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Journal

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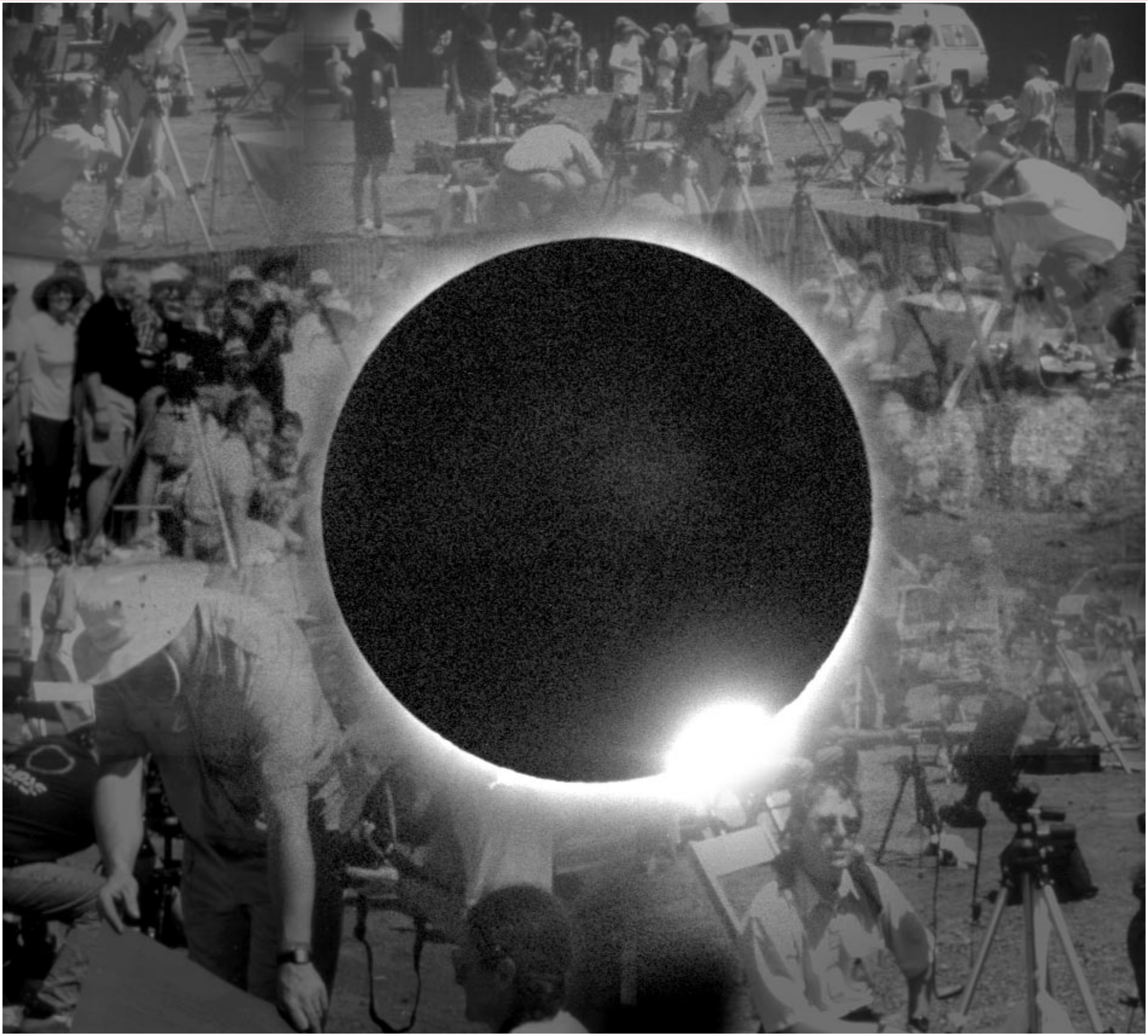

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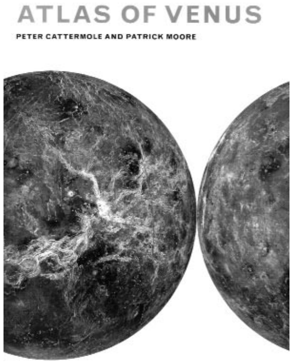

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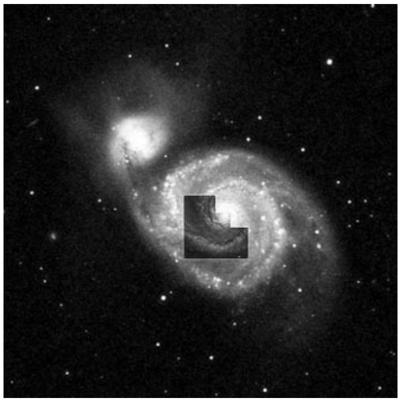

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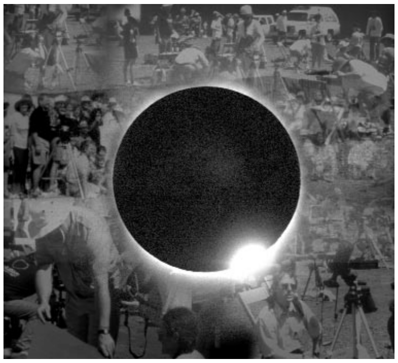

President's Corner

by Douglas B. George

At the General Assembly in June my term will come to an end, and I will be stepping down as President. It seems as if my time on the Executive has passed very quickly; but as I look back quite a lot has happened during that time. There have been a number of changes to operations at National Office, and to the pages of this *Journal*. As always there have been the controversies and difficulties, and we have all made the occasional mistake. But I think true progress has been made, and the Society is better for it.

I would like to thank all of the people who have worked so hard on behalf of the Society during my term. Bonnie Bird, our Executive Secretary, has provided superlative service to the membership, and has been of great help to me personally. In a large, diverse Society like the RASC, the job of Treasurer is one of great responsibility and many challenges. We have been very fortunate to have had the services of Rajiv Gupta in this post, and I am very pleased that he will be continuing as our new Second Vice-President. The Executive Committee has been very busy over the last several years, and it has been a pleasure to work with Rajiv, Raymond Auclair, Randy Attwood, and Robert Garrison. Michael Watson, who is taking over as Treasurer, has been invaluable as our Society's solicitor. I wish him all the best with his added role.

Roy Bishop has perhaps the most important job in the Society — Editor of the *Observer's Handbook*. Roy spends an astonishing amount of time every year preparing the next issue. I cannot understate the importance of the *Handbook* to the Society. It is simultaneously one of the most important benefits of membership, a major source of revenue, and perhaps the biggest contribution the Society makes to the science of astronomy. The *Handbook*'s worldwide reputation is a testament to Roy's skill and dedication.

Every issue of this *Journal* is the result of many hours of work by Dave Turner, Pat Kelly, Dave Lane, Brian Segal, and a team of other volunteers. The multitude of changes made over the last several years have placed an enormous added burden on the team. Even now, small improvements are being made to every issue. The result of this ongoing evolution is a *Journal* which truly fulfills its role of communication, education and promotion of astronomy.

Over the course of my term, I have been able to visit 17 of the 23 Centres. In every case I have been most impressed by the hospitality and enthusiasm of the members. Every Centre has its distinct character, and the cross-pollination of ideas is one of the major strengths of the Society. For those members who have an opportunity to do so during their travels, I strongly recommend visiting other Centres whenever possible. It is an excellent opportunity to make new friends and learn more about astronomy.

I wish my successor, Randy Attwood, the best of luck in his new role. I trust he will find it as rewarding as I have. For myself, I am looking forward to building a small observatory, and spending more time at the eyepiece!

Journal

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

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From the Editor

by David Turner

Despite the Earth's 510 million km^2 surface area, it is a relatively small target for potential impacting objects in the solar system. Most residents of the Canadian Shield are aware, however, that the chances of collision with large pieces of orbiting space debris — comets and asteroids in particular — are far from negligible. The *Observer's Handbook* catalogues about twenty recognized, sizeable, impact sites on the Shield alone, and there are a small number of other sites in the rest of Canada. The inventory continues to grow (see JRASC, 89, 111, 1995). The Sudbury region bears the scars of two different impacts, one of which, Lake Wanapitei, is a scenic, deep, 7.5-km diameter, water-filled lake that lies off the northeast edge of the much older and much larger Sudbury basin. An object perhaps half a kilometre in diameter produced the former, while an object possibly twenty times larger produced the latter. Such large-sized impactors are much less common than the smaller meteoroids that collide with the Earth daily and give rise to meteors — of the shower and sporadic variety — and the occasional fireball. Yet they do exist in sufficiently large numbers that collisions with Earth in future may occur. The main focus of those who study Near-Earth Objects (NEOs) is the discovery and tracking of such objects.

It appears that Hollywood has recently discovered the public's growing awareness of the possibility of a future collision with a large NEO, since two of the new movies released to theatres for the summer season have plots based on the threat of collisions of a comet or asteroid with Earth. In an interesting turn of events, somewhat unexpected publicity for the movies was generated in March by an announcement from Brian Marsden of the International Astronomical Union's Central Bureau for Astronomical Telegrams that the recently-discovered, two-kilometre diameter asteroid 1997 XF$_{11}$ could pose such a threat in 2028. The news was released in the standard form of an announcement in the IAU telegram service to the international astronomical community, and also as a press release to the news media. Both proved to be very effective. A search by Eleanor Helin through her collection of asteroid survey films turned up images of 1997 XF$_{11}$ taken in 1990. The new positions increased the baseline for the orbital calculation, and the newly derived orbit for the object ruled out the possibility of its collision with Earth in 2028. The news media also gave considerable publicity to the story, which as it turns out was not entirely a good thing. The apocalypse/no apocalypse nature of the news headlines related to the story placed Brian Marsden at the focus of criticism from concerned individuals within the astronomical community.

In similar manner, our light-hearted, anonymous, advice columnist *Gazer* became the focus of disgruntled Questar users following his advice to "Anxious in Athabasca" in the February issue. Canada has a long tradition of humour related to making light of our foibles, and Nova Scotia is no exception — "Halifax, the Disaster Capital of the World (The Titanic Gravesites, The Halifax Explosion of 1917, City Council)" proclaimed a recent editorial cartoon. However, it appears from the heavy response to *Gazer*'s column that the collection of Questar users is less tolerant of comments about their telescopes, however light-hearted in intent those comments may have been. In order to provide "equal time" for the other side of the story, this issue contains an article by Clive Gibbons that offers a balanced appraisal of his experiences using a Questar telescope. ◉

News Notes
En Manchettes

CANADIANS FLOCK TO CARIBBEAN FOR ECLIPSE

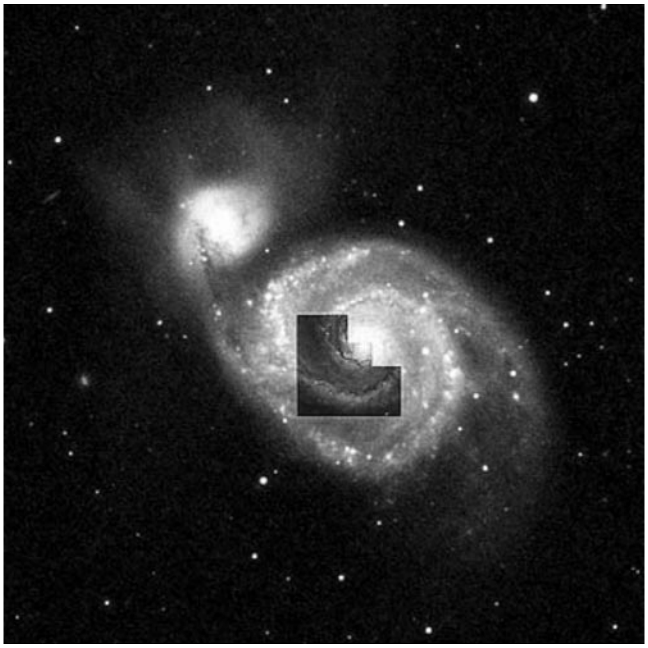
Balmy temperatures combined with the promise of a solar eclipse made the Caribbean region a magnet for Canadian amateur astronomers in late February. The maximum partial eclipse did not exceed 30% as seen from anywhere in Canada, and despite El Niño, February weather held little appeal. Caribbean islands, particularly Aruba and Curaçao in the Netherlands Antilles, were crowded with eclipse viewers, and several cruise ships had eclipse themes with Canadian tour directors or experts. Tortuous air routings meant that western Canadians had travel times as long as sixteen hours to the viewing destinations, with arrival and departure in the wee hours, however, the intrepid travellers to the Caribbean were rewarded with almost cloud-free skies, and totality approaching four minutes. The days before the eclipse, in Aruba and Curaçao, featured generally clear skies and steady Trade Winds, coming from the east at 20 to 30 km h^{-1}. By chance, the events of pre-Lenten Carnival were also in progress several days before the eclipse, adding to the interest of a tropical stay. Those attempting to do night-time observing and see southern sky objects were generally disappointed in the sky conditions, with severe light pollution made worse by high humidity. The islands are too small to allow simply driving away from light sources, each being about the size of metropolitan Toronto. The need to also find shelter from the wind, if a steady telescopic view was desired, made overall observing conditions less desirable than might have been expected. For casual observing, however, many Canadians found staring at Orion directly overhead, while doing the back float in a warm pool, a novel experience.

Pre-eclipse weather conditions heightened the tension leading to the event on February 26. Unlike the preceding days, that of the eclipse was generally cloudy. Disturbances in the region arise locally, and then are carried downwind, forming long streamers of heavy cloud. The phenomenon was particularly troublesome for land-based observers, while cruise ships could maneuver to find generally clear conditions, according to meteorologist Alister Ling, who was on board the *Norwegian Sea*. Some of the disturbances brought heavy, although brief, rain to the windward slopes, along with great anxiety for observers located there. In the face of cloudy conditions, some did make a last-minute dash to the generally clearer leeward side of the islands. Those who stood their ground were relieved as a clearing trend set in after first contact, and the total phase could be well seen through very thin cloud. Some western Canadians remembered the 1979 eclipse, also on a February 26, and found warm viewing conditions more agreeable than those on the central plains! That, and the stunning spectacle of the Caribbean eclipse, convinced many that Europe will be the place to be on August 11, 1999. So many, in fact, that the NASA Goddard Space Flight Center has needed to reprint its guide for that event. Page 106 of the 1998 *Observer's Handbook* gives more details of the upcoming eclipse and how to access the online version of the detailed eclipse guide.

BROADENING THE VIEW

The new electronic imaging technology of charge-coupled devices (CCDs) has brought about a revolution in astronomical photography both for research and recreational use. The many advantages include a high sensitivity, particularly in the red and near-infrared areas of the spectrum, linear response allowing multi-day exposures such as the Hubble Deep Field, the convenience of a non-chemical imaging process, and having digital data with many advantages over analogue photographs. It is not often realized by those who do not actually use CCDs that they have the drawback of very limited physical size, which permits only a very narrow field of view. For example, the Wide Field/Planetary Camera 2 on the *Hubble Space Telescope* has an angular view of about 2.5 arcminutes width, and even that has a part missing. That angle is less than one-tenth the apparent diameter of the Moon! *Hubble* would not be considered a very large telescope if found in a ground-based observatory, and CCDs similar to those used in its camera would produce an even narrower view if used in a much larger telescope.

In the past, making a detector with a larger field of view was mainly a matter of making a larger photographic emulsion, but making CCDs larger is not so easy. They are fabricated on silicon wafers and making large and defect-free wafers is difficult. The best approach is to use several CCDs arranged together in the image plane of the telescope. Such an approach is being taken at the *Canada-France-Hawaii Telescope* (CFHT) now, with ambitious plans for the future development of a "Megacam" imaging a very large field. A camera with 8192 by 8192 pixels is currently in use, soon to be joined by the CFH12k camera, which boosts one of these dimensions to 12288. The resulting image area is similar to that of a 4 by 6-inch photograph, with 15-micron resolution throughout. As a mosaic of 12 CCDs, such an image would have small seam marks throughout. Nevertheless, a much more efficient use of large telescope time can be made with this much of the image plane covered. The 8k and 12k cameras will lead up to Megacam, with an image roughly 250 mm on a side, corresponding to a one degree field of view (over 500 times the angular area of *Hubble*'s WFPC). Such a large area will require modification of the CFHT optical system, and poses other challenges as well. A single exposure will generate half a gigabyte of data, enough to fill a moderately large PC hard disk. Each night of use promises to produce on the order of 30 images, so that computing and data archiving systems need to be completely revamped to cope with the information flow. Early in the next millennium, the new system will be used for projects involving detecting faint objects over large areas of sky, including searches for faint solar system objects and deep surveys of galaxies.



