of the total, an equitable share as radio astronomers accounted for 14% of the recipients.

Those in university departments understand the nature of the internal politics of new appointments: the balance of fields within a department over long periods is never assured. The distribution of university-based radio astronomers bears this out. When radio

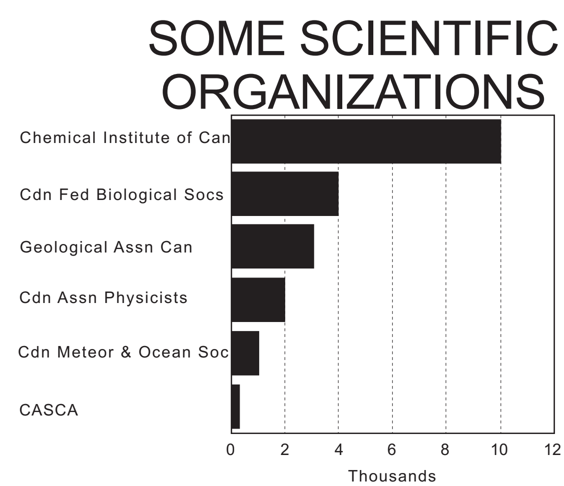


astronomy was a new field, it became established in certain departments (particularly at Toronto, UBC and Queen's), but its addition to other faculties has been more sporadic in the following decades. Drawing from the CASCA and NSERC lists, we find radio astronomers distributed among only nine universities, with no more than four in any one department. Two or three people are more typical. What this can mean, as retirements from the field occur, is that radio astronomy might cease to be an important part of the staff and curriculum.

E. The Organization and Funding of Research were not in University Hands

Because Canadian science developed differently from American science, in structure as much as in scale, we can see the results in terms of who organizes scientific projects and the relationship of that organization to funding. Two extraordinarily successful Amen-can examples are the National Optical Astronomy Observatories (Kitt Peak and other facilities) and the National Radio Astronomy Observatory. University consortia, *not* government departments, conceived, built, staffed and controlled both. Both developments had their roots in the early 1950s before large science budgets for astronomy became commonplace. Although the US federal government, through the National Science Foundation, provides the budgets for these institutions, the consortia set the scientific and infrastructural priorities. Such a system gives university scientists more leverage for lobbying. The different development of Canadian universities and, perhaps, the nature of the NRC as both institution and funding agency, were barriers for the creation of consortia. The grouping of western universities to operate the TRIUMF accelerator laboratory is one rare Canadian example.

Although two of the earliest players in American radio astronomy were government agencies and foundations (the Naval Research Laboratory and the Carnegie Institution of Washington), vigorous university-based programmes at Cornell, Ohio State, Stanford, Illinois, Harvard and Caltech soon eclipsed them. One substantial difference between American and Canadian universities is that many American schools have large endowments. This is not just true of private universities like Harvard, MIT, Chicago, Caltech, Princeton or Johns Hopkins, but also of research-oriented state universities like Michigan and Texas. Canada has nothing comparable.



Source: World Guide to Scientific Assns, 5/3, 1990

F. Canadian Astronomers Form a Very Small Community

It is still quite possible for any gregarious Canadian astronomer to meet every one of his or her colleagues in the country at some time or another. One need only contrast a CASCA annual meeting with the ten-ring circuses of the AAS. The community has grown steadily, but despite the obvious appeal of the oldest science, astronomy is minuscule even within this country. In radio astronomy, if we do not count graduate students who moved elsewhere or into other fields, the total number of active participants between 1946 and the present does not exceed 75. By way of contrast, Graph 6 (bottom left), shows a few examples of national scientific organizations in terms of membership, assuming membership is a rough indicator of size of the active research community.

Interestingly, the size of the American astronomical community, as a percentage of national population, is likely about the same. The problem in Canada is one of concentration of talent and its vulnerability. This is equally true in countries like Australia, where the astronomical community is smaller.

G. Canadian Scientists Do Not Blow Their Own Horns

In the 19th century, the outstanding Canadian engineer, T.C. Keefer, exhorted his fellow engineers to be "honest and modest." Suitably translated into Latin, this would make a perfect motto for the Canadian scientific community. The question of honesty aside, no one would claim that American scientists have been modest. Once the United States established itself as the world's scientific powerhouse after World War II, it attracted talent from all over the world, including Canada. One result has been a remarkably self-centred vision of science by Americans that works to their advantage when dealing with their public. In reading American popular and semi-popular scientific literature, one is scarcely aware that any science exists beyond American borders. In a review of radio astronomy in *Sky and Telescope*, Kellermann managed not to mention Canada once (Kellermann 1991). A special issue of *Cahiers de science et vie* devoted to radio astronomy featured an historical article on the growth of the field internationally since Karl Jansky; the other two authors (both Americans) had mentioned no Canadian scientists or institutions. As a joint author, I insisted upon noting at least Art Covington (pictured on page 17) , the DRAO, ARO and the very-long baseline interferometry experiment (Smith, Tucker, Jarrell 1992).

It is true that some Canadian scientists and journalists have worked hard to bring the results of Canadian science to the wider public, but no one can argue that our efforts come even close to the Americans. We discuss scientific arcana on CBC radio while Carl Sagan appears on talk shows.

5. SHOPPING IN THE BAZAAR

With these historical constraints in mind, let us turn to the more self-consciously political question of finding directions for a national field. First, there is the choice of facilities and instrumentation. The final day of the Penticton conference provided a remarkable contrast to the cool scientific discussions preceding it: one after another, representatives of (mostly foreign) institutions outlined plans and touted for partners. It was, as one participant, noted, like an Oriental bazaar. Several Americans, always the consummate salespeople, pitched openly. Others were more coy. A Japanese representative, with very ambitious plans, admitted that Japan did not want a small partner. Like a real bazaar, there was something for everyone: projects for centimetric work, some for millimetric/submillimetric work, space-based projects, single instruments and arrays, current technologies and untried technologies, for large purses and small.

The issues the Canadian community must face are far more subtle than those faced by the buyer in the bazaar. Buyers choose based on what they like and what they can afford. In this instance, there are other questions to answer. The single most important issue is whether to purchase anything at all, or whether to go home and fashion something for yourself. This is the nationalist dilemma. Within certain limits of technical expertise, Canadian facilities, both university and government, were Canadian designed and organized. The break with this tradition came with the agreement to participate in the JCMT.

Lloyd Higgs (1994) and others have raised questions to address, on both scientific and non-scientific grounds. These include:

• *Does it matter whether a facility is in another country?* We already know the answer: No. Canadian optical astronomers moved offshore in 1979 with the opening of the Canada-France-Hawaii Telescope, although it must be remembered that this move was in response to an unique opportunity. The original major project of that generation was the Queen Elizabeth II Telescope, to be sited in British Columbia. There would be little argument now that the quality of a site, all other factors being equal, is more important than its political location. Location of the Gemini telescopes is also a matter of site quality and existing infrastructure.

• *Does it matter if Canadians have a controlling interest in the facility?* This is a fundamental question facing radio astronomers. Because Canadians have controlled their own facilities since the late 1940s, it would be a difficult choice to abandon that tradition. The JCMT arrangement was a significant step. The ARO was closed so that funding could support a part-share in JCMT, a junior share, of an essentially completed project, at a foreign site. Subsidiary issues are whether Canadians would have an important role in instrument design and whether Canadian industry would participate in developing the facility and instrumentation. Obviously, a smaller financial stake means diminished administrative, design and industrial participation.

• *Is having a minor role in a major facility better than no facility at all?* Several Canadian radio astronomers have argued that the Penticton facility is aging. Should it be closed, and funds shunted to offshore facilities, one may be left with no Canadian-controlled or Canadian-sited facility.

If the Canadian radio astronomy community were homogeneous, then one could choose a facility based on the depth of national pockets. However, the community is not homogeneous. It comprises two important groups defined largely by wavelength regime: those who work at centimetric wavelengths (the older Canadian tradition) and those who work at millimetric/submillimetric wavelengths (the more recent tradition). The DRAO astronomers represent the former, the JCMT group the latter, with university astronomers divided. Earlier discussions of possible directions for radio astronomy focussed upon new, Canada-based instrumentation for centimetnic work, the Radio Schmidt project (Dewdney & Landecker 1991) and on possible international participation in millimetric/submillimetric projects (Fich 1992). Complicating the picture further are what may be a generational divide and the assumption voiced by some conferees that millimetric research is the "wave of the future."

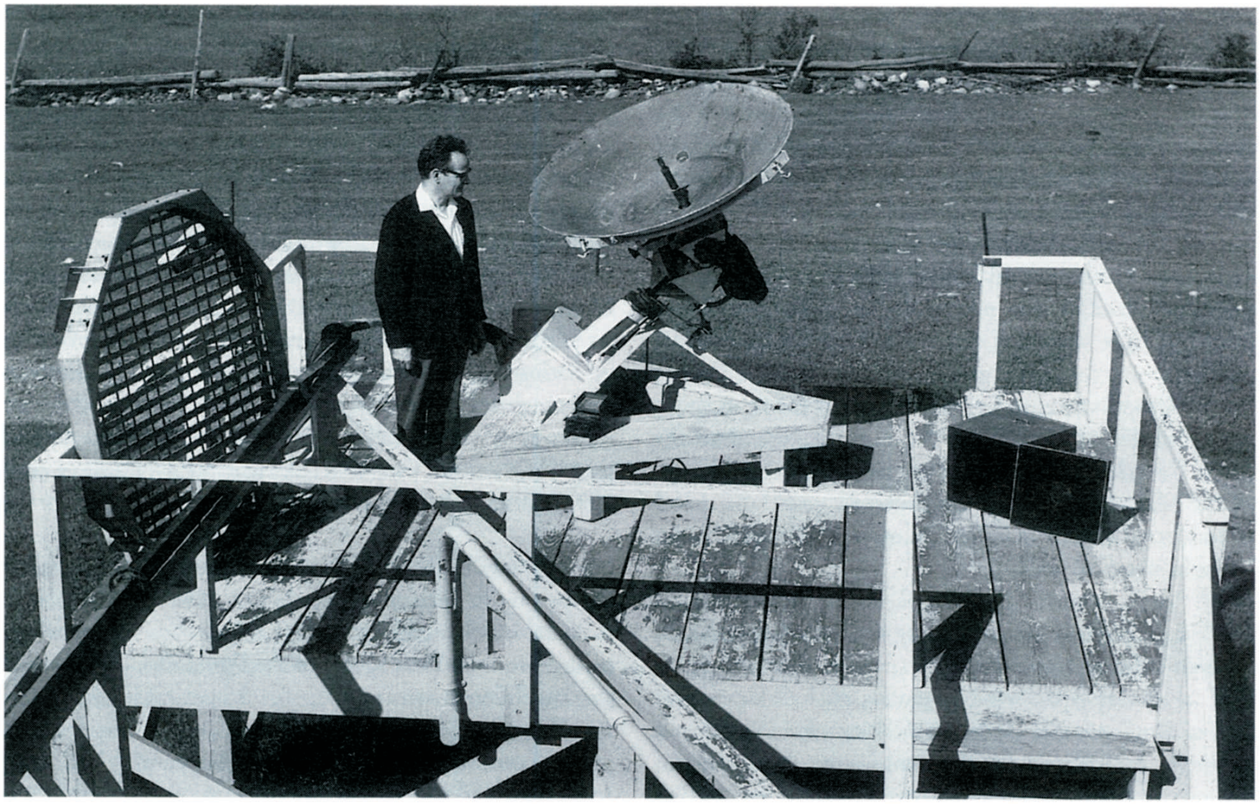
6. TWO ALTERNATE ROUTES FOR SMALL COUNTRIES: AUSTRALIA AND MEXICO

Australia and Mexico offer two quite different examples of how small nations deal with these dilemmas. Australia, smaller than Canada, has been a significant player in the field from the beginning. With feet in both the CSIRO and in universities, radio astronomy rapidly assumed the commanding position in Australian astronomy. The major radio facilities have all been Australian controlled—although not always completely Australian-funded—while the most important optical facility, the Anglo-Australian Telescope, is a joint venture.

The CSIRO is undergoing a similar shift in focus experienced by the NRC, reducing its commitment to pure science and pressing its claims as an applied science institution. At this point, radio astronomy is the sole surviving field of pure science within the organization. Australia, like Canada, has decided that a state body will represent astronomy not just in terms of budgetary assistance, but in infrastructure. Because of the parallels, Canadians may find the Australian response to their problems instructive.