The famous spiral galaxy M51 can have only its central regions imaged at one time by the *Hubble Space Telescope* because of its narrow field of view (inset). For the CFHT 8k camera the whole field shown would take up only one quarter of an image, and for the proposed Megacam only one sixteenth of an image (NASA/STSCI image).

CRATERS ON A STRING

Writing in the 12 March 1998 issue of *Nature*, University of New Brunswick researcher John Spray, with American and British colleagues, presents evidence that a chain of impact craters was formed sometime near the end of the Triassic period. The Triassic is the first of three geological periods during which dinosaurs were important forms of life, and was followed by the Jurassic, which began about 200 million years ago. Five craters of comparable age are found to have a geometric relation once the motion of continents since their formation is compensated through a plate tectonic reconstruction (for example, the Atlantic Ocean had not formed in the late Triassic). The largest and best known crater involved in the pattern put forward is that at Manicouagan, Québec, presently marked by a roughly 80 km diameter circular lake formed by flooding of its eroded structures. Interest in aligned craters was stimulated by the impact of Comet Shoemaker-Levy 9 with Jupiter in 1994, and already in 1993 (after the fragmented comet itself was discovered) workers at the University of Arizona explained crater chains on other bodies by proposing that they were signs of impacts of such comets. Recent work by Mike Rampino of New York University and NASA contends that another crater chain exists within North America itself, and the Clearwater Lakes in Québec have long been accepted as evidence of a double impact, so the concept of multiple impactors on Earth is not unique to the recent paper. As the authors point out, details of the geometical arrangement of the craters are not yet clear (only three are in fact collinear after plate tectonic reconstruction), and Earth's relatively weak gravitational field is unlikely to be able to cause disruption of a comet. Better dating of impact dates, and accurate knowledge of the former positions of Earth's shifting plates are necessary in considering other possible crater chains, and in exploring and verifying this one.

GIANT MIGRATING PLANETS

Recent discoveries of planetary masses orbiting around nearby stars have posed serious challenges to our understanding of planet formation. Some of the newly detected objects appear to be orbiting too close to their parent star in comparison with planets in our solar system.

It is generally believed that large Jupiter-like planets can form only at intermediate distances in a planetary system — close enough to the parent star for there to be enough matter to form a large planet but just far enough from the radiation of the star for the temperatures to be sufficiently low for the condensation of large amounts of rocky and icy solids. Such solids would in turn coalesce to form the cores of the giant planets, which could then accumulate available gases from the surroundings via gravitational attraction. At much smaller distances from the parent star, the higher temperatures would make the protoplanetary nebula too hot for light gases to condense, while stellar winds from the young star would help to drive such gases out of the planetary system. That would leave only small rocky worlds like our own, formed mostly of minerals with high condensation temperatures. Planetary systems are therefore believed to be organized communities made up of two exclusive neighbourhoods, an inner one composed of small rocky planets and an outer neighbourhood made up of giant gas worlds. The discovery of what appear to be Jupiter-mass planets orbiting such stars as τ Boötis and 51 Pegasi has thrown our understanding of planet formation into disarray. Such Jupiter-sized objects are found to orbit their parent stars nearly 8 times closer than the average distance between the Sun and Mercury!

A group from the Canadian Institute for Theoretical Astrophysics (CITA) has suggested a possible solution to this planetary puzzle (January 2 issue of *Science*). Led by Norman Murray, the group calculated that a gas giant planet could have formed in a more distant region but migrated into a much closer orbit about its parent stars. According to the CITA results, the migration is caused by the planet's gravitational interaction with countless smaller planetesimals in the protoplanetary disk that is believed to have existed in the earliest stages of planet formation. If the mass of the disk inside the planet's orbit is sufficiently large (> 0.03 solar mass for a planet at Jupiter's distance), the gravitational interaction between the planet and the planetesimals will rob the planet of enough orbital energy to send it closer to the star. The process continues until the amount of planetesimals falls below a critical value. Such objects are eventually removed from the system through a combination of orbital ejection and collision with the planet and the parent star. Although the time period is highly dependent on the details of the model, the group's results suggest that it takes between ten million and a hundred million years for the planet to assume its new orbit.

Subsequent research also shows that a system with several planets could produce a much more complex migratory behaviour. Placing a suitable disk of planetesimals into a planetary system like our own would actually force Uranus and Neptune to move into more distant orbits while moving the inner planets closer to the Sun.

COMET HALE-BOPP PROVIDES EVIDENCE FOR ORIGIN OF EARTH'S OCEANS

Comet Hale-Bopp (C/1995 O1) has given American, Canadian and French researchers tantalizing new evidence for the composition of comets and possibly the origin of the Earth's oceans. Comets are composed mostly of frozen water and dust and, for some, it has been an irresistible idea to link the source of the Earth's oceans to these vaporous objects.

On April 4, 1997, a team of astronomers from the University of Hawaii (U of H), the Herzberg Institute for Astrophysics in Victoria and the Observatoire de Paris-Meudon used the James Clerk Maxwell Telescope (JCMT) in Hawaii to scan for microwave emission from the great comet's coma. The position of the comet presented Hawaiian based researchers with a thorny problem, since near perihelion, and hence near peak activity, the comet was not easily visible from the island. The comet was high in the sky during the day, however, and the JCMT is the only telescope in its class that can be easily used in broad daylight. The dish is covered with a huge Gore-Tex membrane that protects the sensitive detectors from direct solar radiation. Acting like a "deep-sky" filter, the membrane allows over 80% of the precious microwave radiation to pass.

Roland Meier (U of H) led the international team of astronomers in a search for the telltale microwave emission from deuterated water (HDO). A deuterated water molecule is made of one atom of hydrogen (H), one of deuterium (D) and one of oxygen (O). Deuterium is the heavy isotope of hydrogen and has a nucleus comprised of a proton and neutron, while ordinary hydrogen has only a lone proton. By comparing the strength of the HDO emission with the inferred rate of water out-gassing, the team found that the deuterium/hydrogen ratio (D/H) for Hale-Bopp is around 3.3 ±0.8 atoms of deuterium for every 10,000 of hydrogen.

Their result is in good agreement with the *in situ* measurements done by the *Giotto* flyby of Comet P/Halley in 1986 and ground-based observations of Comet Hyakutake (C/1996 B2). All three are considered to be from the Oort cloud, a reservoir of comets about a light year from the Sun. More importantly, all three values for the ratio of D/H are nearly twice the value for standard mean ocean water (SMOW), which suggests that Oört cloud comets could not be the sole supplier of Earth's oceans.

A full description of the results can be found in the February 6 issue of *Science*.

RALPH NICHOLLS BECOMES OFFICER OF THE ORDER OF CANADA

Ralph William Nicholls was educated at the County School for Boys at Hove in Sussex, at Imperial College, London, and at the University of London, where he was awarded a Ph.D. and then a D.Sc. in spectroscopy. He was Senior Astrophysics Demonstrator at Imperial College before coming to Canada and the University of Western Ontario, where he moved through the ranks to become Senior Professor in 1963. For the latter sixteen years he was Director of the Molecular Excitation Group. In 1965 he joined York University as founding Chair of the Physics Department and as founding Director of the Centre for Research in Earth and Space Science (CRESS), including the directorship of its graduate programme. The original focus of CRESS was on atmospheres — the atmospheres of stars, planets, and the Earth. CRESS remains based on the novel concepts that he originated, including the acceptance of students from a wide range of backgrounds within a single graduate programme, from electrical engineering to chemistry to mathematics and physics. Here CRESS students learned about interdisciplinary research, and the application of basic physical principles to a wide range of applications. Professor Nicholls' research career has been devoted to many experimental, theoretical and observational aspects of the spectra of small molecules. The work emphasized diagnostic interpretation and prediction of intensities of molecular spectra from laboratory, atmospheric, space and astrophysical sources. His work ranged over a wide field, from spectra of the solar corona to the remote sensing of carbon monoxide in Earth's atmosphere, and while he could not be characterized simply as an astrophysicist, his interest in astrophysics was profound, extending from Imperial College to the present day, and involving considerable support for the astronomical community in Canada. The line strengths that he derived have been widely used by both astrophysicists and atmospheric scientists. Thus, on his becoming an Officer of the Order of Canada in May 1998, the astronomical community can share in the pleasure of this recognition of one of their own. ◉ *(Gordon Drake)*

Correspondence
Correspondance

ECLIPSE CONJUNCTIONS

Dear Sir,

In connection with my article "Conjunctions of Jupiter with the Moon or Sun in Eclipse" (JRASC, 91, 74, 1997), I recently received a copy of Jean Meeus' new book *Mathematical Astronomy Morsels* (Willmann-Bell 1997). In it Meeus refers to a similar article, including an explanation, co-authored by him, J. van Mannen and G. P. Können in the *Journal of the British Astronomical Association* (Volume 87, no. 2, pp. 135–145, February 1977). Not having access to the JBAA, I have not seen the paper, but I assume that the explanation given there is similar to my own. Consequently, I cannot make any claim to priority in explaining the Jupiter/lunar eclipse conjunction question, although I arrived at the explanation independently.

In his book, Meeus also states that the occultation of Jupiter by the totally eclipsed Sun on June 30, 1954, was first pointed out by H. O. Grönstrand in *Stockholms Observatoriums Annaler*, Band 16, no. 2, p. 22. Readers of the JRASC should probably be made aware of these facts.

Warren Morrison
Cavan, Ontario

Astrocryptic

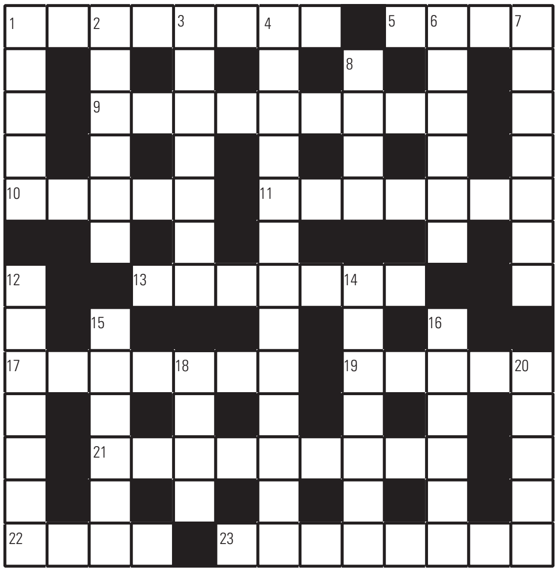
by Curt Nason, Halifax Centre

Across

1 Stellar stage evolved from poor gradient (3, 5)
5 Avon calls back for the starburst pattern (4)
9 Charge holder for captor about disturbed CIA (9)
10 Type G transposed to Africa (5)
11 Unethical memory returns in scrambled mail (7)
13 Delta Eridanus, perhaps? (7)
17 Interstellar molecules of biological tissue, I see (7)
19 An image more annoying than scary (5)
21 Naglers it uses for geometric figures (9)
22 Examine the centre of white stars (4)
23 Wildly disperse the meteors (8)

Down

1 He limited the closeness of planetary relations (5)
2 A metrical foot around Ida (6)
3 An A1 set-up orbiting Saturn (7)
4 Cloudy night lighting is no cult science (13)
6 Bad error by end of day yields model solar system (6)
7 Nullify argon eclipse type (7)
8 It is part of all potato molecules (4)
12 Not some bad time for observing (7)
14 Not Richard, but still a lion-heart (7)
15 Might they form from a stage of meteorite composition? (6)
16 The wrong road is take to Dickson's irregular crew (6)
18 The first name in lunar footprinting (4)
20 Weather satellite puts infrared part into south end (5)



Solution next issue.

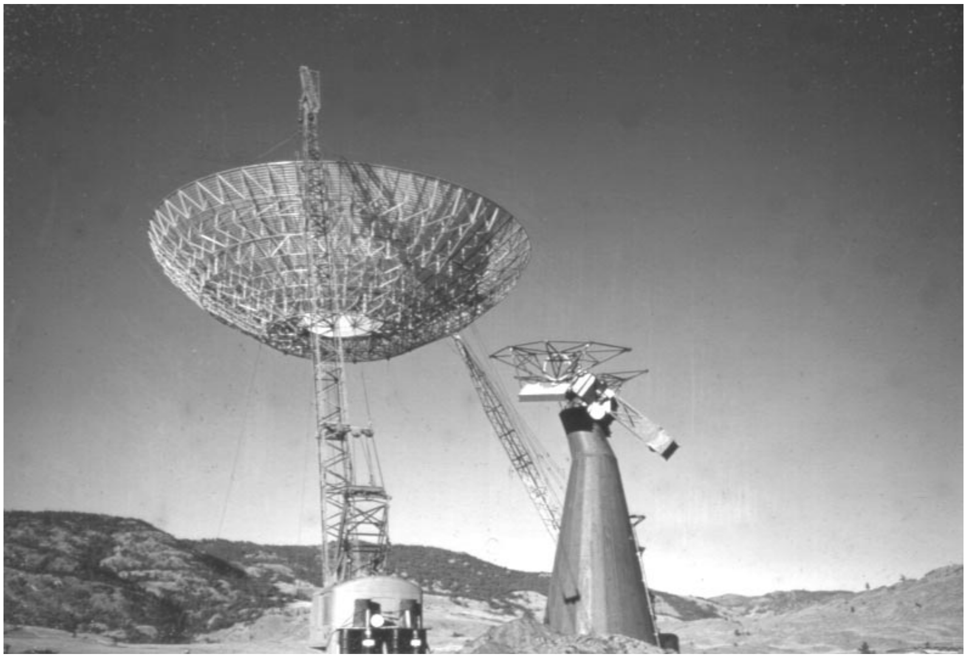
Feature Articles
Articles de Fond

The Beginning of the Dominion Radio Astrophysical Observatory

by Jack Locke, Honorary President, RASC

(This article first appeared in Cassiopeia *#96. It is published here with the permission of the editor.)*

The suggestion to build a radio observatory in British Columbia arose in 1956 in, of all places, Ottawa. It was a time when scientists in many countries were finally awakening to the role that radio observations could play in answering important questions about the universe. It seems incredible to us now that this awakening should have taken so long. Karl Jansky had made the initial discovery more than 20 years earlier, but his work had been largely ignored by the astronomers of the day. There was only one person who did not ignore the discovery. That person was Grote Reber, who was, until the end of World War Two, the only radio astronomer in the world.


Installation of the 26-metre dish in October, 1959. (all photos are by the author)

Unlike Jansky's, Reber's observations were not ignored, and when scientists returned to peacetime endeavours after the war, many turned to radio astronomy. In Canada, Arthur Covington began a lifelong study of the radio emission from the Sun. In other countries, notably England, Australia and The Netherlands, groups of scientists were making startling discoveries of sources of radio emission outside the solar system. The discoveries were so exciting that scientists in many countries realized that they could not afford to neglect this new tool with which to explore the universe.

At the Dominion Observatory in Ottawa, we too were aware of the rapid advances being made in radio astronomy. In April 1956, Dr. C. S. Beals, the Dominion Astronomer, wrote to his superiors in the Department of Mines and Technical Surveys strongly recommending that the Observatories Branch be allowed to enter the new science of radio astronomy. The suggestion was so well received that the preparation of a concrete proposal was begun immediately. The submission, calling for the establishment of a radio observatory in British Columbia, was submitted to the Minister before the end of the summer and was approved by Treasury Board at the end of November — a mere seven months after the first tentative suggestion had been made. Those of you who have been involved recently in putting forward proposals for new facilities for astronomy in Canada will appreciate that seven months from conception to approval is, by today's standards, an incredibly short time. Although it was always intended that the observatory should undertake research in many areas, the case for the observatory was based on the opportunity it would provide to extend into the radio region the studies of our own Galaxy for which the astronomers at the Dominion Astrophysical Observatory in Victoria were well known. Since its discovery in 1951 it had been demonstrated that observations of the 21-cm line of hydrogen could provide important information about the structure and dynamics of our Milky Way system not possible from optical observations. It was a wise decision, for the proposal was seen by the authorities as a proposal to build on existing strengths.