Despite a population of 85 million, Mexico is still a small country in terms of its science budget. The annual Mexican astronomy budget is in the neighbourhood of $US 7 million, divided between two state-supported institutions, the Institute of Astronomy at the Universidad Nacional Autonoma de Mexico and the INAOE near Puebla. In addition, CONACYT, the Mexican equivalent of NSERC, provides funds for special projects. For radio astronomy, two recent programmes are special instrumentation for the VLA ($ 1 million) and the Mexican contribution to a millimetnic telescope jointly proposed with the Five Colleges Radio Astronomy Observatory ($10 million).

For Mexican radio astronomers, a "national field" does not exist. There are only nine radio astronomers in Mexico, four at UNAM, five at INAOE. Only four are Mexican nationals and none hold a Mexican Ph.D. (Rodriguez 1995). Thus, participation—as a minor partner—in foreign projects is the only way to use first-class equipment regularly. This is unlikely to create a quandary for them. Their group is too recent in origins to have known any alternative and too small to dream of anything more significant. The Mexican optical astronomy community, on the other hand, faces issues familiar to the Canadian community. Numbering some seventy members, and con-



Dr. Arthur Covington with the 4-foot radio telescope at Goth Hill, Ontario, in the early 1960s. Covington was Canada's first radio astronomer An asteroid was named for him in 1994.

suming about 95% of the annual astronomy budget, the optical astronomers are lobbying for a major national optical facility entirely under Mexican control. Fiscal realities may doom such a project, at least in the short term. Thus, the experience of Mexican optical, rather than radio astronomers may be more useful to Canadian observers.

7. PLANNING AND THE POLITICS OF BIG SCIENCE IN CANADA

Let me summarize the state of Canadian radio astronomy. The field is healthy, with much exciting research activity, a modest but productive national observing facility, access to fine international facilities, several graduate programmes, a small but steady stream of new students, sufficient funding and an institutional home within the National Research Council. The community is stable in size and mutually-supportive. It deals effectively with the non-radio portion of the Canadian astronomical community. International prospects for radio astronomy, for the immediate future, seem very bright.

The ultimate disease of Big Science—the lack of money—is a very serious threat to the health of Canadian radio astronomy. Let us take an optimistic view first. If funding levels promised for radio astronomy —$20 million over a decade is one estimate—remain in place, the Canadian community still faces a serious political challenge. Would $ 20 million buy one productive facility, assuming there was consensus on instrumentation? It might, if technological innovation and foreign partners are available. Reduced circumstances can concentrate the mind. It will be instructive to watch the American high energy physics community's response to the loss of the Superconducting Super Collider. The chief complicating factor, a community split into two main subfields requiring quite different sites and instrumentation, means either that some people remain suitcase astronomers, or that Canadian-controlled and sited facilities might cease to exist and everyone will become research commuters. Continued funding would at least maintain a steady state for Canadian radio astronomy for some time to come. The fundamental change — which we cannot chart — would be psychological and it is difficult to guess its long-range consequences. Does having national facilities sustain a national community? Or would maintaining the administrative infrastructure without instruments do the same?

To take the worst-case scenario, suppose that the current federal and provincial deficits and debt lead to political decisions in favour of serious programme cuts. On the provincial level, post-secondary education could be savaged. Many provinces, Ontario in particular, have squeezed universities for years. In Alberta, recent cuts have caused serious dislocations. Announced cuts in federal transfer payments to provinces for post-secondary education could mean further distress. Such changes jeopardize both undergraduate and graduate programmes. Equipment, books, journals, laboratory fittings and maintenance budgets suffer or even disappear. Departments do not replace retiring faculty members and internal struggles for dwindling resources can place scientific programmes in peril.

Severe budgetary restraint by the federal government would have a devastating effect on Big Science. Among industrial nations, Canada has never been a generous supporter of science and technology. Budget cuts to NSERC, already a reality, would diminish operating grants to university researchers and facilities, while making doctoral and postdoctoral fellowships even more competitive. What kind of effect would, say, a 25% cut in the National Research Council budget have upon government astronomy? Worse, suppose that the NRC is "privatized" to pursue industrial R & D? If the public believed that severe programme cuts were necessary, would they more likely support health or Big Science?

Should the most dire predictions come true, then the otherwise healthy radio astronomy community would contract a fatal disease. With no long-term funding for new facilities, with a seriously eroded university base, perhaps even the loss of its federal infrastructural support, the field would quickly dwindle. Some astronomers would leave the country, others would move to other fields. Students would go elsewhere. We can imagine that the growth curve of Canadian radio astronomy would quickly plunge. Although a few Canadians would continue to enter the field, assuming its continued health in other countries, "Canadian radio astronomy" would cease to exist.

Compounding the problem is the continuing weak Canadian dollar, which makes even suitcase astronomy an expensive proposition, to say nothing of importing equipment or paying partnership fees in offshore facilities. Such are the potential problems of Big Science in a small country. A challenge for the community is to plan for contingencies; one can construct various scenarios that assume less damage to the field, but over the next decade, Canadian political and financial prospects do not auger well for the expansion of science. Are there ways to reduce damage to the field?

Given the historical parameters outlined above, let me now turn to three observations that an outsider might make concerning Big Science planning in the Canadian context.

(1) Timing is Everything. The Australians have been extraordinarily successful in radio astronomy from the beginning. This occurred though a happy mixture of leadership, dedicated teams, isolation, timely foundation grants and the lack of competition from other Big Science fields such as atomic energy. By the late 1970s, the lack of a major new facility was beginning to depress the field. Planning for the Australia Telescope project coincided with the increasing excitement about Australia's bicentennial celebrations. By linking the two, the radio astronomers could offer their mega-project as a visible symbol of Australian scientific prowess (Robertson 1992). Suppose that the Canadian VLBI experiment had achieved success in the early 1960s rather than in 1967; a large-scale project, such as a cross-Canada VLBI array, might have become an important national Centennial undertaking. One moral is to keep a close eye on the calendar and to use it to your advantage; this is not cynicism, it is self-preservation.

(2) Consensus is Essential. Higgs makes this point forcefully: "If, for some reason, consensus cannot be moulded within our radio-astronomy community, or wide support within the whole Canadian astronomical community cannot be generated, or for some other reason we 'fumble' this opportunity, it may signal the eventual demise of radio astronomy as a vital sector of Canadian research." (Higgs 1994). There are many historical instances of scientific programmes failing because of lack of consensus. Because Big Science programmes are long-term, consensus must be built early and maintamed over long periods. Smith (1989) argues that the Hubble Space Telescope project, resulting in the most expensive scientific instrument ever built, succeeded largely because of consensus-building and coordinated lobbying. To give a Canadian example, the cancellation of the Queen Elizabeth II telescope in 1967 shows what can happen without it. The timing factor worked well: adroit lobbying by astronomers and ministry officials provided the Pearson government with an excellent means to commemorate the Queen's visit to Canada in 1964. The astronomical community did not reach consensus, because of the proposed site, its scale and its focus. This lack of consensus and escalating cost estimates provided the Trudeau government with the perfect excuse to cancel the project. On the other hand, when consensus is built and allies mobilized, as it was in the decisions to fund the CFHT and the Varennes Tokamak in 1981 (Gingras and Trépanier 1993), large-scale projects can happen.

(3) Publicity is Crucial. Canada is not a country given to philanthropy, or at least not for science. The munificent gifts of Sir William MacDonald to McGill for physics, engineering and agriculture, and the Dunlap gift of the David Dunlap Observatory stand out largely because of the flat landscape. And those gifts were long ago. Canada, like Australia, has tended to leave the funding of science and education in government hands. The genius of the Australian radio astronomers was to snare sizable grants from foreign foundations, something Canadians seem loath to do. There may be no Keck Foundation in Canada, but there are foundations and many wealthy people.

If we expect the state to be the primary—even only—source of both capital and operating expenses for a Big Science project, it is essential to persuade the civil servants and politicians who control funding that the project is worth undertaking. This is particularly true for intramural expenditures, such as the NRC. For NSERC funds, the peer evaluation structure requires that colleagues in other disciplines recognize the importance of your project. Funds that go to one group do not go to others in the short term.

A study of the failures of STARLAB and the Canadian Long Baseline Array would be instructive in this light. With politicians and civil servants, almost none of whom understand or perhaps even appreciate curiosity-oriented research, the selling job is formidable. To what extent was their interest piqued and their favour curried by the scientific community? To give a recent example, in 1992, the McMaster workshop explored the possibilities open to Canadian astronomers in millimetric and sub-millimetric research. The participants made a strong scientific case for Canadian participation, but the participants preached to the converted. What about the unconverted?

In dealing with those who hold the purse strings, how would one argue? Obviously, an appeal to something beyond purely scientific issues must be made. No politician is likely to care one whit about supernova remnants. The plight of the "suitcase astronomer" will gain no sympathy from the politician wanting to cut expenditures. National pride may be the last defence. For colleagues in other scientific disciplines, a quid pro quo argument might have more impact. In a sense, this has already developed in the astronomical community in terms of setting priorities for major facilities; it is also a quintessentially Canadian solution.

8. CONCLUSION

Canadian radio astronomy exhibits the growth pattern of other fields in Big Science, but its historical and local peculiarities make it different from other national fields here and abroad. For fifty years, those peculiarities worked in its favour. History can be a straitjacket. The recent debates in Canadian university circles concerning funding cutbacks offer an example of how straitjacketed thinking creates division. Some vocal members of the university community, particularly in Ontario, seem to believe that large, no-strings-attached operating grants from government are a right. Others argue to improve universities' financial health by forging more links with industry, but opposition to such proposals is strong.

The recent International Space University debacle at York University serves to remind us that the American model of university-government-corporate cooperation is not easily transferable. University departments of biology, chemistry, computer science or physics can forge such links with ease if the political will is present and if corporate partners are available. Astronomers have fewer opportunities, but they do exist. Canadian astronomers in both universities and government have long shown a flair for instrument design, and Canadian companies have been innovative and successful partners.

If astronomers, like many university professors, insist that state funding is the only option, then they must provide a convincing rationale. Perhaps the cultural, rather than economic, benefits of astronomy are easier to argue (Jarrell 1990). The shift in priorities at the National Research Council has created dismay in many quarters. Change is in the air—for good or ill we cannot yet foresee—and flexibility in thinking about funding is an essential element in planning for Canadian science in the twenty-first century. The historical forces that served us so well the past fifty years may no longer exist. We face challenges, to be sure, but we must create a window of opportunity—even if it does not exist—and then jump through it.

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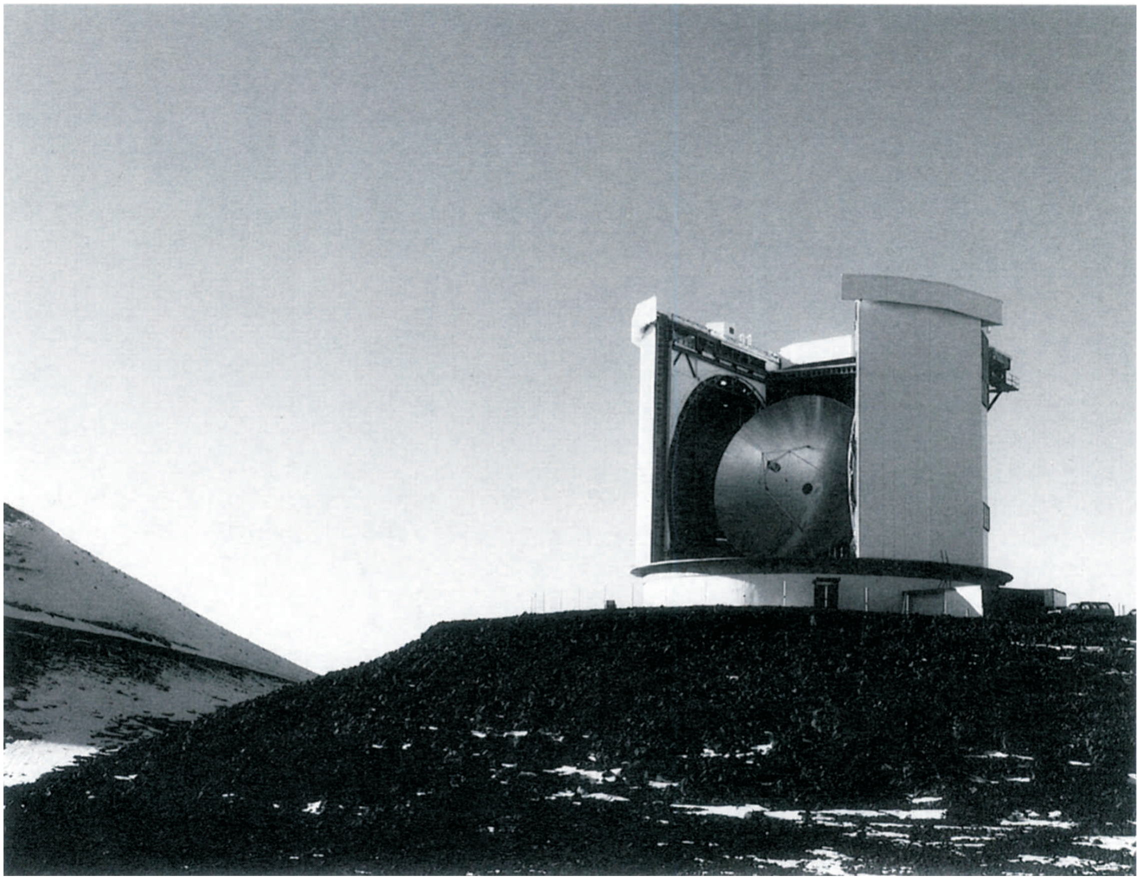
NOTES

1 . This article is an expanded version of the banquet speech given at the Penticton conference on Radio Astronomy: Visions for the 21st Century in 1994. I would like to thank Lloyd Higgs for his comments.