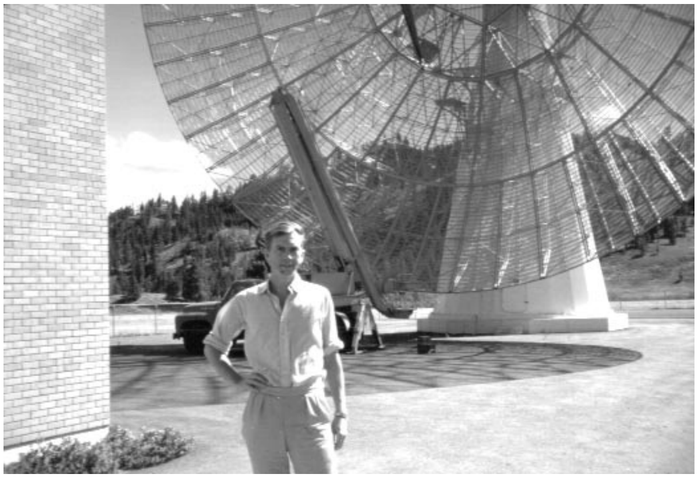
One of the first tasks was to choose a site for the new observatory. The most important criterion for a good radio site is freedom from man-made interference. That dictated a mountain valley where the surrounding mountains would act as a shield. Potential sites were selected by poring over topographical maps and aerial photographs. To assist in the physical investigation of the selected sites, we "borrowed" Ed Argyle from Victoria where he had been involved in developing photoelectric systems for optical telescopes. Together we assembled some site-testing equipment — radio antennae and receiving equipment with which to measure interference levels — and Ed and I set out from Ottawa by truck for British Columbia in March of 1957.

We visited many sites, both on Vancouver Island and in the Interior. In the end the choice was not a difficult one. The interference levels at White Lake in the Okanagan were the lowest of any site we had visited and it had other distinct advantages. The area of reasonably flat land was large enough to accommodate antenna arrays we might wish to build in the future. It was also surprisingly close to very pleasant communities where the staff could live. The decision to build at White Lake was taken in July 1957 following an inspection of the site by Dr. Beals. Detailed planning and land acquisition began immediately thereafter.

The 25-metre parabolic telescope was ordered and arrived in Penticton in February 1959. John Galt also arrived in February and was the first staff member to take up residence in Penticton. John had been taken on staff about a year and a half earlier and had been sent to Jodrell Bank Observatory in England to gain experience. When I moved to Penticton in August of 1959, construction at the site was well under way.

Dr. C.S. Beals, the Dominion Astronomer, visited the staff during the early days of construction. L to R — John Galt, Ed. Argyle, Kaye Adams, Dr. Beals and the author. Missing is Roy Hamilton — who took the picture.

The summer of 1959 was an exciting time. The telescope was erected, the receiving equipment was delivered — to be immediately modified by John Galt — and the buildings were completed. Adequate staffing of the new observatory turned out to be a difficult matter. Approval of funds to build the observatory did not carry with it approval for any new staff positions. When it came time to request the necessary positions, the Government had changed and one of the aims of the new Diefenbaker Government was to decrease, not increase, the size of the civil service. As a consequence, very few positions were available to the Dominion Observatory and at the time of commissioning, the staff was a very lean one. It consisted of a total of 8:



An early visitor to the observatory was Sir Martin Ryle, Director of the Mullard Radio Observatory, University of Cambridge.

- 4 Scientists — Carman Costain had arrived in the fall of 1959, fresh from studies at Cambridge, to join Galt, Argyle and Locke,
- 1 Technician — Roy Hamilton,
- 1 Machinist — Bud Orge,
- 1 Secretary-clerk — Kaye Adams
- 1 Caretaker — master of all trades — Ray Stewart.

The official opening took place on June 20, 1960, at 4 o'clock in the afternoon. Many prominent scientists from both the United States and Canada attended. A large group from Ottawa — government officials and leading scientists — had arrived by special plane. June 20 was a beautiful day but the wind was exceptionally strong, prompting the Mayor of Penticton to remark during his address that, "This wind must have flown in from Ottawa, ha, ha." The wind blew sand into the faces of the dignitaries on the platform, which included, of course, the Minister. At the first opportunity following the ceremony, I fired off to Ottawa a request for funds to pave the area around the telescope and the access road. The Minister approved the allocation immediately. ("It is an ill wind turns none to good." Tusser 1524-1580).

The Observatory was declared open by the Honourable Paul Comtois, Minister of Energy, Mines and Resources, as he pushed a button that caused the telescope to scan across the strong radio source "Cas A." As the telescope scanned the source, the rise and fall of the radio signal was broadcast over the loud speaker system. In those early days we did not have a great deal of confidence in the reliability of the receiver and so, a few days before opening day, we recorded the signal on tape. As the time for the official opening approached, Roy Hamilton made his way to the basement of the Control Building where he placed


An aerial view of the observatory, taken following construction of the T-shaped 22-MHz array.

his hand on a switch that would transfer the loud speaker system to the tape recorder if the live signal failed. Fortunately it did not.

The opening was followed by a 2-day symposium entitled "The Objectives of Radio Astronomy." As I recall, it was at that symposium that the possibility of a Canadian Long Baseline Interferometer was first discussed.

Carman Costain had arrived from Cambridge with thoughts of making low frequency observations at White Lake. Consequently, very soon after the opening, a proposal was forwarded to Ottawa for construction of a low frequency telescope. A plea for quick approval was based on the argument that there would be a sunspot minimum in 1966, at which time interference would be at a minimum. Approval was quickly received.

In those early days we could not have managed without the support and co-operation of the people of the Okanagan Valley, and we quickly felt a part of their community. Some residents must have had reservations, however, for, under pictures of Ed Argyle and Carman Costain , the *Penticton Herald* felt compelled to write:

"Who are these scientists who chart the course of the universe? Well they are all normal, healthy Canadians. And they all are very much concerned with man's welfare. Few, if any, earn much more than a well-paid professional man. All are married, have children, hobbies. They golf, curl, tinker around home, go fishin' and hunting, worry about the Dodgers and Canada's Olympic Hockey Team." ◉

Following graduation from the University of Toronto, Jack Locke joined the Dominion Observatory and was Officer-in-Charge of the Dominion Radio Astrophysical Observatory from 1959 to 1962. In 1966 he joined the National Research Council and was the first director of the Herzberg Institute of Astrophysics, until retirement in 1985.

FROM THE PAST AU FIL DES ANS

OFFICIAL OPENING OF THE DOMINION RADIO ASTROPHYSICAL OBSERVATORY, WHITE LAKE, PENTICTON, B.C., JUNE 20, 1960

On the afternoon of Monday, June 20th, in fine weather but with a stiff breeze troubling the speaker a little, the Hon. Paul Comtois, Minister, Department of Mines and Technical Surveys, formally opened the Department's new Observatory, to be known as the Dominion Radio Astrophysical Observatory, before an audience of over 150 scientists and other guests from both Canada and abroad. The Minister emphasized the importance with which the Government regards fundamental scientific research and contrasted the unprejudiced and international manner of science with the unsatisfactory nature of mankind's achievements in the more general fields of international relations and mutual tolerance. The Dominion Astronomer, C. S. Beals, traced the history of astronomical research in Canada, and showed how the need for a large radio telescope developed from the general galactic researches already pursued and showed the continuity of this new effort with instrumental developments in the past. The President of the National Research Council, E. W. R. Steacie, speaking as a chemist, gently rebuked his astronomical colleagues for their ill-concealed pride in the very large and costly apparatus they require, with the advent of space explorations becoming costlier than ever, and in their ability to choose beautiful sites for their studies. He referred to the fact that science and politics are now inextricably connected, giving rise to many very difficult decisions but also leading to a great increase in governmental scientific effort. The officer-in-charge of the new observatory, J. L. Locke, described the search for a suitable site and enlarged on the eminently satisfactory qualities of the valley in which we found ourselves, both aesthetically and for the purposes of radio astronomy. The problems of the structure and motion of gas-clouds in the Galaxy and the existence of large-scale magnetic fields would be vigorously pursued with the new telescope, one of the finest such instruments in operation, he said.

Not to be forgotten was the comment of his Worship, Mayor Oliver of Penticton, "what a tourist attraction!"

The 84-foot telescope was seen in action immediately after the opening addresses, being set in motion after M. Comtois pressed the appropriate button. As it slowly traversed the strong radio source Cassiopeia A, the signal was broadcast over the public address system to be heard clearly by everyone.

A tour of the office building and grounds followed and the staff-members explained the operation of the control panel of the telescope and the intricacies of the receivers being used with it. In the evening a very enjoyable reception was given at the home of Dr. and Mrs. Locke on the shores of Skaha Lake; a feature of this evening was a short concert of French-Canadian songs conducted by M. Comtois and ably assisted by Maarten Schmidt — from Leiden by way of Pasadena.

Under the joint sponsorship of the National Committees for Canada of the International Astronomical Union and the International Union of Radio Science, a symposium on the objectives of radio astronomy was held on Tuesday and Wednesday, June 21 and 22. In the first paper, P. E. Argyle of the D.R.A.O. staff discussed his design of a proposed 100-channel receiver at 21-cm wavelength suitable for use with the radio-telescope, and later C. H. Costain gave an account of work at Cambridge on low frequency antennas and described a large (about a mile across) "T" antenna which is to be built at White Lake. In the afternoon David Hogg summarized our knowledge of the radiation from thermal sources in the Galaxy, while the paper by Donald A. MacRae (read in his absence) discussed other galactic radiation. G. A. Harrower followed with a talk on the distant radio sources and their importance to cosmological theories.

Dominion Radio Astrophysical Observatory, White Lake, Penticton, B.C., showing the 84-foot radio telescope and the office building on opening day, June 20, 1960. (Photo by *Penticton Herald*.)

After the dinner on Tuesday evening at the Prince Charles Hotel, Penticton, Dr. Beals read various congratulatory messages to the new Observatory, including a long and eloquent address in Latin from Cambridge. The principal speaker, Maarten Schmidt of the California Institute of Technology, then gave a thorough account of our present knowledge of galactic structure obtained from both optical and radio observations (this talk will be published in a forthcoming issue of the *Journal*).

On Wednesday morning, his long continued and well-known work on the Sun was discussed by A. E. Covington, and P. M. Millman gave an interesting account of what might be called "radar astronomy," namely the direct radio contact of meteors and planets. In the open session in the afternoon, this subject was much amplified and proposals were made for the use of the Prince Albert (Sask.) 84-foot radar. With the prospect of more powerful transmitters in the near future, radar contacts with the nearer planets becomes a useful means of interplanetary investigations. D. S. Heeschen and Schmidt gave accounts of current work at Green Bank, West Virginia, and at Owens Valley, California, and Dr. Schmidt re-emphasized the need for more precise galactic surveys than now exist and which could be undertaken at the D.R.A.O.

Various events of a semi-sporting nature took place during lunch hours during these meetings. Several well-known astronomers showed their ability to climb ladders to great heights, and many of the delegates had a ride to the telescope focus some 50 feet above ground level in the hoist "Girette."

Dr. Locke and the staff are to be congratulated on their fine achievement in bringing this powerful instrument into operation so quickly.

by G. J. Odgers,
from *Journal,* Vol. 54, pp. 269-272, December, 1960.

Carnival Eclipse

by Glenn Hawley, Calgary Centre

A total solar eclipse is one of Nature's most magnificent phenomena. As the Moon creeps over the surface of the Sun, the tension mounts, the world slowly darkens, and shadows become eerily precise. The effect of actual totality has enormous power over us mortals. For example, during the Chile eclipse, at 4,380 metres, a skull-splitting altitude sickness headache plagued me all morning. To my great surprise it disappeared completely at the instant of second contact, not to return to full strength until an hour and a half later. Those who have witnessed only partial or even annular eclipses do not know what they have been missing.

The Calgary Centre has participated in chasing total solar eclipses since the 1960s (see article in February 1997 JRASC). The most recent expeditions were in 1991 (Mexico), 1994 (Chile), 1995 (India), 1998 (Curaçao), and the Centre is currently working on 1999 (Turkey). Each tour has offered a variety of accommodations and generally different excursion options. For Curaçao we could take the island option, or witness the eclipse aboard the cruise ship *Norwegian Sea*.

My wife, Lorna, and I chose the island, since it would allow me to set up my telescope to observe the night sky from a mere 12 degrees above the equator. Other attractions listed for our Princess Beach Resort were snorkelling and scuba diving.

Our flights took us through Dallas with just a plane change, but unfortunately we had to stay overnight in Miami in both directions. The only aircraft trouble occurred just as we were about to take off from Miami, when without warning a loud bang shook the plane. I looked around and saw Terry Dickinson with eyes as wide as saucers as I am sure everyone thought a bomb had exploded on the plane. The pilot calmly notified us on the intercom that this model of Boeing 727 occasionally has engine compressor stall problems in strong crosswinds. So, after we taxied off the runway and gunned the engines at full throttle to verify that all was okay, we then successfully lifted off to Curaçao.


The author and his wife Lorna did some pinhole projection at about mid-partial eclipse. They used a pre-made sign which when projected read "CURACAO 98 02 26" in tiny crescents (see inset). (Photo by Dave Lane)


Most of the expedition members set up in the lee of a man-made wind break constructed of sea containers which were provided by the Government of Curaçao. (Photo by Dave Lane)

Curaçao itself was easy to handle. Though the customs people had us fill out forms promising to take back with us our "scientific appliances" (and not sell them to the locals), they seemed more to be covering their position with paper than actually worried about the possibility. The Princess Beach was a delight. After receiving our welcome cocktails and our room keys we quickly explored the beautiful sandy beach. A breakwater of boulders protects the beach itself and provides a shallow lagoon, while outside the breakwater the sea floor slopes gently deeper. Two fresh water swimming pools provide a place to rinse off the salt water. Naturally, pool and beachside bar service was available in addition to the air-conditioned establishments inside. There were even parrots and Caribbean parakeets on display. One parakeet could whistle and sing "La Cucaracha." Some of our tour members stayed at another hotel called the Sonesta Beach Hotel, located on the other side of Willemstad.

The first two nights we went on the evening bus trip out to the official observing site. Beyond the town of West Punt, at the extreme western end of the island, the authorities had stacked a row of shipping containers to create a windbreak. The trade winds blow strongly and steadily in these parts, and the local TV station even has as its symbol a Divi-Divi tree bent over and growing sideways from chronic wind. It was quite bizarre adjusting the wedge almost vertical and searching through the haze near the horizon for Polaris. Despite the wind I managed to gather a few delights in the eyepiece, as well as finally finishing off my "110 Finest NGCs" list. Looking at winter constellations like Orion and Taurus in T-shirts and shorts is something that all Canadian amateur astronomers should do at least once in their lives. Some of the southern sky highlights were Omega Centauri, Eta Carinae, Southern Cross, the Jewel Box and much more.

We had a pre-eclipse meeting (and cocktail party) to give novices some idea of what to expect, how to safely observe and photograph the Sun, and to emphasize that on eclipse day we run on "Eclipse Time." For example, if it says we leave at 06:00, the bus will not be there at 06:01 for any latecomers. Calgary Centre trips are dedicated to serious eclipse chasers, and we permit no slackers to jeopardize the eclipse for others. Meanwhile tours of the island, the Carnival parades, the Sea Aquarium, and other attractions kept us amused.