2. We have no complete census of Canadian radio astronomers. This reconstruction is reasonably accurate for the early and late periods, but has some uncertainty for the 1970s and 1980s. The right-end of the curve may be flatter than it appears here.

Feature Story **RADIO ASTRONOMY**

Dr. E. R. Sequist
University of Toronto



The James Clerk Maxwell Telescope in Hawaii has an aperture of 15 metres. Canada's share is 22.5% of the total time allocated to four countries.

RADIO ASTRONOMY IN CANADA: CHALLENGES FOR THE 21ST CENTURY

Radio astronomy is now approximately sixty years of age, and continues to contribute fundamental discoveries about the nature of the universe. The electromagnetic bandwidth accessible to ground-based radio astronomy ranges from about 10 metres at the long wavelength end down to 0.35 millimetres at the short end. The corresponding frequency range is 30 MHz to nearly 1000 GHz. Whereas optical telescopes observe primarily starlight, radio telescopes observe primarily interstellar and circumstellar gas and dust. Therefore the two types of astronomy are somewhat complementary. The two bands also share an association with the infrared which bridges the gap between the two spectral ranges.

The demands of the field at the frontier of observational astronomy require ever more sensitivity to the weakest radio signals, and this places radio astronomy squarely in the so called “big science” regime in terms of telescope aperture and cost. As we move into the 21st century, we will see the development of powerful new telescopes operating in the relatively unexplored window of millimetre and sub-millimetre wavelengths, and the effective collecting aperture of centimetre wave radio telescopes increase by one to two orders of magnitude. The opportunities are exciting, but they are also costly. As current facilities used by Canadians age and become obsolete, Canada, with a vigorous astronomical community but a relatively small population, will face formidable challenges if it wishes to remain competitive in radio astronomy in the next century. Planning must begin now. The National Research Council (hereafter NRC), in collaboration with the Canadian Astronomical Society, have therefore established a planning exercise whose mandate is to recommend a means for Canada to participate in the exciting future to come. This planning exercise is in its preliminary stages, and is the focus of this article.

From an historical perspective radio astronomy in Canada began with the observations of the sun carried out by A.E. Covington in 1946 (see pg. 17). These observations made Canada an important player in this new and emerging field, and placed Canada in a position to participate in the shaping of the field in the 1950’s and

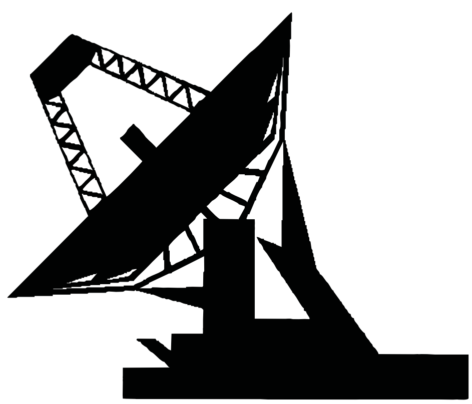
1960's. Perhaps the most significant Canadian contribution was the first successful application of the technique of Very Long Baseline Interferometry in 1967. This technique, used to combine signals from antennas spaced thousands of kilometres apart, is now used routinely to obtain angular resolution of a milliarcsecond or better in the study of compact radio sources such as those found in quasars and active galaxies.

During the 50's and 60's radio astronomy research was conducted using radio telescopes operated by both Canadian universities and by NRC. In the mid 1960's the dynamics of the field made a substantial course change in this country, as it did elsewhere. As the pace of developments accelerated, demand increased for access to radio telescopes of exceptionally large aperture, equipped with the most sensitive receivers possible. This demand could be satisfied only by centralizing the development and operation of radio telescopes into major national facilities open to all astronomers on the basis of the scientific merit of the proposed observations. The universities began to adopt the role of users, whereas the government labs which operated the facilities undertook the responsibilities of continuing development of radio astronomy instrumentation. While this evolution was the inevitable consequence of keen worldwide competition, the downside is that the universities by and large are now in a poor position to train students in radio astronomy instrumentation.

For the past 30 years, NRC has been the body whose mandate it is to provide and operate national facilities for Canadian radio astronomy. Currently, this role is adopted by NRC'S Herzberg Institute of Astrophysics (hereafter HIA) . HIA provides access to two facilities—the Dominion Radio Astrophysical Observatory (DRAO) near Penticton, B.C., and the James Clerk Maxwell Telescope (JCMT) on Mauna Kea on the big island of Hawaii. The telescope at DRAO, shown on pg. 23, is an aperture synthesis telescope, comprising seven 10 metre antennas operating at 21 cm and 75 cm, and specializing in mapping very large fields of view—a kind of "Schmidt Camera" for radio astronomy. Its principal focus is the study of the interstellar medium, notably at 2 1 cm.

The JCMT, shown on page 20, is a submillimetre telescope of 1 5 metres aperture, specializing in continuum and molecular line studies of the interstellar gas and dust. Canada shares this facility with the United Kingdom, Holland, and the University of Hawaii. Canada's share is 22.5% of the total time allocated to the four partners.

As is well known, there will be severe reductions in the federal budget, and these reductions will have an impact on our capacity to do astronomical research. In radio astronomy the impact will lead to a reduction from the two national facilities to one in the long term. The bleak outlook comes at a time when Canadian radio astronomers need to plan for Canadian involvement in a new international project. Can Canadian radio astronomers make realistic plans in this climate, and can we expect Canada to provide the resources to maintain an instrumentation and development program to support involvement in a new major facility? I believe the answer is "yes", but a somewhat new and flexible framework will have to be developed for planning and implementation for radio astronomy initiatives.



First, given that no capital funding for new facilities seems likely until the federal budget is balanced, possibly in the first decade of the 21 st century, the planning process must allow for a "moving window of opportunity". International projects available for investment in the near term may be nearly finished before Canadian funding becomes available. Thus the planning process must be a continuing one, involving reassessments and exploration of new opportunities.

Second, a transition plan will have to be developed to permit an active radio astronomy program to continue which is exciting scientifically and prepares Canadian astronomers technically for involvement in a new project when the opportunity arises. Since no major capital funds will be available in the near term, this activity must build upon what we have now, or on what remains after the impact of the budget cutting is realized.

Third, it is likely that universities will again have to assume a larger role in the engineering technology of radio astronomy, and that partnerships between universities and NRC will have to become more common. These three steps are not simple ones to execute, and they cannot be considered to be independent of the direction eventually taken when an opportunity to invest in a major facility opens up. Moreover, universities are also undergoing severe budget cuts, providing little flexibility to move in new directions.

With this general framework in mind, the planning group struck by the HIA, in consultation with the Canadian Astronomical Society, has begun its work. Essentially, the planning process began in August, 1994 with an international workshop held at the DRAO, entitled "Radio Astronomy: Visions for the 21st Century". The purpose was to hear and discuss likely directions for radio astronomy in the coming decades. Not surprisingly, most of the discussions centred on aperture synthesis array telescopes, since this technique will continue to provide the basis for achieving high angular resolution as well as large collecting aperture. The scientific organizing committee for this workshop identified several projects for potential participation by Canada. Subsequently, the HIA planning committee considered these options, and began preparing advice to the Director of the HIA on the preferred option. Some preliminary conclusions have been reached.

At the time of writing, the options for investment in a new major facility boil down to a mm/sub-mm wavelength array and a giant dcm/cm wavelength array. The table shows the two projects currently being considered which would be open to participation by Canada. Both projects have costs in the $200 Million (U.S.) range, which emphasizes the need for a multiplicity of partners. In the former category, the U.S. Millimetre Array (MMA) is the most well developed, certain to proceed, and is looking for international partners. With a deadline of 1998 for commitments to join, however, it is uncertain whether NRC could commit resources to this project, unless a delay in a commitment were feasible.

The MMA as currently envisaged would comprise 40 antennas, each of eight metres aperture, and would be located on a high dry site such as Northern Chile or Mauna Kea, Hawaii. The angular resolution of the array would be 0.1", better than that achievable with ground-based optical telescopes without adaptive optics. As currently envisaged, it would operate at mm wavelengths, with the potential of extension to sub-millimetre wavelengths. This is an exciting forefront project which would focus on programs such as studies of protostars, detailed molecular cloud chemistry and physics, and conditions prevailing in the earliest galaxies formed in the universe.

Other mm arrays being considered in Europe and Japan are in more rudimentary stages of planning, and represent alternatives further down the path. There are significant chances that these projects too will in some way cooperate with the MMA, if for no other reason than the cost of development of new sites in very remote areas.

In the category of a giant dcm/cm array the most likely candidate is the Square Kilometre Array (SK~A) currently envisaged as a dcm telescope whose equivalent aperture is about one million square meters, or nearly two orders of magnitude larger than the Very Large Array in New Mexico. The shortest operating wavelength would be just shortward of the 21 cm line of neutral hydrogen. The angular resolution of this telescope would also be approximately 0. 1". However, Canadians would prefer an extension to shorter wavelengths—near 1 cm, where the resolution would be near 0.01 " . The scientific programs with such an array would include probing the atomic gas content and dynamics in primordial galaxies, and probing the structure of the interstellar gas and magnetic field of our own galaxy.

Projects which could involve Canadian participation

Name	Wavelength Coverage Currently Planned	Possible Extension of Coverage
Millimeter Array (U.S.)	3-1 mm (100-300 Ghz)	1-0.35 mm (300-1000 Ghz)
Square Kilometer Array (Holland)	150-15 cm (0.2-2 Ghz)	15-1.3 cm (2-23 Ghz)

Conceptual plans by Holland are underway for such an array. There is considerable debate on the design of the antenna elements, and there is plenty of scope for Canada to participate in this debate, particularly since some new ideas on building an inexpensive large antenna have been developed within the HIA. This is truly an exciting project, for which Canada has potential to provide some of the technology, and could even provide the site for the array.

An important factor in the final decision is the role to be played by Canada in project technological development, and this relates to the concerns raised earlier about our capacity for providing this in the wake of declining resources. Currently, Canada is conducting some innovative programs in radio astronomy instrumentation. Development work for the JCMT, notably by HIA and the University of Alberta, is leading us closer to the realization of the world's first planar array feed for sub-mm telescopes, i.e. a coherent imaging detector for spectroscopy. In such a detector the radio telescope would form images similar to that in an optical telescope.