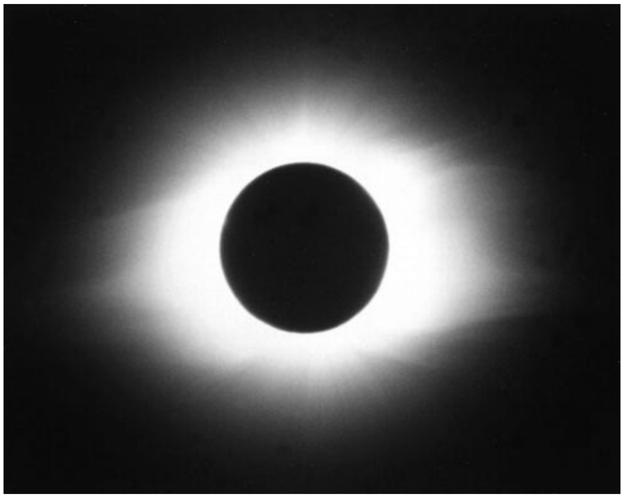

One of the tour organizers from the Calgary Centre, Don Hladiuk and his daughter. (Photo by Dave Lane)

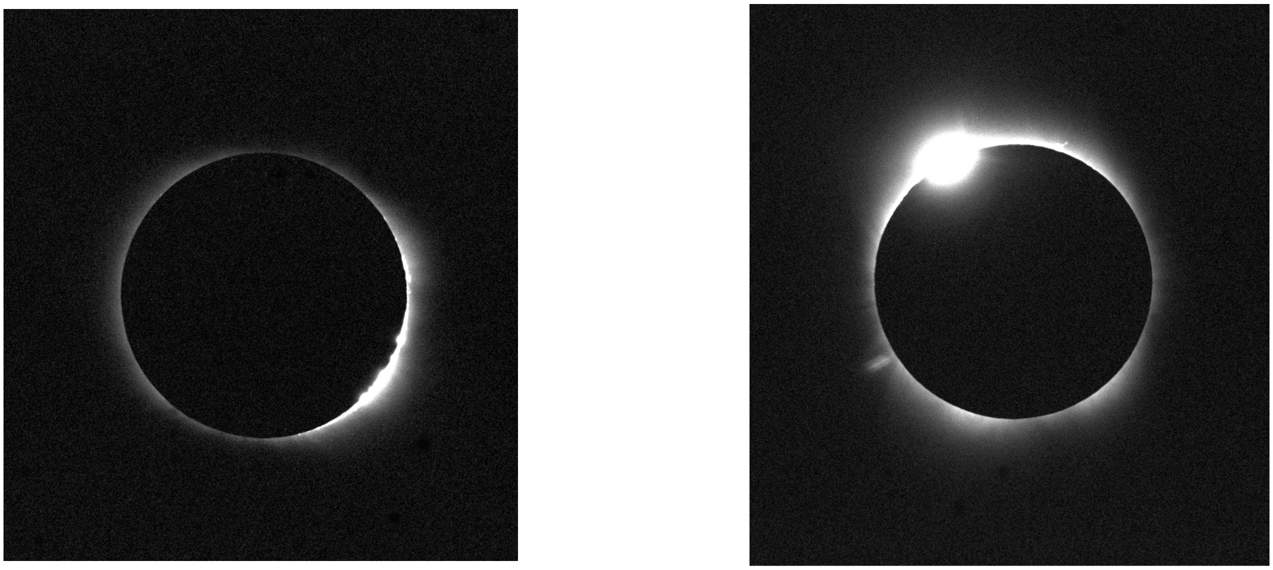
The morning of the eclipse was the cloudiest and gloomiest we had seen on the island. It rained for the first time in almost a month, and we were all a bit tense as we drove out to the site. One of Curaçao's major sources of income is tourism, and the "official site" was the best organized I had ever been to in five eclipses. Great concrete blocks anchored a set of open walled tents for some much appreciated shade. Folding chairs and little tables were available to those who moved fast, and the Polar Beer truck showed up with coolers full of the local brew. Box lunches were served out, including free drink tickets. Around one corner of the windbreak were parked some portable biffies, a hospital tent, and they even had a water truck come around spraying down the dust. As it was still ten-tenths clouds we arranged one bus facing the exit road. That way those who were very determined would be able to make a dash for any clear spots if the site was still overcast at eclipse time.

Happily, the clouds steadily dissipated and the line of clear sky we could see off to the west crept ever closer to the island. By the time of first contact there were but a few scattered clouds, and totality found us under totally clear skies. The decades of historical weather data used to choose observing sites paid off again. Venus became visible when the Sun was a bit more than half covered, adding to the mounting excitement. I had originally thought to mount my camera piggybacked onto the telescope, but with the wind we had experienced at the site I decided to bolt the camera directly to the wedge, and use the wedge angle adjustment and rotation of the whole tripod for alt-azimuth aiming of the camera. It was easier to do than I had feared, although one fellow seeing my Meade 2080 tripod with the little OM-2 on it declared it "the worst case of overkill" he had seen in some time.

Most of the expedition members gathered for a group photo shortly after totality. (Photo by Dave Lane)

Each eclipse is different. As totality neared I looked down and saw the best shadow bands I had ever seen rippling across the ground. At some eclipses they can only be seen on a bright white flat surface, if at all, but these were clear even against the dark reddish soil. The temperature cooled off by 4.5 degrees C as recorded by Marla Hladiuk. The wind even dropped to produce an "eclipse calm," in contrast with the better known phenomenon of "eclipse wind." A beautiful, but short, diamond


A 2 second exposure taken at totality using a Tele-Vue Pronto refractor (500-mm f/7) and Kodak Ektachrome 100 film. (Photo by Dave Lane)



Left: This photo was taken just before the beginning of totality (2nd contact) when some small prominences and the chromosphere and inner corona became visible. Right: More of Bailey's Beads and less of the chromosphere and inner corona are evident in this photo which was taken just after the end of totality (3rd contact). A Meade 4-inch Schmidt-Cassegrain telescope (1000-mm at f/11) and a 1/500 second exposure on Agfacolor HDC (ISO 100) print film was used to capture both photos. (Photos by Don Hladiuk)

ring effect came next, though Bailey's beads were pretty much non-existent. In binoculars some prominences could be seen, but the corona was quite bright and they did not stand out as well as in some eclipses. Jupiter, Venus, and Mercury were brightly seen on either side of the eclipsed Sun. Every eclipse I forget to do one thing or another in the excitement of the moment, and this time I failed to look for Mars and Saturn farther to the left. The corona was a beautiful pearly white, with polar brushes visible in binoculars. In a few very short minutes we could see the edge of the Sun start to glow pink from a forest of small prominences, and we knew that it was time to try to catch the outgoing events. Again a beautiful, but longer, diamond ring, more shadow bands, and it was time to celebrate with champagne!

To view some of our beautiful eclipse photos try our website at http://www.syz.com/rasc/. Look under "Centre Activities."

The Cruise option participants were led by Alister Ling of the Edmonton Centre, and successfully positioned the Norwegian Sea cruise ship right on the centre line to observe a full 3.75 minutes of totality.

Before leaving the site, Terry Dickinson had an interview with Jay Ingram on the Discovery Channel which was viewed across Canada later that evening. Local TV interviewed Alan Dyer and Don Hladiuk, and a team from France's Canal 2 TV slipped me into a documentary on eclipses they were preparing.

The only problem we encountered was a flat tire on the way back to the hotel. That delayed us a mere 15 minutes before a replacement bus arrived, yet another indication of how well the people of Curaçao were prepared for the big event.

That evening we had a party at the hotel beach, with a big buffet spread and an open bar. The Sun slipped beneath the horizon and we partied until midnight (well, Rob Dick of Ottawa and I had our rum punches till midnight, anyway).

The rest of the week was snorkelling, sleeping in, a little scuba diving, and even just lying in the sunshine before heading home. Many eclipse chasers collected souvenir T-shirts, stamps, commemorative beer cans, lapel pins, sea shells and a host of other Caribbean delights. On Friday evening (February 27th) a thin crescent Moon and the planet Mars shone in the beautiful Caribbean sunset skies.

Although the people of Curaçao will have to wait another 500 years for an eclipse to cross their tiny island again, the RASC Calgary Centre has another tour planned for the August 11, 1999, eclipse in Turkey. For more information contact the Turkish Travel Specialists at 1-888-488-7226. A total solar eclipse is an event you must see at least once in your lifetime.

On behalf of the Calgary Centre I would like to thank our co-sponsors the Calgary Science Centre (especially Alan Dyer), the Travel Exchange (especially Nicole Neidermayer and Allen Leong), Alister Ling of the Edmonton Centre, Don Hladiuk of the Calgary Centre and Taber Tours (especially Marcial Garcia) for making the expedition one of the most successful. ◉

Glenn Hawley has witnessed five solar eclipses (partials and annulars don't count) and is currently serving as President of the Calgary Centre. He processes seismic data for a living, wrestling computers in the quest for oil and gas. The time off he is permitted to take for Star Parties and General Assemblies is always greatly appreciated.

Attention Eclipse Lovers!

1999 Solar Eclipse Expedition to Turkey

Sponsored by The Calgary Science Centre and
The Royal Astronomical Society of Canada, Calgary Centre

On August 11, 1999 the Moon will move in front of the Sun, plunging a narrow strip of land and water extending from Central Europe to India into darkness. A total solar eclipse is one of Nature's most dramatic and moving experiences. In minutes the whole Earth-sky environment is transformed. Planets and bright stars appear. A 360-degree sunset glow rings the horizon. The Sun disappears behind the dark silhouette of the Moon which is ringed by the magnificent solar corona. The Calgary Science Centre, the Royal Astronomical Society of Canada, Calgary Centre and the Turkish Travel Specialists have designed a tour to a site in Southern Turkey where weather prospects are excellent.

The expedition will begin in Istanbul where you will tour the Topkapi Palace, St. Sophia, the Blue Mosque and the Grand Bazaar. On the next day we will tour the Dolmabache Palace and take the relaxing Bosphorus Ferry cruise. Later in the evening the group will attend a special dinner at a seaside restaurant complete with local entertainment.

On August 9 the group will fly to Elazig (via Ankara) and transfer to our hotel where the pre-eclipse briefing will be held. Everyone will receive details on how to safely view and photograph the solar eclipse from experienced eclipse chasers. Night sky viewing will also be available from this location. On the next day we will tour the archaeological sites in the area including Harput. The afternoon and evening are free to prepare for the eclipse.

On August 11 we will board coaches and travel to our prime viewing site near Hasankyef on the banks of the Tigris River. Our viewing location is a fascinating archaeological site dating back to the time of the Roman Empire. Totality will be approximately two minutes in duration. Weather prospects are excellent with about an 80% probability of enjoying clear skies. After viewing the eclipse we will have a celebration dinner back at the hotel then have the lights turned off to view the Perseid meteor shower. The next day we will have the morning free before flying back to Istanbul and returning home.

For an additional cost, extensions are available to visit Mount Nemrut, the underground city at Cappadocia, and the spectacular ruins of Ephesus. There are also one week packages to relax at the Kusadasi Resort or take a one week cruise on a traditional Turkish yacht.

Tour pricing for the land package is in U.S. dollars with the basic land program starting at $1195. All pricing is based on twin/double occupancy and is limited to only 80 people. The 8 day tour includes visiting the sites listed above, domestic travel and hotel accommodation with breakfast daily (plus some lunches and dinners also included). Tour program is escorted by professional tour escorts from Turkey, the Royal Astronomical Society of Canada, Calgary Centre, and the Turkish Travel Specialists.

To receive additional information contact: Judy Burdge, Turkish Travel Specialists, #275, 1575 West Georgia Street, Vancouver, BC, V6G 2V3, Phone: (604) 608-0443 or (888) 488-7226, Fax: (604) 608-0449, Website: www.turkish-travel.com

For technical inquiries contact: Don Hladiuk, 28 Sunmount Rise SE, Calgary, AB, T2X 2C4, Phone: (403) 233-3252, E-mail: hladiukd@cadvision.com

Test Report: The Questar 3.5-Inch

by Clive Gibbons, Hamilton Centre, gibbonsc@mcmail.cis.mcmaster.ca

Life is strange sometimes. Up until about two years ago this was one test report I thought I would *never* write. You see I did not have much appreciation for Questar telescopes or what I thought they represented. Perhaps some of you feel the same way; that Questars are something of an expensive curio — too small to be serious, too precious to be used on a regular basis, the sort of instrument you would expect to see under a glass dome, in a doctor's or lawyer's study. And, what stargazer in their right mind would spend $5000 for a teeny weenie telescope, when they could spend that much on a big Schmidt-Cassegrain, or a monster Dobsonian? Well, hopefully this report will shed some light on the answer.

First, some background. The Questar 3.5-inch is a Maksutov Cassegrain telescope that has been in production since 1954. About 11,000 units have been produced over the years and they have changed very little in design and materials. Most recent units have the option of cordless DC-power operation (like the Meade ETX). The basic astronomical version (Standard model) comes with a Pyrex main mirror, single-layer MgF_2 coatings on the corrector, and protected aluminum on the mirrors. The mounting is a dual-tine fork, with electric Right Ascension (RA) drive and slow motions and setting circles on both axes. Three tabletop legs are included, along with two oculars, an off-axis solar filter, a power cord and the carrying case. Today, the entire package sells for approximately US$3500. When Questar first appeared in 1954, the price was US$795, so if inflation is factored in, today's price is a relative bargain. A "Duplex" model is available, which allows the optical tube assembly to be easily removed from the fork mounting, for use as a spotting scope or telephoto lens. Optional enhanced coatings are also available, as is a Zerodur primary mirror.

The Questar I tested was a 1962 vintage Standard model, with Pyrex mirror and standard coatings. It had been obviously well used, but was mechanically fit. This was no doubt helped by the quality of materials used in the construction and the overall fit and finish of the instrument. There is no plastic here! The optical coatings were dusty, but after a cleaning showed no sign of deterioration. The two oculars included with the unit were a 26-mm Koenig and a 13-mm Erfle. Both use a proprietary thread to attach them to the telescope. Newer Questars use Brandon oculars, but again, having a "non-standard" mounting. There is a 1.25-inch adapter available, though. One of the nicer features of the scope is its "control box" at the rear of the optical tube. It houses a built-in Barlow lens, star diagonal prism and finder. By flipping a control lever, you can flip the diagonal out of the optical path, which allows you to look through the built-in 4× finder scope. Flip another lever and the Barlow slides into place, increasing magnification by a factor of about 1.8×. The action of these controls is quick and positive. Focusing the scope is done by a micrometer screw, which moves the primary mirror along its optical axis. This action is very precise, especially since the test instrument is over 35 years old. Some lateral image shift is seen when focusing and amounts to about 45 arcseconds, which is considered normal. Other fine Questar touches include a Moon map printed on the exterior of the optical tube assembly and a star chart portrayed on the outside of the sliding dew shield/ light shade. A mention should also be made of the RA and Declination slow motion controls. They have a smooth, continuous action and are clutched so that no locks need to be engaged or disengaged to make positional adjustments.

The first celestial target I viewed was the First Quarter Moon. At low power (48×), the image was tack sharp. At 96× (using the Erfle ocular), the apparent field is 75 degrees and still looks extremely sharp. Only towards the edges of the wide field does the image go soft, as a result of aberrations in the ocular. With the Barlow flipped in, the power goes to 160× and craters still snap into focus. The only drawbacks to using the Barlow are a broad, ring-like reflection that appears towards the edge of field and a very slight amount of residual colour. The reflection is not present when viewing other, less field-filling objects, but the tiny dose of secondary colour can be spotted when viewing bright planets or stars.

Jupiter was the next target, and nice detail was immediately seen at 48×. The best view seems to be 96×, with good image brightness, contrast and still no shortage of fine detail. The shadow of one of Jupiter's satellites could be seen transiting the disk. At 160× the mediocre seeing spoiled things a bit and it became apparent that image brightness was beginning to suffer slightly. Next up were some stars. The diffraction image looked close to textbook in quality; a nice regular Airy disk surrounded by one diffraction ring. The brightest stars show a second, much fainter ring. The double double in Lyra was nicely resolved. Even Eta Corona Borealis (about 1 arcsecond separation) was revealed as overlapping disks.

It is clear from all this that the Questar performs about as well as an obstructed 3.5-inch instrument. But the *true* pleasure of using the instrument comes from its tremendous portability and user-friendliness. It is only a matter of minutes between deciding to go observing and actually looking though the eyepiece, and once you get to that point, all controls are easily at hand and a pleasure to use. The clock drive is accurate and dependable, with only a few seconds lag when first starting up.