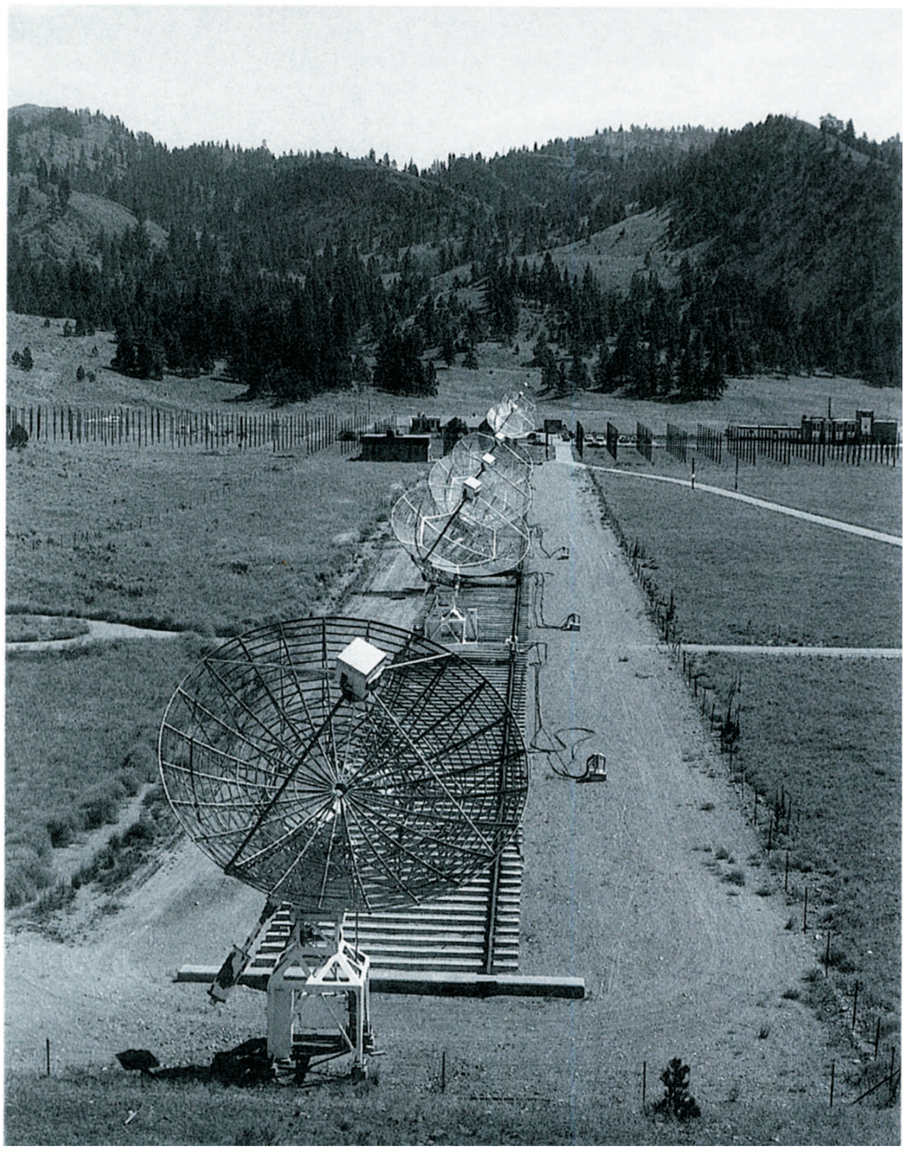
In addition, at the DRAO there is considerable experience in developing and building fast correlators, both for their own telescope as well as for very long baseline interferometry in space. This technology is readily transferable to the construction of either cm or mm wave interferometer arrays. These correlators are necessary to combine and process the signals from the various antennas in the array. However, we must be careful that budget reductions don't leave Canada without the critical mass of personnel necessary to maintain such activities at the leading edge of radio astronomy technology.

What, then, should be the nature of the transition plan to ensure a continuing program of instrumentation development, particularly if no capital funds become available for a new major project in the next decade? There are three principal areas on which to focus. First, the DRAO has just begun a major survey of the galactic plane in the 2 1 cm hydrogen line and 75 cm continuum. At 21 cm, this would be the highest resolution survey ever done (about 1 arcminute), and would require about five years for the initial phase. Since the survey is an exciting project, and since the data will be available to all astronomers, this will be an important and lasting contribution to astronomy.

In addition, the project is likely to introduce new and innovative methods for making high fidelity wide field images, and new methods for visualizing 3-D images, necessary to interpret spectral line data. A high priority must therefore be given to its completion.

A second project would be sub-mm interferometry on Mauna Kea using the JCMT linked with other telescopes on the mountain. The other elements would be the Caltech Submillimetre Observatory's (CSO) 10 meter telescope, and the submillimetre array currently under construction by the Smithsonian

Astrophysical Observatory (SAO). Initially, this array will comprise six antennas, each 6 meters in aperture, with plans to begin operation in late 1997. Some telescope time on the JCMT is already devoted to interferometry with the CSO telescope.



The Dominion Radio Astrophysical Observatory comprises seven 10-metre antennas operating at 21 cm and 75 cm. (Reproduced by permission of the Director).

The scientific importance of this work is evident from the fact that the addition of the JCMT alone to the SAO array would double its collecting aperture. Since we already have a share in the JCMT, our investment need not involve a major capital expenditure. It would provide Canadian astronomers with both exciting opportunities to do science and acquire the technology to contribute later to the development of a larger mm/sub-mm array. Third, work in the development of planar array feeds and high speed correlators would continue to improve our existing telescopes. For example, the availability of planar array feeds and associated signal processors would greatly enhance the mapping capability of the JCMT, and would also maintain us in a state of readiness for a new project.

The transition plan requires ambitious and aggressive planning, and commitment of resources in short supply. Not all initiatives may be possible, but there is no shortage of potential opportunities. As noted earlier, extraordinary efforts may be required to bring the university community back into a more vigorous technical role to support such programs.

Thus the next 10-20 years may prove to be a difficult and trying, and yet possibly very exciting period for Canadian radio astronomy. Success will require a collective will and determination to succeed, a strong focus eventually in one particular area, and a realization that the trials ahead cannot be solved by relying on sufficiently high levels of government funding. It is however likely that Canadian radio astronomers are up to the challenges that face them, and we will see Canada entering the 21 st century with a vigorous new program in radio astronomy.

Dr. E. R. Seaquist is director of the David Dunlap Observatory at the University of Toronto

Paul Boltwood
Ottawa Centre

A SUBURBAN CCD OBSERVATORY

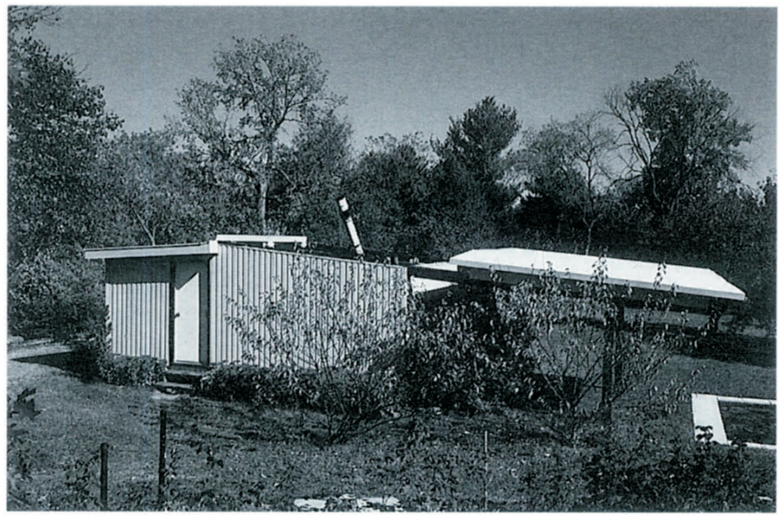
The first in a regular series on Canadian observatories.

This observatory is the culmination of 30 years of dreams and plans. Before designing it I set several goals: (1) it had to be convenient and comfortable - I am a very lazy person when it comes to observing; (2) it had to be capable of some form of measurements useful to science, or at least to amateur science; and (3) it needed to satisfy my emotional desire for precision in instruments, optics and mechanics.

Boltwood observatory is a two room roll-off roof building that was built in 1989. It houses an Astrophysics 7" f/D=9 Starfire apochromat refractor on an Astrophysics 800 mount. The telescope is equipped with a homemade cooled CCD camera.

The first major decision was to locate it in my 2 acre backyard in a suburb of Ottawa, rather than at a remote dark site. This was done to meet the convenience goal at the price of bright skies, and to avoid paying for land. The suburban location ruled out faint deep sky visual use of the observatory and most film astrophotography; the location also impacts CCD astrophotography. The bright skies made precision rather than aperture the most desirable feature when choosing the telescope.

To make scientific measurements both a photomultiplier photometer and a CCD camera were considered. When I calculated that a cooled CCD camera would make my 7" under bright skies more sensitive for astrophotography than a 16" under dark skies using film, I opted for the CCD. With BVRI photometric filters, the CCD camera allows me to do more accurate photometry than a photomultiplier would. At the time the observatory was being planned such a CCD camera cost more than $30,000 so I decided to design and build my own- a three year project. My CCD camera cools to – 72° C, and features a dark current of 15 electrons/pixel/sec, 19 electrons of read out noise, 576 by 384



pixels, many filters on a computer driven wheel, a computer controlled shutter, and a lot of control and image processing software.

The Building Design

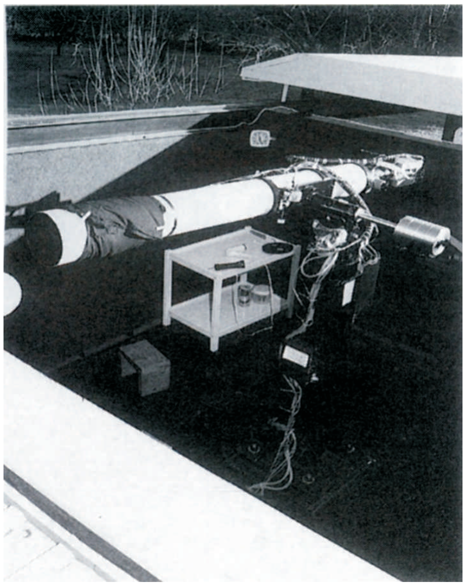
The building was designed to suit the equipment, bright sky location, and the type of observations planned. It is of frame construction with white steel and aluminum siding and roofing for low maintenance. The building was aligned north-south with the roof rolling off towards the south.

The telescope room was designed with high (6 foot) walls to shield the observer from the local lights and wind. The east, south and west walls are covered with steel siding on the outside and Aspenite on the inside. The steel siding does not have wood sheathing under it so as to minimize the thermal mass of the walls. The inner Aspenite sheathing is necessary for thermal radiation control. The wall construction allows air to flow from under the building, up between the wall coverings, and out at the top, even with the roof on. Air also flows from under the building into the room and out at the top of the walls. The air flow keeps the telescope room at the outside air temperature during the day, rather than allowing it to get hot. The west wall is equipped with three 1/2" plywood panels running in barn door tracks which can be raised to shield the telescope from wind and lights.

The flat roof is covered on the top and bottom with Aspenite. It is ventilated with air rising into a centre slot in the inside sheathing and out the eaves. A disadvantage of this ventilation scheme is that the telescope room is very dusty—the telescope is covered with a tarp and the mount RA mechanics are covered with sandwich wrap when not in use. The tarp fastens to the ceiling and rolls off with the roof when the telescope is prepared for use. The ceiling of the telescope room is painted white. This makes it much easier to see when working in the room with the roof on; when the roof rolls off the white area disappears from view.

I was concerned that with the roof to the south I might be looking out over a hot roof, thus ruining the seeing. The ventilation provided avoids this problem: the roof surface feels quite cold at night.

Safety is also a concern in this room—it was designed with no steps or holes in the



The Astrophysics 7" telescope in Boltwood Observatory.

floor. The black painted floor and all the lumber below it are pressure-treated because snow can blow in.

The roof rolls on six 5" diameter V groove steel casters on two rails. The rails are 6" W section steel I beams with steel angle welded on top, the corner of the angle upward. The rails are sloped 1:10 such that the roof descends below the horizon as it rolls off. I used a 15:1 worm gear winch with a 1/4" steel cable to pull the roof up the rails. Even with the worm gear a brake is needed when rolling off the roof as, contrary to the maker's claims, a 15:1 worm gear winch will backdrive.

The building is supported by eight 6" × 6" pressure treated wood posts sitting on concrete pads five feet below ground level in sandy soil. The posts are around the edge of the building, as far away from the telescope pier as possible. The resulting stability is excellent-even jumping on the floor does not disturb the telescopic image.

The telescope mount is attached to a steel pier that, at floor level, fastens to a reinforced concrete pier. The assembly was structurally engineered and is quite massive: 350 lbs for the steel pier and 5,000 lbs of reinforced concrete. As good as it is, the Astrophysics 800 mount is the weak point; a larger equatorial mount that was not designed for portability would have been better.

The Equipment Room

Comfort and the electronic equipment required for the CCD camera dictated the need for an equipment room. It is heavily insulated and electrically heated, has no windows, and inside is painted white with a grey floor. It has a good ventilation fan, work tables, and shelves for books and equipment. There is a 20 A 230 V electric service, alarm system, intercom and telephone. The room is rodent proof, with all of the insulation being covered to keep them out.

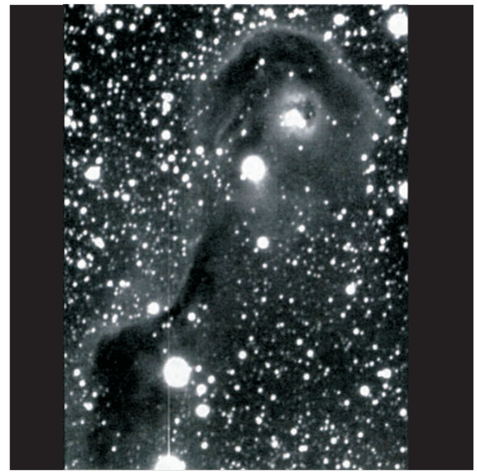
This room was placed at the north end of the building to ensure that any heat leaking from it could not harm the seeing in prime observing directions. Without this room I would be reluctant to observe in winter. I regularly observe visually down to – 20° C, and down to –37° C with the CCD camera. The room also provides storage for the books, charts, and accessories that would be damaged by the damp if left in the telescope room. There is a fold-down bed fastened to the north wall which eases all-night CCD sessions.

The Telescope

The Astrophysics telescope and mount were selected due to a high reputation for quality. Fortunately the Astrophysics equipment met the precision goal, and a refractor proved to be a reasonable choice for a bright sky site. If an equal quality reflector had been available with a larger aperture for the same price, I would have chosen it. This is the first telescope I have used that turns many of the globular clusters into pinpoint stars instead of a ball of fuzz. A 6 mm Clavé eyepiece (278 ×) gives fabulous views of star clusters, planets and the moon. Mechanically the telescope is a joy to use.

The telescope is equipped with an 11 × 80 finder, Clavé, and Brandon eyepieces, and anti-dew heaters for the objective, finder, and eyepieces.

The Astrophysics mount was modified and fine-tuned to provide declination stiffness and RA tracking performance a factor of two to three better than that obtained initially.



A 464-minute exposure by Paul Boltwood of vdB 142 within the nebula IC 1396 The image covers 8.8 by 13.2 arcminutes.

A computer control system was designed and built to move the telescope, focus it, and run the CCD camera. By using the circles to position to within a few arcminutes, and then the finder to locate a nearby star whose position is known, objects being sought can be located with an accuracy of 10 arcseconds. There is no facility provided for guiding. Instead, many short exposures are taken of the same object and then superimposed by the CCD camera software.

The observatory is currently being used for VRI photometry of quasars, CCD astrophotography, and astrometry of asteroids. Photographically, the results rival the film-based images obtained with the 100" telescope that are reproduced in Burnham's Celestial Handbooks; stars down to magnitude 20.5 can be imaged.

The observatory is now being upgraded with a 16" Newtonian and a Byers mount.

Anyone planning to build an observatory who would like more details may contact me by phone at (613) 836-6462 or Internet at ae772@freenet.carleton.ca.

The GENERAL ASSEMBLY 1995: a Photo Album

PRESIDENTIAL ACTIVITIES

Top: Peter Broughton autographs his book "Looking Up" for Paul Gray under the watchful eye of president Doug Hube.

Middle: Present and past presidents of the RASC demonstrate proper leadership methods! Left to right: Peter Broughton, Doug Hube, Damien Lemay.

Bottom: National Council in session in Windsor.

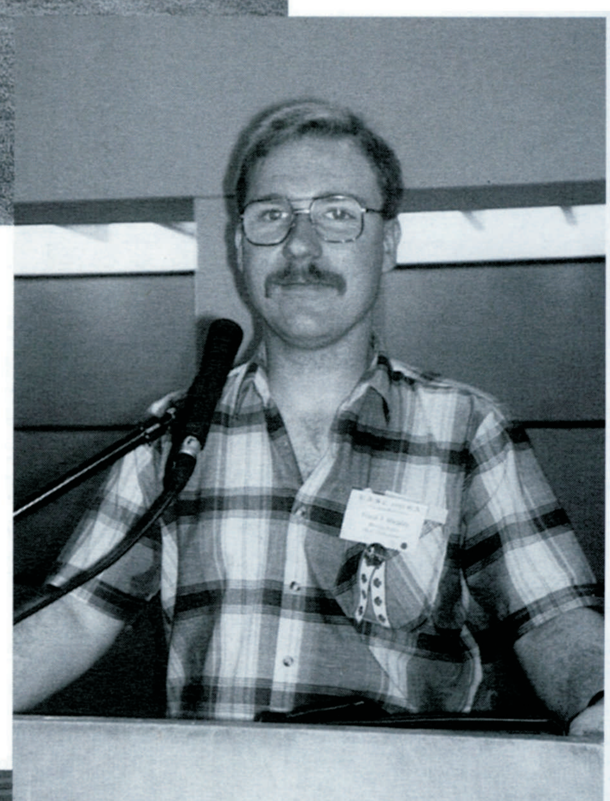
HONOURED GUESTS and AWARD WINNERS

Top: A chat session with the Shoemakers.

Middle: Carolyn and Gene Shoemaker with David Levy (centre).

Bottom: Award winners—Paul Boltwood (Chant medal); Paul Gray and Dave Lane (Ken Chilton Prize); Pat Kelly (Service Award); Ron Gasbarini (Service Award).

All photos by Peter Ceravolo unless otherwise noted.



FUN AND BUSINESS

Top: A second attempt at a five-layer pyramid. It almost worked! The gang is getting older.

Middle: GA Organizing Committee Chairman Frank Shepley kept things running smoothly.

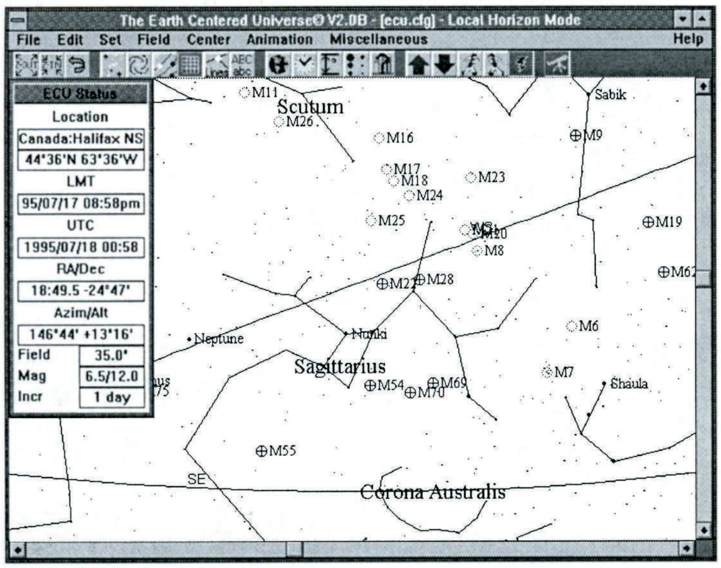
Bottom: Chant medal recipient Paul Boltwood presenting his paper at the GA.

NOVA Astronomics

THE EARTH CENTERED UNIVERSE™

Planetarium and Telescope Control Software for Windows™

The ***Earth Centered Universe*** (ECU™) V2.0B is a "Canadian" full featured *Planetarium and Telescope Control Program* for Amateur Astronomers. It is capable of simulating many of the features visible in the Earth's night sky. Just specify your location and the time — the local sky will then be simulated on the screen in a colourful display. The stars, planets, the Sun, the Moon, comets, asteroids, and "deep sky" objects are accurately displayed. High-quality star charts can be printed using any Windows-compatible printer. It connects to modern computerized telescopes, too.



SOME OF ECU'S FEATURES

- The sky is drawn in either a **Star Atlas** or **Local Horizon** mode.
- It exhibits a **colourful display** ⇒ the colours of all screen elements are controllable by user.
- User customizable **high quality star charts** can be printed with any Windows compatible printer or plotter.
- ECU displays the local time, universal time, latitude and longitude, RA/DEC, AZ/ALT, field size, and magnitude limit using a movable and configurable status box.
- The **Yale** and **SAO** star catalogues (~250,000 stars to magnitude 9.5) and the over 10,500 object **SAC** deep sky database are included. ECU is capable of reading **NASA's Hubble Guide Star Catalog** CD-ROM's which includes about 1 5,000,000 stars.
- It accurately plots the positions of the planets, the Sun, the Moon, and up to 50 **comets and asteroids**.
- **ECU is very easy to use**. Most operations are performed with the mouse including centering, zooming, etc. A Toolbar and hot keys are provided for easy access to most common functions.
- Clicking on an object causes an information box to pop up which provides a wealth of information about the selected object.
- The user can display an objects image in any format through the use of an external image viewer (not included).
- All user settings can be saved to named configuration files.
- The time can be set as local time, UTC, or from the computer's clock. Dates can be entered from **4713BC** to **9999AD**.
- The observer's location is entered by latitude and longitude or from a **list of cities** (add your own, too).
- The effects of observer's parallax, nutation, precession, light travel time, aberration, and atmospheric refraction can be individually controlled.
- The sky can be displayed as white on black or black on white, or in full colour. Two "red" modes protect your night vision when ECU is used at the observing site or in an observatory
- The deep-sky and stellar **magnitude limits** are controllable.
- The types of deep sky objects displayed is controllable.
- ECU displays the horizon line, ecliptic line, RA/DEC grid, constellation lines, boundary lines, labels for bright stars, constellations, Messier objects, coordinate grid, etc.
- Adjustable field circles can be drawn to represent the fields of view of your telescope and finder scope.
- The user can **centre the display** at any RA/DEC, AZ/ALT, bright star, constellation, Messier object, point on the horizon (north, south, etc.), or solar system object. The database can also be searched by entering text.
- ECU's **animation mode** allows time increments from 1 mm. to four years. During animation, the display can be "locked" to the Sun, Moon, a planet, an an AZ/ALT. Object trails can be displayed.
- Extensive support is provided for **Meade® LX200™** telescopes.
- Extensive support is provided for the **Micro~Guider™** and most other commercial digital setting circle devices.
- A dialog box to display the **rise/set times** of the Sun and Moon on the current day is provided. It also shows the times of civil, nautical, and astronomical twilight.
- ECU is **fast** compared to many other astronomy programs. A math co-processor is not needed. It is supported, however, to improve the speed of solar system and local horizon calculations.
- An 95+ page User's Manual is provided.
- **System requirements:** 386/486 PC with Windows 3.1 ; Math co-processor beneficial; VGA or better screen; minimum 1 M free memory; Mouse; Windows compatible printer.

Price (including air mail shipping) — $70 CDN **($50 US)**
Canadians must add 7% GST • Nova Scotians must add 11% PST

Also visit the ECU Internet World Wide Web Page at:
http://fox.nstn.ca/~ecu/ecu.html

Write or call for a **free demo disk**, or download from the internet at
ftp://hercules.stmarys.ca/pub/ecu/ecushare.exe

Dealer Inquiries Welcome
ECU is also available in a French language version (V1.5)

***Nova Astronomics**, PO Box 31013, Halifax, NS, B3K 5T9 Canada* • ***Phone:** 902-443-5989* • ***Fax:** 902-445-5790* • ***E-mail:** dlane@hercules.stmarys.ca*

SEEING CLEARLY

My first experiences in astronomy were reading about the planets. Artist's impressions of the spacescapes inspired my youthful imagination. I finally managed to build a 2" refractor at age 13 and it opened a door to the universe. I held the image of the rugged moon with fascination and my first views of Jupiter and Saturn really blew me away. The razor thin crescent of Venus 4 degrees below the sun on a July afternoon: what more could you want?

Good optics make the difference in planetary observing, but you need more than that. There are many items that affect your telescopes' performance.

The earth's atmosphere acts as another optical element that the light has to pass through. "Seeing" is the term that refers to the state of the atmosphere. Heat causes nonuniformities in the light path that scrambles the wave front of the light coming to your telescope. This is much like the distortion you see on a summer day over a hot asphalt highway. Seeing ultimately determines whether you perceive a myriad of details on the planet, or one devoid of detail. The way to check the seeing is to select a bright star and examine the out of focus image in your eyepiece. There are three main types of seeing.

1 . Heat inside your telescope tube. An out of focus star image usually shows either a plume of light drifting off one side of the image or slowly swirling eddies. The focused image seems to have a mist drifting off it. If you take a telescope out of the house or garage, it will be warmer than the outside air temperature. The warm air inside the tube ruins the image until the scope cools down. This cooling period can take several hours but in the case of a Newtonian it can be reduced with a fan to blow air into the back of the telescope tube. This can cut the cool down to half an hour or so. A method that I find effective is placing a fan in the telescope to draw air out the back, thus improving air uniformity inside the scope.

Mars as drawn by Murray Paulson on Jan. 24, 1995. He used 540x on a 12.5" with a 7mm Nagler and 2.4x Barlow. Seeing was rated 6

2. Locally generated. Hot spots should be avoided anywhere in your observing line of sight. Hot asphalt, a warm car engine, a furnace flue or even a person in front of your scope. The heat coming through the light path can really ruin an image. The defocused star image shows a stream of rising or falling heat waves like a slow moving river. The focused image will seem to flicker as you watch it.