Does the Questar have flaws? Sure, but they are largely caused by tradeoffs in its ultra compact design. The finder scope's aperture is a mere 15-mm. That is actually too small, but it is somewhat compensated by the sharpness of images it delivers. The farthest south the scope can observe when polar aligned is declination −42 degrees, because of the relatively short length of the fork arms. Also, the drive base obscures the finder scope's field of view when pointed south of declination −25 degrees. Finally, it does have only 3.5 inches of aperture, so it is not the best choice for a diehard deep sky fanatic.

Is it expensive? I guess that depends somewhat on your financial resources, but when one considers the longevity of a Questar and how often it will get used during that time, the price might not seem so large after all.

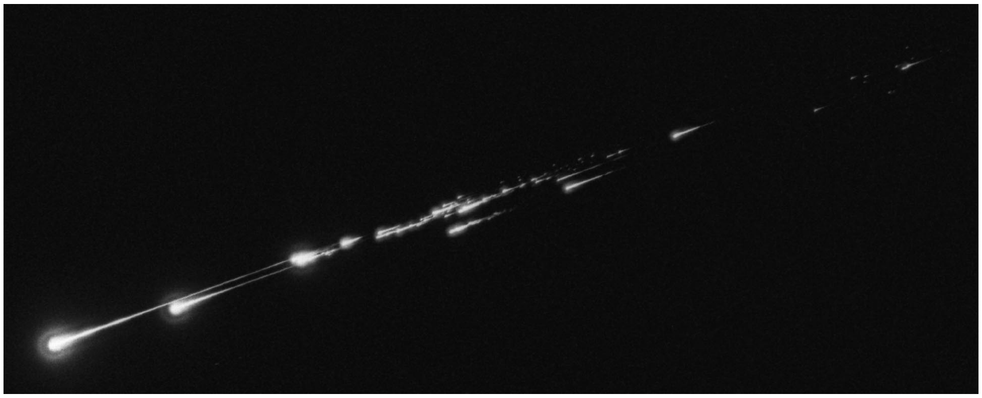
So, what is the final verdict? Well, let me say that my previously negative opinion of things Questar has been largely overturned. Its high quality, ingenious features and ultra-portability have opened my eyes to why it is the right choice for some, very sane, stargazers, and, if you ever see one available for a "fire sale price," I would recommend you snap it up! ◉

Clive Gibbons is a technician in the School of Geography and Geology at McMaster University in Hamilton, and lives with his wife Edna in Burlington with two cats, two Questars, a Celestron 8 and a homemade 8-inch f/7.5 Dobsonian. Previously sales manager and technician at The Scope Shop *in Toronto, he now provides care and feeding for the computers, microscopes and other geo-science-related equipment at McMaster. He is a member of the Hamilton Centre of the RASC as well as the Hamilton Amateur Astronomers. His hobbies include amateur astronomy, photography, computing and the appreciation of fine wines.*

Reflections

Chicken Little, Big Time

by David M. F. Chapman



A still photograph of the Peekskill meteorite fireball (Oct. 9, 1992). (Photo by Sara Eichmiller using a 300 mm focal length lens).

If you weren't closely following the nightly news back in mid-March, you might have missed the news blip about the recently discovered asteroid known as 1997 XF_{11}. Based on about three months of observations, the International Astronomical Union announced that the asteroid would pass very near Earth on 2028 October 26, perhaps coming as close as 55,000 kilometres, or one-seventh of the distance to the Moon. The I.A.U. added the object to the list of just over 100 "potentially hazardous objects," and the media had a field day with the gloom-and-doom story based on the slender possibility that 1997 XF_{11} might actually strike the Earth. The very next day, the same news announcers were chuckling over the "goof" that astronomers had made, as new calculations including additional positional data resulted in a revised closest approach distance of about one million kilometres, or three times the Moon's distance.

In fact, there is no contradiction at all between the two calculations. Predictions 30 years into the future based on a fraction of an asteroid's orbit are necessarily imprecise, with large error margins. Part of the asteroid-monitoring programme includes repeated recalculation of orbits based on new observations. These include pre-discovery positions found by running the models backwards in time and matching estimated positions with images from a photographic archive. More orbital data improve the accuracy of the calculations, and the predictions become more trustworthy, although they may not coincide with preliminary results.

For all the astronomers involved in these studies, it must be difficult to balance the responsibility of providing timely warning of potentially disastrous events with the requirement to collect sufficient data to provide a reasonably accurate prediction. Weighing the pros and cons of such decisions is routine in the conduct of science, yet the purveyors of news often ignore the probabilities and cast stories in black and white, with no shades of grey. After a few days, everyone seemed to forget about asteroid 1997 XF_{11}, but an alert television programmer was sufficiently inspired by the story to re-run the awful mini-series *Asteroid* that originally aired a few years ago.

I wonder what today's news media would have made of the spectacular near-disaster that actually occurred early this century in a remote part of Siberia? Ninety years ago, on 1908 June 30, a large meteoroid of diameter 50-60 m disintegrated in the atmosphere 6 kilometres above Tunguska, Siberia, exploding with the energy of 1000 Hiroshima bombs (10-20 megatons of TNT). Seismographs thousands of kilometres away recorded the event, and observers 500 km away heard deafening bangs and were terrified by a fiery cloud in the sky. People as far away as 60 km were thrown to the ground. Within an irregular area about 60 km across, entire stands of trees were flattened, with their trunks pointing radially away from "ground zero." Along the rim of this area, surviving nomadic reindeer herdsmen recounted tales of devastated camps and being badly shaken or knocked unconscious. Several people are known to have died.

Due to the remoteness of the site and its sparse population, the event is poorly known outside of astronomical circles. However, imagine how the history books would read if the meteoroid had exploded over a heavily populated area, such as Western Europe! As a youth member of the RASC Ottawa Centre in the late 1960s, I remember attending a lecture on the Tunguska event at the NRC building on Sussex Drive. It may have been the first "scientific" lecture I attended, and it left an impression on me, although I cannot recall the name of the presenter. I have often wondered why tales of surprise comets and large meteorite falls have such special appeal. Perhaps it is their unpredictability — the passage of most comets — including the two great comets of the past few years — cannot be anticipated, and I expect there is no entry in the 1908 edition of the *Observer's Handbook* that reads "June 30. Devastating meteorite impact in Tunguska, Siberia." The transient nature of these events is a thrilling change from the clockwork revolutions of the stars and planets. You just never know when you will see a splendid comet or get bopped by a meteorite!

Although we cannot predict the exact date, time, and location of all potentially hazardous impacts, researchers have amassed a body of statistical evidence that helps us assess the risks of meteorite falls alongside more commonplace activities we undertake every day. By studying the relative numbers of different-sized lunar craters, the late Eugene Shoemaker concluded that earthly impacts of large, energetic meteoroids are considerably less frequent than impacts of small, non-hazardous ones — thank goodness! Cosmic debris is continually bombarding the Earth, but most of the matter is fine dust, the larger grains of which burn up in the atmosphere and are seen as meteors. Several times a year, one hears reports of extremely bright fireballs. Some of the larger objects survive their fiery descent and occasionally inflict damage, but to my knowledge there is no verified report of death by a meteorite of this size. There is, however, the case of Mrs. Hulitt Hodges of Alabama, who in 1954 was bruised by a meteorite that crashed through her roof and ricocheted off the radio. The 1991 Peekskill meteorite whacked Michelle Knapp's newly acquired used car; the car and the football-sized meteorite fetched $69,000 from collectors! A Tunguska-sized impact might occur every 200 years or so, but there is only a 1 in 7 chance that the impact would be near a populated area. The kilometre-wide Barringer Crater in Arizona is thought to have been caused by a meteoroid about 100 m across; we should expect these at the rate of one in 10,000 years.

As the size and kinetic energy of the objects becomes even larger, we must begin to consider global consequences. There is no dodging the big ones! Whether they fall on land or in the ocean, the world-wide effects would be truly inescapable. Even if you are lucky enough to live some distance from the impact site, the shock wave, the tsunami, the flying debris, the fires, or the ensuing deep freeze caused by the dust clouds would get you! We should be thankful that the mean time between such events is measured in tens of millions of years. One notorious impact of that magnitude is thought to have taken place 65 million years ago, ending the reign of the dinosaurs and leaving an iridium-rich clay layer just 6 mm thick marking the boundary between the Cretaceous and Tertiary geological periods.

If all this is getting you down, perhaps you will take solace in the following fact: experts have estimated the combined chance of a given person perishing in a comet or asteroid hit is about the same as for an airplane crash, which is 1 in 20,000. If that seems high, the same experts estimate the probability of dying in an auto accident is 1 in 100. There, that should cheer you up! ◉

David M. F. Chapman became interested in astronomy at the age of 8, and studied physics at the University of Ottawa (B.Sc. 1975) and the University of British Columbia (M.Sc. 1977). Since then he has performed research in ocean acoustics at the Defence Research Establishment Atlantic. He occasionally writes astronomy scripts for the StarDate *and* Earth&Sky *radio broadcasts.*

Second Light

The Baseball Model of Neutron Star Spins

by Leslie J. Sage

We know that almost all neutron stars are born when massive stars explode as supernovae, and that pulsars are rapidly rotating neutron stars. Pulsars, however, move very differently from the precursor massive stars. They rotate much more rapidly than the pre-supernova star and they zoom through space with average speeds of about 400 km s^{-1}, while the average speed of a massive star in our Galaxy is less than 30 km s^{-1}. Moreover, pulsars seem to have very strong magnetic fields. Why they should have such properties has been very unclear to astronomers.

Pulsars emit beams of radiation that sweep over the Earth, like a searchlight passing over a ship at sea; they are normally detected by radio telescopes, but occasionally the pulses are seen in X-rays or visible light. "Normal" pulsars can have periods as short as 0.03 seconds, and as long as a few seconds. That is a direct measure of the speed with which the neutron star rotates — the idea of an object with the mass of the Sun spinning on its axis thirty times a second is quite something! (Millisecond pulsars rotate even faster, but it is generally believed that they are not born that way.)

Henk Spruit (Max-Planck-Institut für Astrophysik) and Sterl Phinney (Caltech) think they have an explanation for the observed properties of pulsars, which ties them all together (see 14 May issue of *Nature*).

A common explanation of the magnetic field strength and spin rate has been that if you compressed the Sun down to the size of a neutron star, you would get values for both that are comparable to what are observed. (The Sun is used here as an analogue for the core of the massive progenitor star.) For such an explanation to work, the core of the supernova progenitor has to be able to spin freely; it has to be disconnected from the slowly rotating envelope. That has not been thought to be a problem, but Spruit and Phinney show that the magnetic field will in fact keep the core rotating at the same slow speed as the envelope! So, being able to explain the magnetic field strength essentially kills the explanation for the spin rate — the slowly rotating core has 1000 times less angular momentum than is needed to explain the pulsar observations.

Spruit and Phinney have looked at an alternative explanation for pulsars' spins. Even though the exact mechanism for kicking the newly born neutron stars has not been identified, the existence of a kick is not in any doubt. Moreover, it seems that the most probable time to kick the star is during the supernova explosion, when there is lots of energy to spare. They propose that the kick itself is responsible for most of the spin of the star. Imagine hitting a baseball with a bat — if you don't hit the ball squarely, then it spins (often as a "pop fly" or a "foul"). Much of the energy of your hit has gone into the spin of the ball, rather than the desired forward bulk kinetic energy that you need to get the ball to the outfield. They propose that the same thing happens with neutron stars as they are born — the more squarely the birth kick hits the neutron star, the faster it will move through space but the more slowly it will spin. As the kick becomes increasingly off-centre, more of the energy will go into the spin, and less into the space velocity. Spruit and Phinney use their model to predict a correlation between the spin rates and space velocities of pulsars, and compare the model with observations.

> Imagine hitting a baseball with a bat — if you don't hit the ball squarely, then it spins (often as a "pop fly" or a "foul").

The correspondence between model prediction and observations is reasonable, but not striking. Given that the very origin and duration of the kicks is completely unknown, a discrepancy between the observations and predictions is not really surprising, because the model predictions are very sensitive to the duration of the kick. (Different types of kicks will have different durations.) Of necessity, Spruit and Phinney had to pick a particular type of kick in order to produce their model; they predict more quickly rotating, high-velocity neutron stars than are observed. The discrepancy may in fact indicate that the kick lasts a second or more (much longer than the model assumed) — the longer-lasting kicks may put more energy into rotation than the shorter ones. Where does it leave the model? It seems to be a very clever idea and good way to connect pulsars to the progenitor stars, but either the type of kick will need to be identified or some other observational support for the model will need to be found.

One remaining prediction of the model is that many neutron stars will be born rotating relatively slowly, probably too slowly to be seen as radio pulsars. We ought to be able to see such isolated neutron stars as they move through clouds of gas in the Milky Way. Indeed, several candidates have recently been observed (regular readers of this column may remember that I wrote about one in October 1997, vol. 91, p. 203), but there have been fewer found than expected. Perhaps most such isolated, non-pulsating neutron stars move through the clouds so quickly that their observational signature is not at all what we expect, which is why we have found so few. Theorists and observers will need to get together to see if the lack of observed isolated neutron stars is connected to their speed. If it is, that would seem to be good support for Spruit and Phinney's model. ◉

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

STAR QUOTES

"But that which will excite the greatest astonishment by far, and which indeed especially moved me to call attention to all astronomers and philosophers, is this: namely that I have observed four planets, neither known nor observed by any of the astronomers before my time, which have their orbits around a certain bright star [Jupiter], one of those previously known, like Venus or Mercury round the Sun, and are sometimes in front of it, sometimes behind it, though they never depart from it beyond certain limits. All of which facts were discovered and observed a few days ago by the help of a telescope devised by me, through God's grace first enlightening my mind."

Galileo Galilei
Italian astronomer/physicist (1564–1642)

Research Papers
Articles de recherche

L'ATMOSPHÈRE RICHE EN HÉLIUM DES NAINES BLANCHES DE TYPE DB[1]

par Alain Beauchamp

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(Reçu le 5 mars 1998)

Résumé.. Les naines blanches se divisent en deux groupes spectroscopiques distincts: celles dont le spectre est dominé par des raies d'hydrogène et celles dont le spectre est dominé par des raies d'hélium neutre ou ionisé. Parmi ces dernières, les naines blanches de type DB ont une atmosphère riche en hélium neutre, ainsi qu'une température effective entre 10 000 et 30 000 K. Des contraintes d'ordre observationnel ainsi que des incertitudes théoriques dans la modélisation des spectres synthétiques ont amené un certain retard dans notre compréhension de ces objets. Nous passons en revue ces incertitudes, qui touchent le phénomène de la convection dans l'atmosphère, ainsi que le calcul de l'opacité de l'atome d'hélium, et proposons une méthode, basée à la fois sur l'observation d'un échantillon important de spectres visibles et ultraviolets, et sur le calcul de modèles d'atmosphères, qui permet de cerner ces incertitudes.

Abstract. White dwarfs can be divided into two distinct spectroscopic groups: those dominated by spectral lines of hydrogen, and those where the lines of neutral or ionized helium are dominant. Among the last group, the white dwarfs of type DB have atmospheres rich in neutral helium and effective temperatures ranging from 10,000 to 30,000 K. Observational constraints and theoretical uncertainties in models of synthetic spectra have delayed the development of our understanding of these objects. We review the model uncertainties with reference to atmospheric convection and calculations for the opacity of neutral helium, and suggest a method, based on the observation of a large sample of spectra in the visible and ultraviolet as well as on the evaluation of model atmospheres, whereby restrictions can be placed on the uncertainties.