3. Atmospheric. If the atmosphere has mixing of weather fronts or a jet stream, the out of focus star image will look like a fast moving river. This usually ruins the image leaving a planet looking like a fuzzy tennis ball.

Patience is crucial. You have to wait for those moments of good seeing to freeze up the planets' image into a wealth of detail. You also need perseverance. If the night does not have good seeing, try again tomorrow. I have noticed that the seeing just after twilight is usually good, but it usually deteriorates later in the night. If your telescope is out of collimation, the image quality will degrade. Look at the slightly out of focus high power image of a bright star and see if the light is evenly distributed around the central spot. If not, collimate the telescope and the image will improve.

Eyepieces are a very important factor. The fewer the elements the better. Each surface scatters a bit of light and this glare reduces the image contrast. If you have a clock drive, eyepieces like Orthoscopics and Plossls are great. If you don't, then the Nagler type of eyepiece is my substitute for a drive. There is a trade off when it comes to glare and the time the object stays in the eyepiece. I usually use as high a power as the image contrast and the seeing will tolerate. This is usually 220 to 540 X on Mars, Jupiter and Saturn in my 12.5" Dobsonian and 180 to 330 X in my 94 mm refractor. You may need a barlow to get the magnification up to the 50 to 100 power per inch limits. I really recommend that you try the high power just to see what your scope can do. I have observed the disk of the asteroid Ceres at 540 power in my 12.5" Dobsonian.

Filters are another important item. They select out a wavelength region that enhances the contrast of particular features on a planet. The blue or violet filter enhance atmospheric features on Mars and Venus. Try blue and orange filters on Jupiter and Saturn: they enhance belt and polar details. Red or orange filters enhance maria details on Mars. I prefer the orange filter and if you only have one filter, it should be this one. I find it improves the image contrast in twilight conditions as well.

I will conclude by suggesting that you make a log of your observations. I make drawings and record a few details about each session. I would be interested in seeing copies of your drawings of the planets. Please direct items to Murray D. Paulson, 11 Gladstone Cr. St. Albert, Alberta Canada T8N 0W6

Murray Paulson is a laser engineer who has been an avid planetary observer since 1966 He was president of the Edmonton Centre 1991-92.

THE CHASM OF BLACKNESS

Alister Ling
Edmonton Centre

OBSERVING M24

As I gaze deeply into the heart of the Milky Way, I love to simply sweep the telescope around. It is like standing at the edge of the Grand Canyon—there is no need to photograph or record your words—just contemplate. For the moment, let the clusters and their companions float past mysteriously in the cloak of the night.

There are few places in the sky as wonderful as the small star cloud in Sagittarius (M24). The wide field sightseeing here is arguably second to none. Sure, the starfield is rich beyond belief, but it is the Great Rift's chasm of blackness surging past the eastern flank that grants M24 its true splendour.

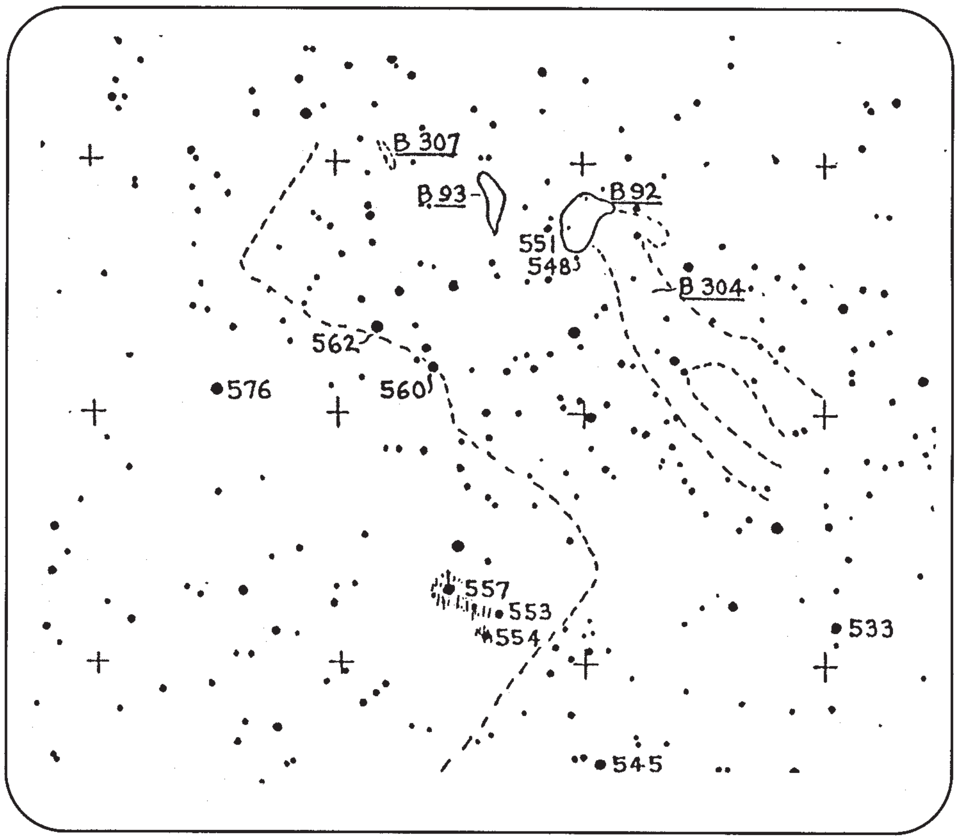
The western edge of M24 is vastly different. Here a celestial artist has splattered irregular patches of black paint on a starfilled canvas. It is easy to imagine a delightful playfulness in the pattern.

Like many great paintings, this section of the Galaxy soon draws one into examining its details, to appreciate its construction all the more. Charles Messier discovered this object on June 20, 1764. He described it as: a degree and a half in size; a large nebulosity in which there are several stars of different magnitudes; the light which is spread throughout this cluster is divided into several parts.

One can plainly see from this description that Messier was indeed referring to the large object, and not to the small open cluster NGC 6603 embedded within. Unfortunately the M24=NGC 6603 myth continued to be perpetuated on Tirion's Sky Atlas 2000 when it was first published. It is difficult to pin the myth's origin, but it goes back to at least Sir John Herschel. His observation was labeled M24 and he described it as "A glorious concentrated part of Milky Way, almost amounting to a globular cluster."

In the notes section of the New General Catalogue John Herschel himself commented: "[my] two observations hardly consist with this description [NGC 6603= M24] and their deviation of nearly +3min from Messier's place makes it very doubtful whether he [Messier] really saw this object."

If you remain unconvinced that they are two separate objects, here is Messier's description of M13: "Nebula without star."



On the top of Mt Kobau one August evening, I noted that the internal cluster NGC 6603 was plainly visible at 64x in a 10-cm Astroscan reflector.

That night I drew the outlines of the dark nebulae surrounding M24 on my Uranometria Atlas. Barnard 92 is definitely the most opaque of the dark spots. I could only see B93 as shorter than what Barnard had plotted, not having picked out the more diffuse tail running 15' southwards. The third darkest area is B304, estimated to be about 13' N-S and 10' across E-W. Was I distracted by other sights beckoning, or was my 10-cm aperture simply insufficient to pick up the fainter stars which delineate the dusky lanes stretching to the southwest?

To my later surprise, the elongated dark gap (about 20' X 6') capping the northeast end of the starcloud was not a Barnard object. It turns out to be catalogued as LDN 335. Then how did I miss B307? Firstly is was not plotted on my early copy of Uranometria; secondly, it was probably too small to be picked up at only 64x.

The objects on Barnard's chart labeled 553, 554, and 557 are catalogued today as NGC 6589, 6595, and IC 1284 respectively. Colour photographs of this region show an intriguing mix of emission and reflection nebulae surrounding 8th and 9th magnitude stars.

THE CHARMING DRAGON

Fr. Lucian J. Kemble
Edmonton Centre

DRACO OFTEN NEGLECTED

While browsing through Uranometria one day, I came across a most unusual bright asterism in Draco. I checked through various catalogues and found it is not a true open cluster. Intrigued, I scanned the area with binoculars and located this bright asterism and several others in the field, below the body of Draco.

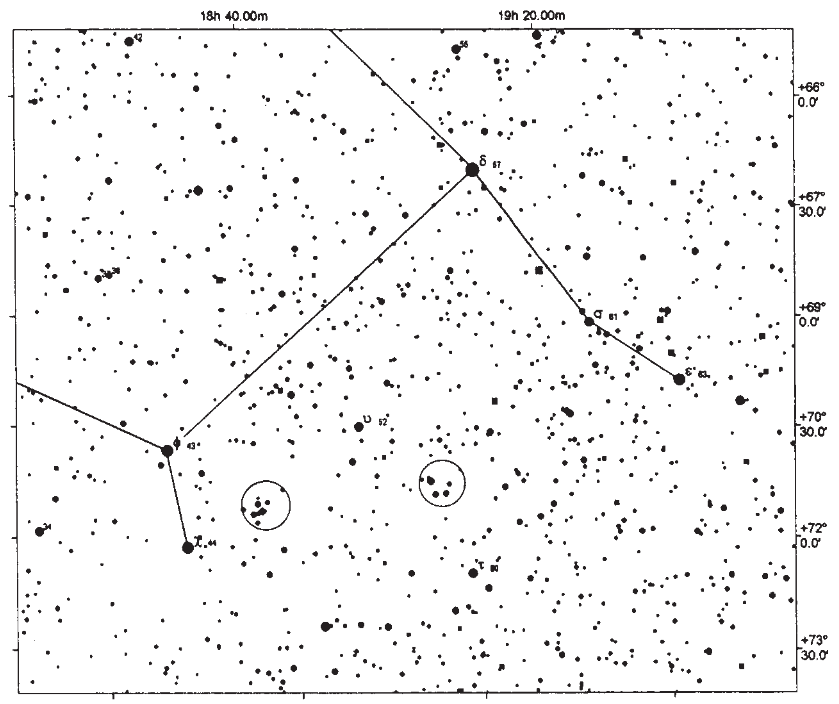
Dragons have been a frequent element in many peoples' myths—sometimes benevolent and bearers of good fortune; sometimes fire-breathing monsters of havoc and destruction. In many myths they are presented as hoarders of vast treasures of jewels and gold and silver. One that comes to mind is J. R. R. Tolkein's Smaug, in "The Hobbit." Smaug is a destroyer, but somehow a rather delightful character. I have come to love the old beastie, and his next-of-kin in the sky, Draco, prompting the title of these reflections.

Draco, with his prominent head, long neck, and log tail curving between Ursa Major and Ursa Minor, is well known to amateurs. Years ago I learned his configuration from the line drawing in Rey's "The Stars"—the same one to be found in the monthly centre-fold chart in *Sky & Telescope*.

Draco is often neglected: in part because, being circumpolar for us northerners, we kind of 'leave it to later'; in part because, when it is high in the northern sky, as in spring and summer, we tend to look to the south where the wonders of the Milky Way lie. Actually, what it may seem to lack in spectacular deep-sky objects, it makes up for by its strategic position.

Since the North Ecliptic Pole, defining the northern axis of the orbital plane of the solar system, lies between the neck and tail of Draco, it would seem that the Dragon oversees the turning of our system. Around it, at a distance of 23 degrees 30' lies the axis of our Earth. Due to precession, the North Celestial Pole traces out a 25,800-year cycle. Our North Star is presently Polaris, but eventually it will be back at alpha Dra [Thuban], where it was at the time of the Egyptian "Old Kingdom." Some stars of Draco serve as good pointers: his nose, bright gamma, points to Vega; the two stars of his hind leg, phi and chi, point to Polaris, 17.6 degrees away.

Marking the North Ecliptic Pole, only 11.5' to the NW is Draco's finest deep-sky jewel, the magnificent planetary nebula, NGC 6543, featured on the cover of *Sky & Telescope*, April, 1995. Nearby, in the same field and even closer, is the 14.6 mag. galaxy, NGC 6552. A good challenge is a large, very faint jewel of a galaxy, UGC 10822, the Draco Dwarf and member of our Local Group. It can be found about 3 NW of nu 1 ,2, a lovely jewel which our Dragon carries on the back of his head. This gem is one of the nicest binocular doubles consisting of two A5 stars of 5th magnitude separated by 1' of arc.



The constellation Draco includes two asterims (circled) that resemble Cassiopeia (left) and a hoard of diamonds (right). Chart by permission of MegaStar.