1. Introduction

Les observations nous révèlent que les naines blanches se divisent en deux groupes spectroscopiques distincts: celles dont le spectre est dominé par des raies d'hydrogène (type DA) et celles dont le spectre est dominé par des raies d'hélium neutre ou ionisé (type non-DA), qui forment un ensemble beaucoup moins homogène que les étoiles de type DA. Depuis Schatzman (1958), on explique la grande pureté de l'atmosphère de la majorité des naines blanches des deux groupes en faisant intervenir le tri gravitationnel, qui sépare les différents éléments chimiques d'une atmosphère en des temps caractéristiques de l'ordre d'une année ou d'un siècle seulement. Lorsqu'aucun autre processus physique ne vient contrer ce tri gravitationnel, l'élément le plus léger dans l'étoile, hydrogène ou hélium, demeure, seul, dans l'atmosphère.

La classe DA comprend 80% des naines blanches connues, avec des températures effectives entre 5 000 et 100 000 K environ. Le spectre visible d'une étoile de type DA est caractérisé par la présence de raies de Balmer fortement élargies comparées à celles observées chez les étoiles de la séquence principale. Parmi les naines blanches de type non-DA, celles qui sont plus chaudes que 45 000 K ont des spectres dominés par les raies de l'hélium ionisé et sont classifiées DO.

Dans ce travail, nous nous intéressons plus particulièrement aux naines blanches dites de type DB, pour lesquelles les raies de l'hélium neutre prédominent. Le spectre visible de ces étoiles montre des raies d'hélium neutre fortes et larges, qui forment un ensemble plus riche que celui des naines blanches de type DA (voir figure 1). On y observe occasionellement des traces d'hydrogène (type spectral DBA) ou d'éléments lourds (type spectral DBZ). Les étoiles de type DB représentent environ le cinquième des naines blanches dans l'éventail des températures entre 10 000 et 30 000 K. La borne inférieure en température reflète le fait que l'atome d'hélium tend généralement à se trouver dans son état fondamental ($n = 1$) à basse température. Les transitions du domaine du visible, dont le niveau inférieur est un état excité ($n = 2$), ne peuvent donc se produire à ces températures, et l'hélium devient alors invisible spectroscopiquement même s'il est l'élément dominant dans l'atmosphère. Par ailleurs,

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[1] Cet article est basé sur le discours donné lorsque l'auteur a été décerné la médaille J. S. Plaskett à la réunion de la Canadian Astronomical Society/Société canadienne d'astronomie en 1997. La thèse de doctorat pour laquelle il a mérité cette médaille a été complétée à l'Université de Montréal.

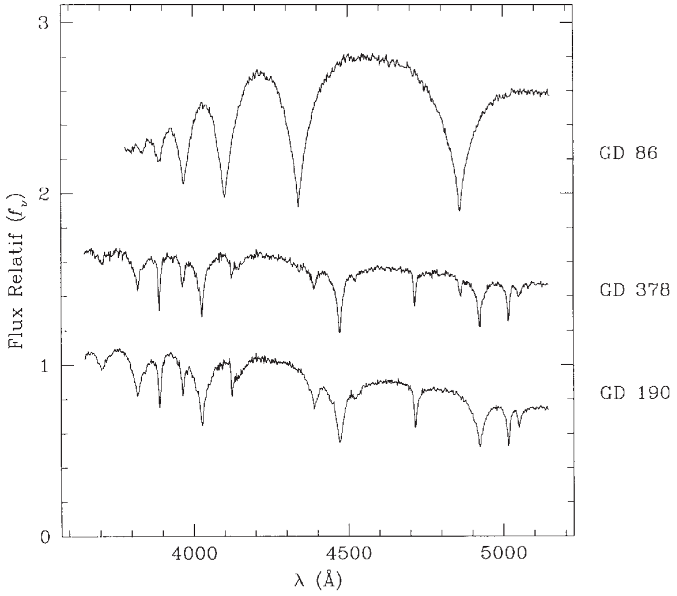

Fig.1 — Spectres typiques de naines blanches de types DA, DBA et DB (de haut en bas). Les spectres sont normalisés à 4300 Å et décalés verticalement.

on ne connait aucune naine blanche avec de fortes raies d'hélium neutre à des températures excédant 30 000 K (Liebert *et al.* 1986; Thejll *et al.* 1990). Ceci n'est cependant pas une conséquence de l'équilibre d'excitation ou d'ionisation, puisque les modèles montrent que les transitions d'hélium neutre dominent celles de l'hélium ionisé jusqu'à environ 40 000 K. Cette absence d'étoile de type DB aussi chaude doit donc être considérée comme une véritable coupure dans la distribution des objets de ce type. L'éventail des températures entre 30 000 et 45 000 K à l'intérieur duquel toutes les naines blanches ont une atmosphère riche en hydrogène est appelé brèche des DB.

La méthode de détermination des paramètres atmosphériques la plus générale, dans le contexte de l'étude des naines blanches, est la comparaison directe du spectre observé avec une grille de spectres synthétiques paramétrisés en T_{eff}, log g et composition. Cette approche permet, en principe, de déterminer simultanément tous les paramètres recherchés. Il y a cependant un prix à payer pour son utilisation: le calcul de spectres synthétiques exige une bonne description de la structure atmosphérique de l'étoile, description qui dépend à son tour de notre connaissance de certaines caractéristiques du plasma, telles l'opacité et l'équation d'état. Il faut également tenir compte des différents modes de transport d'énergie, radiation et convection, et de l'interaction entre les particules du plasma, qui provoquent l'élargissement du profil des raies.

Les contraintes d'ordre observationnel rendent une telle étude spectroscopique des naines blanches de type DB plus ardue que celle des étoiles de type DA. La rareté relative d'objets de type DB a pour conséquence une plus faible brillance apparente en moyenne. On constate de plus à la figure 1 que l'intensité des raies d'hélium de la DB présente est plus faible que celle des raies de Balmer de la DA; cette situation est vraie en général. L'étude spectroscopique des étoiles de type DB dans le domaine du visible exige donc des spectres de rapport signal/bruit élevé pour ces étoiles, dont la magnitude moyenne est $V \approx 15.5$.

Nous proposons ici de faire l'inventaire des autres contraintes, de nature non observationnelle, qui ont amené un retard important dans notre compréhension des étoiles de type DB. Ces contraintes touchent le comportement des spectres visibles en fonction des paramètres atmosphériques, présenté à la section 2, ainsi que les incertitudes dans la modélisation de la convection, de la contribution de l'hélium neutre à l'opacité du continu, de l'élargissement des raies d'hélium neutre du visible, et du traitement de l'opacité de type pseudo-continu, aux sections 3, 4, 5 et 6, respectivement. Nous discutons de l'impact d'un traitement inadéquat des raies de résonance de l'atome d'hélium à la section 7, et présentons, à la section 8, une méthode qui permet de cerner ces précédentes incertitudes dans la modélisation des atmosphères de naines blanches de type DB. Nous concluons à la section 9.

2. Dépendance des spectres d'étoiles de type DB aux paramètres physiques

Il est extrêmement difficile, en se servant de la seule spectroscopie du visible, de déterminer avec précision la température effective des naines blanches de type DB entre 20 000 et 30 000 K, c'est-à-dire à l'intérieur d'un éventail couvrant la moitié de leur échelle de température. Cette difficulté résulte du comportement des raies d'hélium neutre dans les spectres synthétiques en fonction à la fois de la température effective et de l'abondance d'hydrogène, et ce, *même si cet élément est spectroscopiquement invisible.*

La figure 2 illustre la dépendance à la température effective du profil des raies du visible pour des modèles avec la gravité typique log $g = 8.0$. Les profils sont tous normalisés dans leur continu, et sont décalés verticalement. L'intensité des raies d'hélium neutre

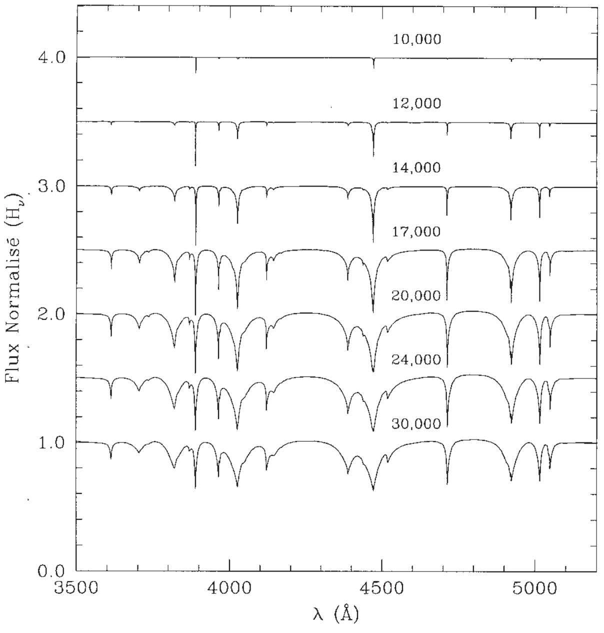

Fig. 2 — Spectres synthétiques de naine blanche de type DB dans le domaine du visible pour différentes températures effectives et log $g = 8.0$.

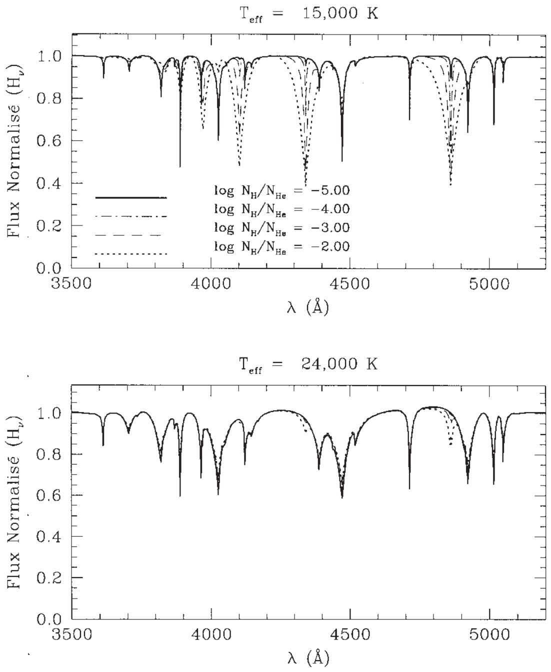

Fig. 3 — Spectres synthétiques de naine blanche de type DBA dans le domaine du visible, à $T_{\rm eff}$ =15 000 (en haut) et 24 000 K (en bas). Les raies d'hydrogène les plus fortes sont (de droite à gauche) Hβ, Hγ et Hδ.

augmente rapidement à partir de 10 000 K, température à laquelle les raies sont à peine détectables, jusqu'à 20 000 K environ. A plus haute température, la profondeur et la forme des profils de raies sont très peu sensibles aux variations de température effective; les seules différences notables sont observées au cœur des raies fortes λλ4026, 4471 et 4922, dont la profondeur diminue avec $T_{\rm eff}$. Cette très faible sensibilité des profils dans les étoiles chaudes est un phénomène bien connu (Wickramasinghe 1979; Koester 1980; Koester *et al.* 1981; Wickramasinghe et Reid 1983).

Un comportement qui n'a, à notre connaissance, jamais été discuté est celui des raies d'hydrogène et d'hélium dans les spectres d'étoiles de type DBA à faible abondance d'hydrogène. La figure 3 illustre les variations apportées à ces spectres synthétiques par la présence d'hydrogène, pour des températures de 15 000 et 24 000 K, et log [*N*(H)/*N*(He)] entre −5.0 et −2.0. On observe une diminution de l'intensité des raies d'hydrogène lorsque la température augmente à composition constante. Le spectre à $T_{\rm eff}$ = 15 000 K avec log [*N*(H)/*N*(He)] = −4.0, par exemple, montre une raie H*β* à 4860 Å *d'intensité comparable à celle des raies fortes d'hélium*, en accord avec les spectres observés d'étoiles de type DBA froides (Wesemael *et al.* 1993). Cependant, à 24 000 K, et avec cette même composition, la raie H*β* n'est plus détectable. Il n'est donc pas inconcevable qu'un objet classifié DB chaude, selon la spectroscopie du visible, ait en fait une abondance d'hydrogène aussi importante que log [*N*(H)/*N*(He)] ≈ −4.0, pour laquelle les raies de Balmer sont absentes du spectre observé.

Une étude des spectres synthétiques d'étoile de type DBA plus chaude que 20 000 K révèle également que la sensibilité du profil *des raies d'hélium* à l'abondance d'hydrogène augmente lorsque la température effective fait de même, alors que, paradoxalement, les raies d'hydrogène deviennent presque invisibles. Cette apparente contradiction vient du fait que le saut d'ionisation de l'hydrogène à 912 Å bloque une plus grande proportion du flux émergent de l'étoile lorsque la fréquence d'émission maximale se déplace vers ce saut d'ionisation, donc lorsque la température effective augmente. Ceci a un impact sur la stratification atmosphérique dans les couches superficielles de l'étoile, ce qui, à son tour, influe sur le profil des raies fortes de l'atome d'hélium à 4026 Å, 4922 Å et surtout 4471 Å, raies dont le cœur est formé dans ces régions.

Ainsi, pour les étoiles chaudes de type DB, les trois mêmes raies du domaine visible montrent un comportement analogue en fonction d'une variation en température effective et/ou abondance d'hydrogène (spectroscopiquement invisible). C'est pourquoi il est impossible de déterminer une température effective fiable pour ces étoiles à partir de la seule spectroscopie du visible, à moins de cerner avec précision l'abondance d'hydrogène. Dans le cas contraire, une mauvaise estimation de la quantité d'hydrogène présent peut introduire une erreur systématique de *quelques milliers de degrés* dans la température effective déterminée spectroscopiquement. Toutefois, même en connaissant bien l'abondance d'hydrogène, l'incertitude sur la température d'une telle étoile demeure de quelques milliers de degrés, à cause de la trop faible dépendance du profil des raies de l'atome d'hélium à la température effective (voir figure 2).

La seule alternative pour déterminer la température effective des étoiles chaudes de type DB est de se rabattre sur la forme de la distribution d'énergie dans l'ultraviolet, laquelle, heureusement, demeure fortement dépendante à la température effective, même pour les objets chauds. De plus, la distribution d'énergie dans l'ultraviolet offre deux avantages sur la spectroscopie du visible pour le traitement de l'hydrogène: une faible dépendance de sa forme générale à l'abondance d'hydrogène, et la présence de la raie L*α* à 1215 Å, qui demeure détectable dans les spectres synthétiques *à des abondances d'hydrogène auxquelles les raies de Balmer sont déjà disparues*.

Malheureusement, en raison de la faible luminosité des étoiles de type DB, la grande majorité des distributions d'énergie obtenues à ce jour pour ces objets, principalement avec le satellite *International Ultraviolet Explorer* (IUE), sont de qualité discutable. Cette situation ne peut qu'aller en s'améliorant avec l'apport du télescope *Hubble*, quoique l'échantillon observé avec ce télescope ne permette pas encore de faire une étude statistique d'envergure. Qui pis est, la raie L*α*, qui permettrait en principe de cerner beaucoup mieux l'abondance d'hydrogène que les raies de Balmer, pourrait être affectée par la composante d'absorption du milieu interstellaire.

3. Le rôle crucial de la convection

Les problèmes liés au traitement de la convection dans les modèles d'atmosphères ont également des répercussions importantes sur notre compréhension des propriétés atmosphériques des étoiles de type DB, puisque la grande majorité d'entre elles ont une atmosphère convective.

Lors du calcul des modèles d'atmosphères, la description du flux convectif turbulent, transporté par des bulles de matière en interaction avec leur environnement, pose un problème d'une grande complexité. La seule option reste la théorie de la longueur de mélange (*e.g.* Mihalas 1978), qui dépend de quatre paramètres relativement arbitraires. Trois ensembles de ces paramètres sont couramment utilisés lors du calcul de modèle d'atmosphères convectives de naines blanches: ils se nomment ML1, ML2 et ML3, en ordre croissant d'efficacité de transport convectif (Fontaine *et al.* 1981).