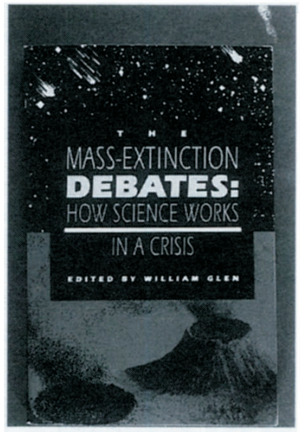
Draco's main jewel hoard lies below his belly and between front and hind leg, in an area defined by the stars chi, phi, delta and epsilon . The most beautiful is a tight cluster of about seven stars of 7th and 8th magnitude fitting well within a low-power eyepiece. It can be seen as a miniature Cassiopeia. Just East, midway between his two feet, lies a small diamond of 6th to 8th magnitude stars.

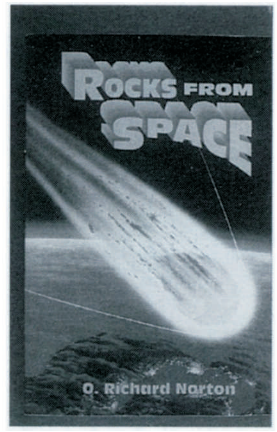
There are no open or globular clusters and only four planetaries in Draco, illustrating the scarcity of such objects far from the plane of the Milky Way. Sky Cat. 2000.0 lists well over 100 galaxies, of which 27 brighter ones are listed in Burnham's, vol. 2, p 859. The Observer's Guide #26 lists 43. In the course of my years of observing I have observed, drawn and noted well over 75% of these objects.

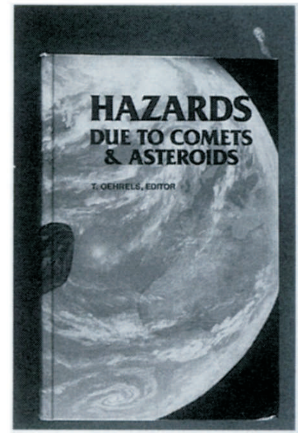
Our charming Dragon, then, while guarding his jewelled treasure trove, opens to our gaze his bright gems and the dim cloud of fuzzy galaxies that surround him.

BOOK REVIEWS

Clifford J. Cunningham







This recent trio of books treats asteroids as impacting bodies. Their most famous role was played before an audience of dinosaurs 65 million years ago, and by most reports the performance was a killer. The great debate sparked by the 1980 Luis Alvarez paper is examined in **The Mass-Extinction Debates: How Science Works In A Crisis** (edited by William Glen; Stanford Univ. Press; ISBN 0-8047-2286-2; $17.95, 370 pgs).

With 80 pages of endnotes, index and references, this softcover book is one of the finest contributions to the historiography of science ever produced. Glen, the histonan of the U.S. Geological Survey, has brought together nine world experts who propound their diverse views. Some view the mass extinction as caused by an asteroid impact, while others actually deny that mass extinctions have ever taken place! As an examination of the behaviour of scientists caught up in a major paradigm shift, this book is unique.

Rocks From Space by O. Richard Norton (Mountain Press, Montana; ISBN 0-87842-302-8; $20, 446 pgs) deals with a more tractable subject- the actual impact of meteorites on the Earth. While the text tends to be repetitive at times, Norton (a former planetarium director) has done an admirable job of explaining virtually every aspect of meteor science. The first section gives an historical overview, with prints illustrating meteorite falls going back to 1492. It was not until the early 19th century that scientists accepted the fact of stones falling from the sky, and not until just a few decades ago that impact craters were accepted as the result of those impacts.

Norton devotes whole chapters to the great Tunguska blast in 1908 and Meteor Crater in Arizona. It is a shame that such a well-illustrated book does not have a photo of Eugene Shoemaker, whose work at Meteor Crater laid the groundwork for all modern crater studies.

While most of the book is an entertaining read (especially the section on Robert Haag, who has become a millionaire searching for and selling meteorites), many readers will find the section on composition to be a bit dense.

Hazards Due To Comets & Asteroids (ed. by Tom Gehrels, Univ. of Arizona Press, ISBN 0-8165-1505-0, $75.00, 1,300 pgs.) is a massive tome marred by typographical errors. I found mistakes on pages 33, 39, 64, 83, 113, 150, 207, 233, 261, 280, 320, 324, 326, 428, 590 (where Vesta is repeatedly called Vega), 601, 604, 714, 717, 729, 731, 740, 742, 765, 769, 803, 871, 929, 951 and 1113. Hopefully the equations in the book have not suffered the same fate.

A combined effort of 120 authors, Hazards looks at the effects of collisions on our planet, and what we can do to prevent it. Instead of blowing up an asteroid with a nuclear bomb, one paper suggests a more sensible approach: concentrate on efforts to exploit its mineral riches.

Even though most attention has been focused on very large impacts, a chapter by Steel et al makes it clear that the global hazard on short time scales (less than 100,000 years) is dominated by objects in the size range from 50 to 300 metres. They maintain that such objects arrive in groups, not randomly like the big asteroid impacts. They cite 11 asteroids known to be associated with periodic comet Encke, all part of the so-called Taurid Complex. The implicaiion is that most of the small objects that pose a threat to mankind are in Taurid-like orbits.

One of the largest chapters in the book, spanning 56 pages, deals with crater size distributions in the solar system. Thanks to spacecraft studies, we can now compare these figures for such diverse objects as the Moon, the planets Mercury, Venus and Mars, and asteroids Gaspra and Ida. The authors conclude that an object capable of producing a 1-km crater could hit Earth every 1,600 years. Despite its flaws, this is the best book available for the study of near-Earth asteroids.

C. J Cunningham is the author of Introduction to Asteroids, published in 1988.

LES AMATEURS de CCD au QUÉBEC

Damien Lemay
Centre de Québec

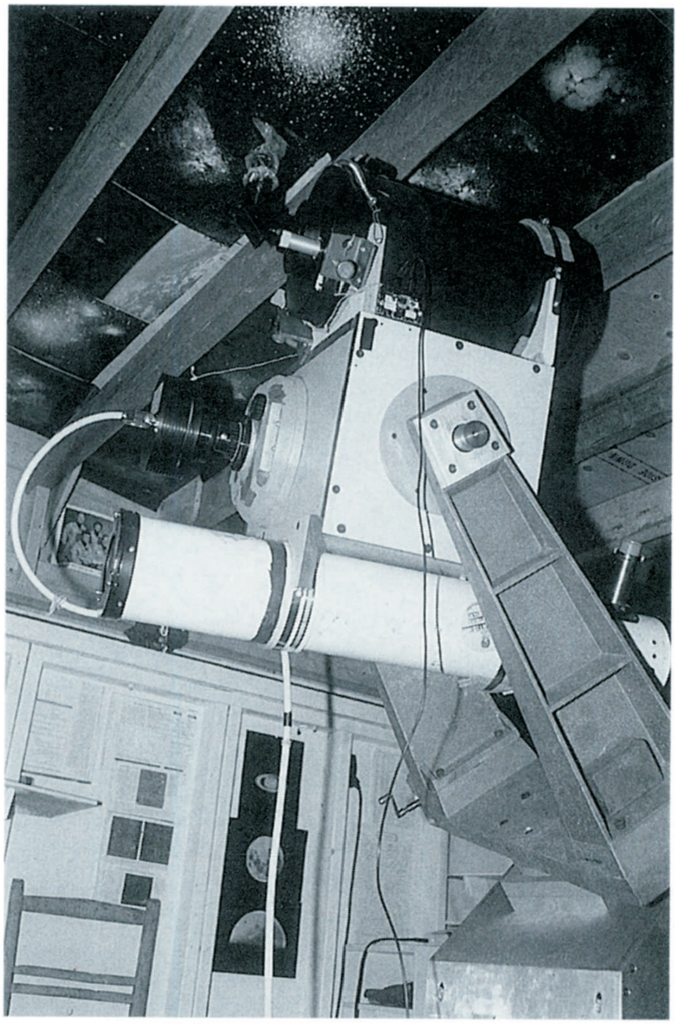
Abstract

The CCD fever has affected a number of Québec's amateurs, as it did elsewhere. In this article I will review the work of those who, at my knowledge, have been and continue to be the most active. It is based on personal contacts and on the content of the publication "CCD Québec" (see note-1).

Résumé,

La fèvre des CCD a bien sûr gagné des adeptes au Qu,bec comme ailleurs. Dans cet article, je veux passer en revue les amateurs qui, a ma connaissance, sont pr,sentement les plus actifs. Ii est base sur des contacts personnels avec ces gens et/ou sur le contenu de la revue "CCD Québec" (voir note- 1)

Gilbert St-Onge et Denis Bergeron sont ceux qui ont fait le plus d'observation CCD a date au Québec, et ils demeurent les plus actifs. C'est au printemps 1990 que Gilbert a acquis sa premiere ST4, fabriqu,e par Santa Barbara Instrument Group (SBIG), avec l'id,e de l'utiliser principalement pour le guidage. C'est a cette fonction qu'il l'a utilisée la premiere fois, mais à sa seconde soirée d'observation avec celle-ci il realise la puissance de ce nouvel outil pour la prise d'images et presque immédiatement, il se ravise et decide que c'est de la photo CCD qu'il fera d,sormais. Il demeurait alors a Dorval dans la banlieu ouest de Montr,al et avait l'habitude de se déplacer à un site au nord de la ville pour ses observatons; mais il découvre que Dorval n'est pas mal du tout avec un CCD. Il entreprend alors un programme intensif depuis son observatoire permanent a Dorval, qui l'ameneront à faire de la photometry ubvri d'étoiles particulières, comme RMON. Au début, il utilisait des logiciels de traitement d'images comme celui qui était fourni avec la ST4, CCDB1ink et CCDUTIL aussi de SBIG, puis AlP de R. Berry. En 1993 il a fait un bond en avant avec l'acquisition d'une ST6.



L'observatoire de Damien Lemay

Depuis peu il demeure a Plessisville, a quelque 200 km a l'est de Montréal. Dans peu de temps il aura fait la mise en operation d'un 17.5 po en remplaceemnt de son ancien 12.5 po. On peu donc s'attendre à ce qu'il fasse encore parler de lui dans le futur.

A la suggestion de Gilbert St-Onge, au début de 1991 Denis Bergeron (il observe depuis sa résidence de Val-des-Bois, à quelque 50 km au nord-est de Hull) se laisse convaincre de passer au CCD. Vétéran de la photo astronomique conventionnelle, il songe lui aussi à utiliser sa ST4 pour le guidage automatique des longues expositions sur pellicules. C'est ce qu'il fera à temps partiel, mais il l'utilisera de plus en plus pour de l'imagerie CCD.

Denis est vert avec les PC, mais n'hésite pas à plonger dans l'informatique avec l'achat d'un 486 comme premier ordinateur. Il a tout un monde à découvrir, mais grâce à sa determination et son énergie il maîtrise rapidement l'environnement DOS et Windows, de même que plusieurs logiciels puissants de traitement d'images. En 1993 lui aussi se procure une ST6 et continue sa course à la quête du meilleur logiciel. Entre temps, á son Dynamax de 8 po a succédé trois générations de Meade 10 po, celui qu'il possède présentement est un LX-200. Enfin, il possède toujours sa ST4 qui est revenue à sa vocation initiale, soit le guidage alors que les images proprement dites sont prises avec la ST6. Avec ce montage idéal pour le "deep sky", il prend des expositions de 10 à 60 minutes. Denis est un grand producteur de photos d'objets de toutes sortes qu'il prend simplement pour le plaisir, tout en ayant un oeil attentif à une supernova possible dans les galaxies qu'il capte avec ses instruments. Mais, il commence à sentir le besoin de se spécialiser et de donner une vocation plus scientifique à ses travaux. C'est ainsi qu'il s'est inscrit à la campagne d'observation de Chiron, ancien astéroide reclassifié, comme comète.

Il en fait de la photometrie et des images afin d'en capter la coma. Le logiciel de traitement d'image qu'il préfére présentement est PRISM de Astro-Equipements et Cyril Cavadore.
A Québec, Denis Martel est devenu propriétaire d'une ST4 en janvier 1991.

En compagnie principalement de Clermont Vallières, pendant deux ans et demi ils ont accumulé pour environ 20 Meg Bytes d'images, dont la majorité, furent prises avec le newtonien de 1 6 po qu'ils possèdent conjointement à l'Observatoire de St-Luc (cet endroit situé à quelque 40 km au sud de Québec est vraiment spécial, en ce sens que c'est un ensemble de huit observatoires installés sur un site commun, avec un chalet principal de 20 x 24pi). Il était donc prêt en 1993 pour une experience plus poussée lorsqu'il a acquis à son tour une ST6.