On peut comprendre qualitativement l'effet de la convection sur la structure atmosphérique des naines blanches de type DB avec l'expression suivante pour le flux radiatif dans l'approximation de diffusion,

$$\frac{H^{\mathrm{conv}}}{H^{\mathrm{tot}}} = \left(1 - \frac{\nabla}{\nabla_{\mathrm{R}}}\right) = \left(1 - \frac{\nabla_{\mathrm{ad}}}{\nabla_{\mathrm{R}}}\right)\zeta \quad , \qquad (1)$$

où $\nabla \equiv (T/P)\, \partial \ln \mathrm{T}/\partial \ln P$ est le gradient de température sur une échelle de pression, $H^{\mathrm{conv}}/H^{\mathrm{tot}}$ est le flux d'Eddington convectif normalisé par le flux total, ∇_{R} est le gradient qui serait présent si le champ de radiation transportait tout le flux, ∇_{ad} est le gradient adiabatique, et ζ est un nombre entre 0 et 1 qui dépend des conditions thermodynamiques locales et des paramètres de la théorie de la longueur de mélange. Cette équation, formellement valable uniquement dans les régions opaques de l'atmosphère, décrit néanmoins le comportement approximatif de l'atmosphère dans les couches superficielles qui demeurent convectives, comportement qui correspond à une diminution du gradient ∇ lorsque le transport convectif est efficace.

Il y a par contre une limite supérieure imposée au gradient. Pour un transport convectif très efficace, le paramètre ζ de l'équation (1) converge vers l'unité, et le gradient devient identique au gradient adiabatique ∇_{ad}, qui est une propriété purement thermodynamique du gaz. On peut donc prédire deux régimes de température pour lesquels les incertitudes dans le traitement de la convection ont peu d'impact sur les modèles d'atmosphères et spectres synthétiques: celui pour lequel le transport convectif est négligeable, et celui pour lequel le transport convectif est maximal pour tout choix raisonnable des paramètres convectifs.

En raison de l'adiabacité de la convection à faible température, et de son importance négligeable à haute température, le profil des raies de l'hélium neutre dans les spectres synthétiques d'étoiles de type DB est indépendant de la paramétrisation de la convection pour des températures effectives inférieures à 18 000 K ou proche de 30 000 K, alors que la dépendance à ces paramètres est maximale autour de 24 000 K. La dépendance du spectre visible aux paramètres de la théorie de la longueur de mélange est présentée à la figure 4, pour $T_{\mathrm{eff}} = 24\,000$ K. Les seules différences apparaissent dans les régions de superposition de raies fortes (entre $\lambda\lambda$4388 et 4471 et, dans une moindre mesure, $\lambda\lambda$3965 et 4026). Cette variation des profils de raies, faible en apparence, introduit tout de même une erreur systématique de quelques milliers de degrés dans la détermination de la température effective obtenue à partir des spectres *visibles*. À 24 000 K, la dépendance de la température effective à l'efficacité convective est moindre si T_{eff} est déterminée à partir d'observations ultraviolettes; elle reste néanmoins de l'ordre de 1 000 K.

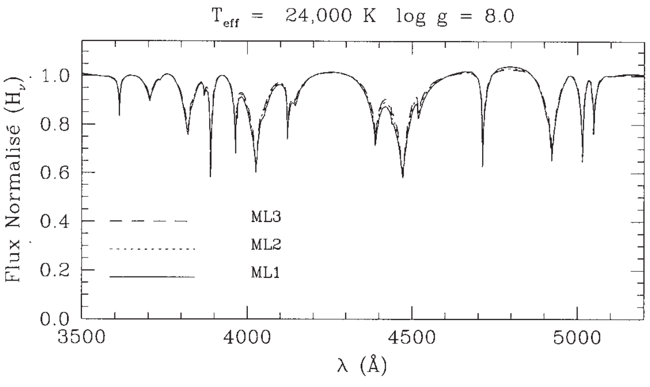

Fig. 4 — Spectres synthétiques normalisés de naine blanche de type DB dans le domaine du visible à $T_{\mathrm{eff}} = 24\,000$ K, pour les paramétrisations de la convection, ML1, ML2 et ML3.

4. L'opacité de l'hélium dans le continu

L'opacité monochromatique $\kappa_\nu(T, P)$ est un ingrédient fondamental de tout modèle d'atmosphères, car elle caractérise la capacité d'absorption de la lumière par la matière.

De par sa nature plus simple, l'hydrogène est l'atome que l'on comprend le mieux. Des expressions semi-analytiques ou des tables sont depuis longtemps disponibles pour décrire les opacités de l'hydrogène tant pour le continu que pour les raies. C'est pourquoi il est maintenant possible de reproduire presque parfaitement les spectres de naines blanches de type DA observés dans le visible, et d'en analyser des échantillons importants. La situation est bien différente pour l'atome d'hélium.

Notre compréhension de la contribution du continu de l'hélium neutre a toujours accusé un certain retard sur celle de l'hydrogène. Des valeurs précises pour l'opacité de l'hélium due aux transitions de type lié-libre (photoionisation) à partir des niveaux avec $n \leq 3$ (les plus peuplés dans les atmosphères d'étoiles de type DB) n'ont, en effet, été tabulées que relativement récemment (Koester *et al.* 1985; Seaton *et al.* 1992), alors que celle de type libre-libre, dite opacité de He^-, demeure encore mal connue. Des valeurs théoriques de la section efficace de He^- ont pourtant été tabulées par John (1968) et Bell *et al.* (1982), mais uniquement à des longueurs d'onde plus grandes que 3000 Å et 4500 Å, respectivement. Dans un contexte d'atmosphère riche en hydrogène, ceci est amplement suffisant parce que l'opacité de He^- diminue très rapidement avec la fréquence, et devient négligeable à des longueurs d'onde de l'ordre de quelques 10^3 Å, où l'opacité de l'hydrogène prédomine. Dans les atmosphères riches en hélium neutre, He^- reste une source d'opacité majeure autour de 10^3 Å, et il faut alors extrapoler les valeurs tabulées.

L'hélium nous a même réservé une surprise récente. Par suite de l'observation de Gaur *et al.* (1988) suivant laquelle les populations de la molécule He_2^+ n'étaient pas négligeables dans l'équation d'état d'un gaz d'hélium aux conditions photosphériques des étoiles froides de type DB, Stancil (1994) a calculé les sections efficaces d'absorption de cette molécule. Il se trouve qu'elle est la source d'opacité continue la plus importante dans les atmosphères plus froides que 15 000 K, où son importance est comparable à celle de He^-.

Dans ce contexte, la contribution de la molécule *neutre* He_2, qui serait extrêmement instable en raison de sa très faible énergie de dissociation, n'a encore jamais été étudiée. Pourtant, dans les atmosphères froides, les deux principales sources d'opacité connues dans le continu, soit He^- et He_2^+, nécessitent la présence d'hélium ionisé et d'électron — qui ont la même densité en nombre selon la conservation de la charge et l'équilibre d'ionisation. La molécule neutre, par contre, est le résultat de la rencontre de deux atomes d'hélium, qui sont typiquement 10^{10} fois plus abondants que les électrons dans la photosphère des étoiles de type DB froides. Malgré la courte vie d'une molécule He_2 individuelle, le nombre total de collisions entre atomes d'hélium pourrait impliquer une très importante contribution de cette molécule à l'opacité.

5. Les processus d'élargissement des raies de l'atome d'hélium dans le visible

Malgré les problèmes que soulève la modélisation du continu de l'hélium, ce sont les processus d'élargissement de raies, cruciaux dans la modélisation des spectres synthétiques, qui en posent le plus. Si on considère leur contribution à l'opacité, les raies d'hélium neutre forment deux groupes aux propriétés fort différentes. Celles dans l'ultraviolet proche et le visible sont le résultat de transitions à partir d'un niveau inférieur excité (avec $n = 2$), alors que les raies de résonance, toutes dans l'ultraviolet lointain, proviennent de l'excitation du niveau fondamental. Nous étudions les raies du premier groupe dans cette section, et celles du second groupe à la prochaine section.

Pour une transition d'un niveau inférieur i à un niveau supérieur j, la contribution à l'opacité monochromatique est proportionnelle au produit du nombre N_i d'atomes par unité de volume dans le niveau inférieur de la transition avec le profil monochromatique ϕ_ν, qui représente la probabilité que le photon émis lors de la transition ait une fréquence ν. La principale difficulté dans le calcul de l'opacité de type lié-lié réside dans la détermination de ce profil monochromatique, qui nécessite une bonne compréhension des processus d'élargissement de raies.

Aux conditions caractéristiques des atmosphères d'étoiles de type DB, le processus d'élargissement à considérer est l'élargissement par pression, qui provient de l'interaction électrostatique entre l'émetteur et les autres particules; celles-ci perturbent les niveaux d'énergie de l'atome émetteur et, par conséquent, la fréquence du photon émis. Le profil monochromatique résulte de la contribution de tous les atomes émetteurs à un temps donné, chacun soumis à sa propre configuration de perturbateurs. Pour les naines blanches de type DB, on rencontre deux types de perturbateurs : ce sont les particules neutres (atomes d'hélium) qui produisent les élargissements par résonance et de van der Waals, et les particules chargées (He II et électrons) qui produisent l'élargissement Stark.

Dans la région de formation des raies d'étoiles plus froides que 16 000 K, l'hélium est presque complètement à l'état neutre, et la densité de perturbateurs neutres dépasse largement celle de perturbateurs chargés. Pour cette raison, la contribution totale des perturbateurs neutres à l'élargissement domine à ces températures. Les théories d'élargissement disponibles, que ce soit pour l'élargissement par résonance ou de van der Waals, traitent de façon très approximative les interactions, et prédisent toutes un profil Lorentzien,

$$\phi_\nu = \frac{1}{\pi}\left[\frac{w}{(\nu - \nu_0)^2 + w^2}\right] \quad , \qquad (2)$$

avec une largeur w et un décalage $d\,(\nu - \nu_0)$ par rapport à la fréquence d'émission ν_0 en l'absence de perturbations. Pour une raie donnée, les paramètres du profil Lorentzien changent d'une théorie à l'autre, parfois par autant qu'un ordre de grandeur. On peut donc douter de la fiabilité des paramètres atmosphériques d'une étoile froide déterminés à partir du profil des raies du visible.

La situation est bien meilleure pour l'élargissement Stark des raies du visible par les ions et électrons, car il existe une théorie sophistiquée pour ce type d'élargissement (Griem *et al.* 1962; Barnard *et al.* 1974). Certains auteurs ont reproduit de façon satisfaisante des portions de spectres observés en se servant des tables de profils, longtemps disponibles pour seulement cinq raies de l'atome d'hélium (Wickramasinghe et Reid 1983; Koester *et al.* 1985). Avec les travaux de Beauchamp *et al.* (1997), le profil de l'*ensemble* des raies de l'atome d'hélium dans le visible peut maintenant être incorporé dans les spectres synthétiques. Pour les étoiles plus chaudes qu'environ 18 000 K, il est maintenant possible de modéliser entièrement le spectre visible, car l'élargissement Stark domine.

Avec ces développements récents, notre compréhension des processus d'élargissement des raies de l'hélium neutre des naines blanches de type DB se compare maintenant à celle des raies de Balmer des étoiles de type DA: dans les deux cas, les profils Stark s'inspirent de théories d'élargissement sophistiquées, alors que le traitement de l'élargissement par les particules neutres reste approximatif.

6. Le profil des raies de résonance dans l'ultraviolet lointain

Le profil des raies de résonance de l'atome d'hélium, dont le cœur est situé dans l'éventail 500–600 Å, pose un problème fort différent de celui des raies du visible.

En appliquant les théories d'élargissement disponibles, la contribution de toutes les raies du visible devient négligeable à quelques centaines d'Angströms de leur cœur, et ce, pour les trois types d'élargissement par pression. Ceci n'est plus vrai pour les raies de résonance de l'hélium neutre, dont la contribution reste importante même *jusque dans le visible*, à plusieurs milliers d'Angströms de leur cœur. En introduisant un tel surplus dans l'opacité du continu de la partie visible du spectre, les raies de résonance, selon ces théories, ont une très grande influence sur la structure thermodynamique de l'atmosphère.

Cette opacité peu réaliste associée aux ailes des raies de résonance, beaucoup plus importante que celle des raies du visible, résulte de la conjonction de deux phénomènes. En premier lieu, le comportement du profil normalisé ϕ_ν des raies des deux types, tel que déduit des théories disponibles, est relativement similaire. En second lieu, l'opacité de la raie de résonance est proportionnelle au produit de ce profil par la densité en nombre d'atomes dans l'état inférieur de la transition considérée; cette densité est extrêmement élevée pour ces raies, car la presque totalité des atomes d'hélium est au fondamental dans les atmosphères d'étoiles de type DB.

Aucune théorie d'élargissement disponible aujourd'hui, même sophistiquée, ne traite correctement les collisions impliquant des énergies d'interaction élevées, seules susceptibles de provoquer un élargissement à plus de quelques centaines d'Angströms du cœur d'une raie. Le seul traitement possible actuellement pour les raies de résonance est l'utilisation de profils calculés avec les théories disponibles, dans le régime restreint où elles sont valables, alliée à une réduction de la contribution de l'aile rouge s'étendant dans le visible. On peut, par exemple, imposer une coupure abrupte de la forme $\phi_\nu \equiv 0$ pour $\lambda > \lambda_{\text{coupure}}$.

La stratification atmosphérique est fortement influencée par le choix de la coupure, ce qui a un impact à la fois sur la forme de la distribution d'énergie et l'intensité des raies du visible, *pourtant très éloignées du cœur des raies de résonance*. Cet effet est important à toutes les températures effectives, mais plus spécifiquement aux deux extrêmes; pour les modèles froids, à cause de la plus grande proportion d'atomes au fondamental, et pour les modèles très chauds, parce que les raies de résonance sont alors plus près du sommet de la distribution d'énergie. L'erreur systématique associée au traitement des raies de résonance peut atteindre quelques milliers de degrés sur la température effective déduite des observations du visible.

7. LE FORMALISME DE PROBABILITÉ D'OCCUPATION ET LE TRAITEMENT DU PSEUDO-CONTINU

Pour tout ion, chaque série de transitions à partir d'un même niveau inférieur produit une séquence de raies spectrales convergeant à un saut d'ionisation. La série des raies de Balmer, observable par exemple dans les naines blanches de type DA, en est le cas classique. A mesure que l'on se rapproche d'un saut d'ionisation, le recouvrement des raies individuelles de la série de Balmer, ou d'une série similaire de l'atome d'hélium dans les spectres d'étoiles de type DB, devient de plus en plus important. Ce recouvrement, conjugué à une diminution graduelle de l'intensité des raies individuelles à l'approche du saut, peut être modélisé par une opacité de type continu, appelée pseudo-continu, qui s'estompe lorsqu'on s'éloigne du saut d'ionisation vers les plus grandes longueurs d'onde.

L'opacité pseudo-continue peut être traitée dans le cadre d'un formalisme de probabilité d'occupation qui tient compte correctement de l'interaction entre les particules du plasma. Ce formalisme permet de déterminer la probabilité, dite d'occupation, qu'un niveau normalement lié d'un atome le demeure (c'est-à-dire n'est pas détruit) malgré l'interaction avec les autres particules. Intuitivement, on peut s'attendre à ce que, plus la densité de particules augmente, plus l'interaction que subit l'ion perturbe ses états fortement excités, et en fin de compte les détruise. Cet effet serait donc plus important chez les naines blanches par rapport aux autres types d'étoiles.

Däppen *et al.* (1987) expriment la section efficace de type pseudo-continu produite par une transition entre un niveau lié i et un niveau supérieur qui serait lié en l'absence de perturbations par le produit

$$D_i(\nu)\sigma_{\text{photo}}(\nu) \quad , \tag{3}$$

où $D_i(\nu)$ est appelé facteur de dissolution, et $\sigma_{\text{photo}}(\nu)$ est la section efficace de photoionisation usuelle que l'on extrapole vers les longueurs d'onde plus rouges que le saut d'ionisation. Selon le formalisme de probabilité d'occupation, le facteur de dissolution $D_i(\nu)$ dépend de la probabilité d'occupation des niveaux supérieurs qui sont impliqués dans une transition $i \rightarrow j$ avec émission de photon à une fréquence ν_{ij} située près de la fréquence ν. Cette probabilité dépend du type de perturbateurs.