Pierre Ouimet est un autre heureux propriétaire d'une ST6 depuis février 1994 et d'un Meade LX200, de 8 po, f/10, qu'il utilise a son observatoire de Dorval. Il s'est amusé avec des objets de toutes sortes, jusqu'à ce qu'il soit s,duit par l'astrométrie apres avoir pris connaissance du partagiciel ASTROMETRICA de Herbert Raab et Erick Meyer. En prenant le Hubble Star Catalog comme r,f,rence, ce logiciel peut déterminer les coordonnées d'un objet céleste avec une précision d'environ 0.1 second d'arc.

Au total, le logiciel et le catalogue coûtent environ $100, ce qui est une aubaine. Pierre s'est embarqué sur un programme d'observation d'astéroides et de comètes et il entend répondre a l'appel de Brian Marsden, éditeur du "Minor Planet Circular (MPC)" pour des données astrométriques de qualité pour le calcul d'éphémérides de ces vagabonds de l'espace.

D'autre ont choisi la voie tracée par Richard Berry dans son CCD Cookbook; comme par exemple Jean Vallières, Patrick Dufour, Michel St-Laurent, Dominique Beauchamps, Dan Coté (ce dernier est aussi informaticien et il a produit un logiciel de traitement d'images TIASTRO, qui s'apparente au logiciel AIP de Richard Berry). Même si Jean Vallières s'est lui aussi inspiré du livre de Berry, sa grande experience en électronique et en informatique l'a amené à apporter plusieurs innovations, lesquelles on peut s'attendre à retrouver ventuellement dans des caméras commerciales.

Je pense entre autres aim deux méthodes de guidage qu'il propose dans son design; la première avec une caméra guide non refroidie et la deuxième avec une seule caméra dont une portion du chip peut être lue à répétition indépendamment du reste de la matrice qui prend la photo proprement dite. Dans les deux cas, un logiciel qu'il a d,veloppé lui même permet la fonction guide et prise de photo avec un seul ordinateur.

Personnellement, j'ai suivi le mouvement en prenant livraison d'une ST6 a l'automne 1993. J'ai alors modifié mon observatoire (cette dernière fut construite en 1989 après mon retour à Rimouski suite à un séjour de trois ans à Ottawa), afin de prendre avantage de la pièce chauffée pour fournir un environnent permanent propice au PC286 associé à la caméra. En effet, le PC et le moniteur sont installés à la chaleur, une fenêtre dans le mur séparant l'observatoire proprement dit et la pièce chauffée permet de voir le moniteur, alors que le clavier lui est près du télescope dans l'observatoire. Le câble reliant la caméra au PC est dissimulé sous le plancher, ce qui fait une installation propre et bien protégée dont je suis fier. Cependant, je n'ai pas été aussi productif qu'on aurait pu s'attendre. Les raisons sont nombreuses, mais je dirai qu'à part les obligations professionnelles qui se font plus exigeantes quant au temps, il y a lieu d'admettre certains problèmes techniques comme un jeu (backlash) de l'équatoriale qui a été long à identifier et le manque d'un télescope guide adéquat. Ces deux derniers problèmes sont maintenant résolus, ce qui a permis une augmentation importante de la production de bonne photos avec mon observatoire. Une bonne partie de ces images sont le fruit de collaborateurs fiables (Luc Bellavanceet Sylvain Lévesque) qui y ont accès à volonté lorsque je ne puis l'utiliser moimême. Un nouvel instrument (14 po, F/4, Schmidt-Newtonian) par Peter Ceravolo devrait améliorer mon installation d'ici la fin de 1995, ce qui devrait être mon dernier instrument pour plusieurs années à venir. Jusqu'à maintenant j'ai fait de la photo CCD de divers objets, mais depuis au moms dix ans je rêve de faire de la photometrie. Je suis heureux de constater que des logiciels accessibles aux amateurs permettent la photometrie et l'astronométrie à partir des expositions CCD; je compte aller dans cette direction.

Note-1:

1-CCD Québec en est à sa deuxième année d'existence. Commencée en 1 994 par Denis Martel (Vol. I, no 1 à 4), avec le premier no de 1995, Dominique Beauchamp a pris la releve comme éditeur (Denis et Dominique sont du Centre de Québec). CCD Québec est publié quatre fois par année, chaque numéro contient entre 24 à 30 pages de format 8.5 x 11, et est habituellement accompagné de quelques disquettes contenant des photos par les amateurs et des logiciels du domaine public. Pour abonnement ($25/ann,e) vous adresser à: CCD Québec, (SRAC Centre de Québec), 2000 boul. Montmorency, Québec, Qc, Canada, G1J 5E7. On peut aussi rejoindre l'éditeur par l'Internet: beauchamp@astro.phy.ulaval.ca

Damien Lemay is a past president of the RASC.

OBITUARY: William Henry Wehlau

Peter Jedicke
London Centre

WILLIAM HENRY WEHLAU
1926 - 1995

A memorial service was held April 25, 1995, for Dr. W H. Wehlau, Professor Emeritus of Astronomy at the University of Western Ontario. Professor Wehlau suffered a stroke while he was attending a meeting in South Africa on Astronomical Applications of Stellar Pulsations and he passed away in Cape Town on February 24, 1995.

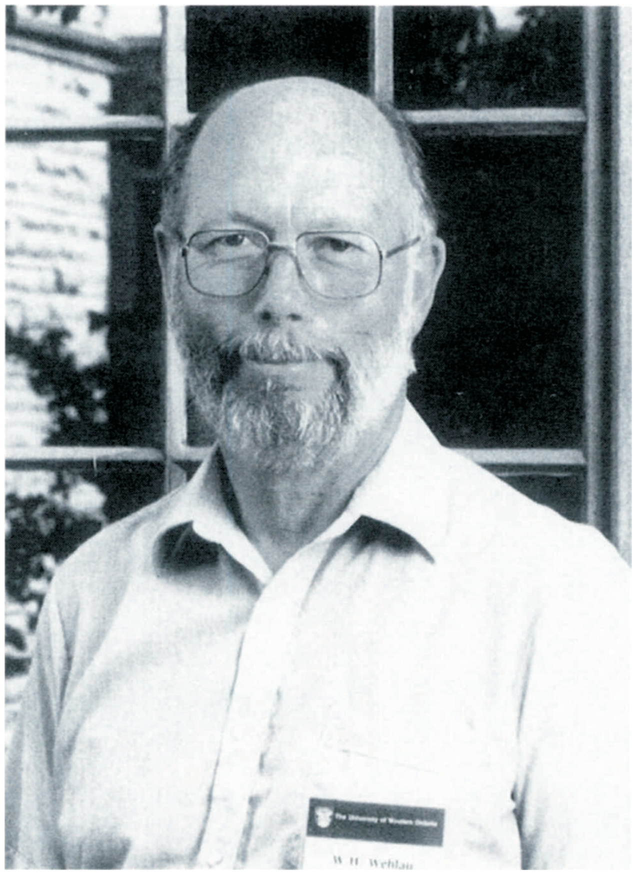
William Henry Wehlau was born in San Francisco on April 7, 1926. He grew up in poverty and demonstrated considerable aptitude for science. He won a scholarship, but his studies were delayed by World War Two. At the age of 18, Wehlau was in combat in the Philippines, and he was part of the occupation army in Japan at the end of the war. Only after this experience did Wehlau continue his studies at the University of California at Berkeley, where he earned a Ph.D. in 1953.

Following this, he spent two years at Case Institute of Technology and came to UWO in 1955 with his wife, Amelia, who is also an astronomer. Wehlau joined the Department of Mathematics and Astronomy as a National Research Council Postdoctoral Fellow, then became assistant professor in 1957, associate professor in 1959, and professor in 1961.

When the Department of Astronomy was formed in 1966, Wehlau became Department Head. The 1.2m telescope at Elginfield was conceived, funded and constructed in the 1960s as a result of Wehlau's efforts. He remained head of the Department of Astronomy until his official retirement in 1991, and then became Professor Emeritus.

Wehlau first attended a meeting of the London Centre of the Royal Astronomical Society of Canada on October 21, 1955. He was secretary of the London Centre in 1956 and 1957, was president in 1958 and 1959, and served as national representative from 1962 until 1972. He became a life member of the Society in 1965, and from 1972 until his death, Wehlau was the honourary president of the London Centre.

He spoke at many London Centre meetings, and presented a special lecture about the Canada-France Hawaii Telescope at the 1979 General Assembly, which was hosted by the London Centre. Over the years, he often helped arrange visits by London Centre members to UWO's observing facilities.



Various aspects of stellar surface structure and related astrophysical problems were the general focus of Wehlau's research career. Peculiar stars of spectral class A (designated as Ap stars) figured prominently in his publications. Wehlau used photoelectric photometry, polarimetry and spectrometry in his observing, and also made significant contributions to the analysis of such topics as multiple periodicity.

The surfaces of Ap stars, Wehlau realized, have various chemicals non-homogeneously distributed over them. These variations in abundance should be visible in the line-profile variations of the spectra of these stars, and Wehlau worked on techniques to search for and observe this effect. With high-quality spectra and a digital method of inverting the information in the line-profile variations, Wehlau was able to make maps of the abundance and temperature of stellar surfaces.

In the last decade, Wehlau studied rapidly oscillating Ap stars, and his observations proved that variations in the velocity observed in the spectral lines of such a star are due to pulsation. In October, 1995, an international meeting on Stellar Surface Structure, held in Vienna, was dedicated to Wehlau.

Included in Wehlau's extensive contribution to the community of astronomical research in Canada was 22 years as a member of the NRC Associate Committee on Astronomy, from 1960 to 1982.
He was chair of this committee from 1979 to 1982. He was a member and chairman of the NRC Grant Selection Committee for Space and Astronomy from 1969 to 1971. He played a significant role in changing the focus of Canada's efforts in astronomy from the proposed Queen Elizabeth Telescope to the Canada-France Hawaii Telescope, developing the collaboration with France. Wehlau was on the CFHT's Scientific Advisory Council from 1974 to 1979, and chaired this body in 1978 and 1979. From 1980 to 1985, he was on the CFHT Board of Directors, and served as president.

From 1975 to 1980, Wehlau was a member of the Conseil de Direction de l'Observatiore Astronomique de Quebec, which is responsible for the telescope on Mont Mégantic in Quebec. Internationally, Wehlau actively promoted scientific exchanges, particularly with astronomers in the former Soviet Union. Few western astronomers were invited to observe with the 6m telescope at the Special Astrophysical Observatory, but Wehlau was one of them.

More recently Wehlau was chair of the Gemini Twin 8 Meter Telescope Review Committee for the National Science and Engineering Research Council and NRC, and also chair of the Awards Committee of the Canadian Astronomical Society from 1992 to 1994. He was a member ofCommission 29 and Commission 42 of the International Astronomical Union, and chaired the Working Group on Ap and Related Stars in 1994.

The memorial service held in Middlesex College was a warm and personal tribute to Wehlau. Friends from both the astronomical community and the London community spoke of his quiet and unassuming leadership, his good humour, his sense of justice and compassion, and his keen enthusiasm for art, baseball, and mountains. The early comedy films of Laurel and Hardy and Buster Keaton particularly made him laugh.

Wehlau was an avid badminton player until late in life, when troubles with his back turned him into a cyclist. As John Landstreet, the current chair of the UWO Department of Astronomy, expressed it, Wehlau "left deep footprints." A scholarship fund has been established in his memory at UWO. Wehlau is survived by his wife Amelia and their four children, Ruth, Jeanne, Alice, and David, and by two grandchildren.

About The Royal Astronomical Society of Canada

The Royal Astronomical Society of Canada is a nation-wide organization devoted to the advancement of astronomy and allied sciences. The Society was first incorporated in 1 890, and received its Royal Charter in 1903. Since that time, the RASC has grown to include more than 20 local Centres and 3000 members.

Membership in the Society is open to anyone interested in astronomy. The annual fees of $36 ($22.50 Youth) include a subscription to the Society's bi-monthly publications and annual Observer's Handbook. Members may affiliate with one of the local Centres and receive further benefits which include regular meetings, observing events, and Centre facilities (some Centres levy an additional surcharge).

Information For Authors

The RASC welcomes original research papers by professional or amateur astronomers. All such contributions are refereed. Professional astronomers with institutional affiliations are asked to pay page charges. These charges may be waived for Society members who do not have access to professional funds.

Articles of general interest to the amateur and professional astronomical community are also welcomed. Manuscripts for both research papers and general interest articles may be submitted in either English or French, and should be sent to the appropriate Editor whose address is given below.

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