Pour déduire la probabilité d'occupation due à l'interaction avec des particules neutres, Hummer et Mihalas (1988) adoptent un modèle de sphère dure avec un rayon d'interaction dans la forme hydrogénique

$$r_{\text{n}} = n^2 a_0 \ , \tag{4}$$

où n est le nombre principal du niveau atomique, et a_0, le rayon de Bohr. Dans le cas de l'interaction avec des ions, Hummer et Mihalas (1988) supposent que, pour chaque état lié i d'un atome ou ion, il existe une valeur critique F_i^{crit} du champ électrique ionique local au-delà de laquelle l'état est détruit. Ici, la probabilité d'occupation du niveau i est donc équivalente à la probabilité que le champ électrique résultant de l'ensemble des particules chargées est inférieur à la valeur critique.

Les valeurs caractéristiques de Hummer et Mihalas (1988) dont dépendent les probabilités d'occupation, soit le champ critique et le rayon de la sphère dure, sont des quantités théoriques sujettes à des modifications d'ordre unité à partir de résultats expérimentaux. Bergeron *et al.* (1991) ont démontré à partir de la spectroscopie des naines blanches froides de type DA que le formalisme des sphères dures de Hummer et Mihalas (1988) dépeuplait trop efficacement les niveaux les plus excités de l'hydrogène, mais qu'un rayon critique diminué de moitié permettait de reproduire beaucoup mieux l'ensemble des raies de Balmer. La même contrainte pour les étoiles plus chaudes impose que le champ critique soit le double de la valeur théorique de Hummer et Mihalas (1988) pour le calcul des probabilités d'occupation due à l'interaction avec les particules chargées. Ces résultats suggèrent que le formalisme de probabilité d'occupation est la bonne solution pour modéliser le pseudo-continu dans les spectres de naines blanches de type DB, mais que des incertitudes relatives d'ordre unité demeurent pour les valeurs critiques dont dépendent à la fois les probabilité d'occupation et l'intensité du pseudo-continu.

La figure 5 illustre l'importance du pseudo-continu dans un spectre d'étoile de type DB à 24 000 K. Deux spectres synthétiques, basés sur la même stratification atmosphérique, et construits avec et sans le formalisme de probabilité d'occupation, y sont comparés. Les effets introduits par une modification des valeurs critiques dans le formalisme d'occupation sont importants: en réduisant de

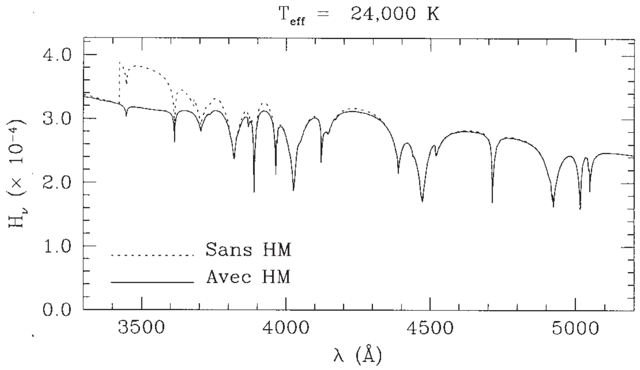

FIG. 5 — Spectres synthétiques normalisés de naine blanche de type DB dans le domaine du visible à T_{eff} = 24 000 K. Ils sont basés sur la même stratification atmosphérique, mais construits avec et sans le formalisme de probabilité d'occupation.

moitié la contribution du pseudo-continu aux abords des raies à 3700–4500 Å, sensibles à la gravité, on augmente de façon significative leur intensité normalisée par le continu dans le spectre synthétique. La gravité moyenne déduite des observations est alors augmentée de 0.1 dex. Un tel décalage systématique est de l'ordre de la largeur de la distribution en gravité des étoiles de type DB!

8. UNE MÉTHODE POUR CONTRAINDRE LES INCERTITUDES THÉORIQUES

Nous avons démontré que l'étude spectroscopique des naines blanches de type DB se heurte à des problèmes complémentaires dans deux régimes de température effective, de part et d'autres de 18 000 K environ.

- A basse température, l'hydrogène invisible spectroscopiquement a peu d'impact sur les spectres synthétiques. De plus, les profils des raies d'hélium neutre sont très sensibles à la température effective, tout en demeurant indépendants de la paramétrisation de la convection. Malheureusement, l'élargissement des raies dans le visible est causé par l'interaction avec les particules neutres, difficile à modéliser.

- A haute température, l'hydrogène — même invisible spectroscopiquement — ainsi que la paramétrisation choisie pour la convection ont une influence importante sur la température déduite des observations. L'élargissement dominant, de type Stark, est bien compris, mais les profils de raies sont presque insensibles à la température effective.

- Enfin, l'effet du pseudo-continu du visible et celui de l'aile rouge des raies de résonance reste important à toute température.

On dénombre six facteurs importants associés à l'atome d'hélium qui peuvent influencer les propriétés des atmosphères d'étoiles de type DB. Beaucoup de ceux-ci restent encore mal compris. Dans l'attente de meilleures contraintes théoriques, ils peuvent tous être considérés comme des paramètres libres à déduire expérimentalement. Ce sont: le traitement de l'élargissement des raies du visible par des particules neutres, la paramétrisation de la convection, l'effet du pseudo-continu, produit par les interactions avec les particules neutres et/ou chargées, et le profil des raies de résonance, produit par un élargissement par des particules neutres et/ou chargées (on ne peut certes pas comptabiliser l'opacité due à une molécule He_2, hypothétique à ce stade). A cela s'ajoute l'abondance d'hydrogène invisible spectroscopiquement, à haute température. Comment déterminer les paramètres atmosphériques des naines blanches de type DB avec un si grand nombre d'inconnues lors de l'élaboration de la grille de modèles d'atmosphères?

L'élément essentiel d'une amorce de solution est le découplage entre certains de ces paramètres libres, conjugué à l'observation spectroscopique d'un échantillon important d'étoiles de types DA et DB. Le comportement hydrogénique des niveaux excités de l'hélium neutre permet déjà de modéliser son pseudo-continu dans le visible en se servant de l'observation d'étoiles de type DA. Il est raisonnable de supposer que les quantités critiques permettant de calculer les probabilités d'occupation des niveaux excités de l'hélium neutre ont la même forme que pour les niveaux correspondants (c'est à dire de même nombre quantique principal *n*) de l'hydrogène. Ces quantités ont déjà été déduites par l'étude spectroscopique d'un échantillon important d'étoiles de type DA (voir section 7).

Du côté des étoiles de type DB plus froides que 16 000 K, les seuls paramètres libres ayant un impact sur les spectres synthétiques (autres que le pseudo-continu, maintenant contraint par l'observation des naines blanches de type DA) sont l'élargissement par des particules neutres des raies du visible, et l'intensité de l'aile des raies de résonance, également produite par ce type d'élargissement. L'effet des interactions par les particules chargées peut être négligé, tout comme celui d'une mauvaise paramétrisation de la convection, car cette dernière est adiabatique pour les objets froids. De même, à $T_{\mathrm{eff}} > 18\,000$ K, les seuls paramètres libres à considérer sont l'intensité de l'aile des raies de résonance due à l'élargissement Stark (celui des raies du visible est bien compris), l'abondance d'hydrogène invisible spectroscopiquement, et la modélisation de la convection.

Lors de l'analyse d'un échantillon important de spectres de ces étoiles dans l'ultraviolet et le visible, on doit exiger que les températures effectives de tous les objets, déduites indépendamment des observations dans les deux régimes de longueur d'onde, soient en accord entre elles. Il faut également que la masse moyenne de sous-échantillons d'étoiles à diverses températures effectives soit indépendante de la température effective, car les naines blanches se refroidissent à masse constante. La répartition des objets doit également être relativement uniforme dans l' éventail permis en température, sans "zone" exempte d'objet.

Ces exigences à satisfaire pour un échantillon important d'étoiles *froides* fournissent une relation entre le traitement de l'élargissement des raies du visible et celui des raies de résonance par les interactions avec les particules neutres. En émettant l'hypothèse que l'hydrogène est suffisamment peu abondant dans la majorité des étoiles chaudes où il est invisible spectroscopiquement, ces mêmes exigences fournissent cette fois une relation entre la paramétrisation de la convection et l'élargissement des raies de résonance produit par l'interaction avec des particules chargées. De plus, les contraintes d'une gravité moyenne identique pour les étoiles froides et les étoiles chaudes force un couplage entre les paramètres libres associés aux deux régimes en température.

9. CONCLUSION

Une telle étude systématique de toutes les incertitudes connues dans la modélisation des atmosphères de naines blanches de type DB est l'extension logique d'un travail entrepris en 1990, et qui a culminé avec la détermination de la distribution de masse pour ces objets (Beauchamp 1994; Beauchamp *et al.* 1996).

Celle-ci a été obtenue en adoptant un traitement particulier pour quatre des six paramètres libres énumérés à la précédente section, tout en explorant le sous-espace formé par les deux autres paramètres. En effet, en considérant différents traitements de l'élargissement de van der Waals (par les particules neutres) et les paramétrisations de la convection, Beauchamp (1994) démontre qu'une excellente corrélation est possible entre les températures effectives déduites d'observations dans l'ultraviolet et le visible pour les objets plus chauds que 15 000 K, et que la masse moyenne de sous-échantillons d'étoiles à différentes températures effectives est indépendante de T_{eff}, *à la condition que la paramétrisation de la convection adoptée pour les modèles d'atmosphères soit de type ML2 ou ML3, et que l'élargissement de van der Waals soit décrit avec la théorie de* Deridder et Van Rensbergen (1976); la paramétrisation de type ML1 et le traitement classique de l'élargissement de van der Waals (Unsöld 1955) ne sont pas appropriés à la modélisation des atmosphères de naines blanches de type DB. Une telle cohérence interne n'aurait cependant pas été possible sans le calcul de profils d'élargissement Stark (par les particules chargées) pour l'ensemble des raies de l'hélium neutre dans le domaine du visible (Beauchamp 1994; Beauchamp *et al.* 1997).

Une exploration plus complète de l'ensemble des paramètres libres présentés dans ce travail apportera de nouvelles contraintes au traitement de l'opacité de l'atome d'hélium et permettra de mieux évaluer les incertitudes dans la distribution de masse des naines blanches de type DB.

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A SEARCH FOR HELIUM SPECTRUM VARIABLES

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Abstract. Helium spectrum variables, which show periodic variations in the strengths of their helium lines, form a very rare subgroup of the peculiar B-type stars. The amplitudes can be quite large, though smaller variations are more common, and the periods found so far are of the order of a week, ranging from one to ten days. In an attempt to discover new variables, twelve helium-peculiar OB-type stars were observed during a twenty-night run in May/June 1992 with the Helen Sawyer Hogg 60-cm telescope[1] of the University of Toronto Southern Observatory in Chile. Ninety-two spectra were taken of the twelve stars during this period. No gross helium-line variations, such as those seen in the prototype, HD 125823 (a Cen), were observed. Smaller variations are easily seen in one other known, small-amplitude spectrum variable. Attention is called to some of the program stars that show small amplitude variations significantly larger than the errors and that warrant further observation. Some of the stars exhibit variations of other lines, including hydrogen. Our data indicate that the period of a Cen is closer to 8.816 days than to 8.814 days, supporting a suggestion by Fahey (1984).

Résumé. Les étoiles variables contenant de l'hélium démontrent de la variabilité périodique dans l'amplitude de leurs lignes spectrales et constituent un groupe très rare de variables particulières de type B. L'amplitude des variations peut être assez importante, quoique celles qui sont moins grandes sont plus communes et les périodes observées à date sont d'environ une semaine, avec une marge de variabilité d'un à dix jours. Dans le but de découvrir de nouvelles variables, douze étoiles particulières de type OB contenant de l'hélium ont été observées durant vingt nuits courrantes en mai et juin 1992, avec le télescope Helen Sawyer Hogg de 60 cm, de l'Observatoire du Sud de l'université de Toronto au Chili. Quatre-vingt douze observations du spectre des douze étoiles ont été faites durant cette période. Aucune variation importante des lignes spectrales n'a été observée, comme on en voit dans le prototype, HD 125823 (a Cen). Des variations plus attenuées ont clairement été observeés dans une autre variable reconnue pour la faible amplitude de ses lignes spectrales. Une attention doit donc être portée sur certaines étoiles au programme qui font preuve de petite amplitude, mais plus grande que celle des erreurs, et qui méritent de nouvelles observations. Certaines de ces étoiles présentent des variations dans d'autres lignes du spectre, y compris celles de l'hydrogène. Nos données indiquent que la période de l'étoile a Cen s'approche plutôt de 8.816 jours que de 8.814 jours, appuyant donc la suggestion de Fahey (1994). SEM

1. Introduction

Spectrum variables are good testing grounds for theories of stellar interiors, atmospheres, and evolution. Helium spectrum variables are especially interesting because the variability involves an element that is probably primordial and that is second in abundance only to hydrogen. They generally occur among the B stars and especially among the He-weak and He-strong stars, though some are also found among other classes of B-peculiar stars, such as the silicon Bp stars. (see Bolton 1983 for a review). Our sample is biased in favour of the discovery of new helium spectrum variables among the He-strong B-type stars, though we have included two O-type stars with helium peculiarities and three He-weak stars in the program.

In this search, we have targeted mainly members of the helium-strong subgroup, characterized by helium lines that are too strong for the MK spectral type as determined from the hydrogen and metal lines. In fact, the helium lines in the He-strong subgroup are much stronger than observed in any normal star and are classified as "peculiar" because they fall outside the normal range of observed helium-line strengths. Though the He-strong and He-weak stars are often described as "helium rich" or "helium poor," caution dictates that the classification should not imply an interpretation. Strong or weak helium lines may be a structural phenomenon and are not an unambiguous indicator of helium enrichment or deficiency. The helium-peculiar stars also exhibit very strong magnetic fields, comparable to those in the well-known magnetic A-type stars (Bohlender *et al*. 1987).

Some abundance analyses do find an excess of helium relative to hydrogen in the helium-strong stars, with typical values of $N_{\mathrm{H}}/N_{\mathrm{He}} \sim 1$. Effective temperatures are found to be about 20,000 K, consistent with a spectral type close to B2 V (Bohlender & Landstreet 1990; Hunger 1986a).

The first extreme helium star to be discovered was HD 124448 (Popper 1942), though it differs markedly from the others in the subgroup in that it displays no hydrogen lines at all. It is probably an evolved object, not related to the unevolved He-strong stars being discussed here. A better example of the subgroup is the well-known and intensely studied star σ Ori E, whose peculiarity was first described by Berger (1956) but whose variability was not noticed until much later (Walborn 1974). Descriptions are given by Bolton *et al*. (1986), Short & Bolton (1994) and Groote & Hunger (1997). There has been some controversy over the models for this star. HD 37017, also in the Orion Association, was studied extensively by Lester (1972).

The most dramatic helium spectrum variable known is HD 125823 (Norris 1968; note that this star is "a Centauri," not to be confused with α Centauri), which is included in our sample. It varies between the extremes of the helium-weak and helium-strong types. Since its discovery, fewer than a dozen of this particular type of helium variable star have been reported in the scientific literature (Hunger 1986a,b; Drilling & Hill 1986) and none varies as much as

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[1] Dedicated on June 19, 1992 to Helen Sawyer Hogg in recognition of her distinguished research career and her long service to the University of Toronto.

a Cen. More systematic searches are needed in order to establish patterns.

The helium spectrum variations are periodic to a high degree. Typical periods are a few days, though periods up to 9-10 days have been observed (Underhill *et al.* 1975; Bond & Levato 1976). In addition to the helium lines, the metal lines may vary in strength, but usually only very slightly; if they do, the periods are invariably the same, though sometimes the phases are different. It is not unusual for the metals to vary in antiphase with helium.

The hydrogen absorption lines, however, do not vary in HD 125823 (a Cen). While there are a few reported cases of mild Balmer-line strength variations (Walborn 1982; Barker 1986), most of the stars have not been known to show strongly variable hydrogen-line absorption strengths. HD 125823 (a Cen), whose helium lines vary from stronger than normal to almost zero in an 8.8 day period, shows no variation in the Balmer lines. Photometric variations are small or non-existent, consisting of at most a few hundredths of a magnitude in the U and B bands (Pedersen 1979). A few of the stars show variable Hα emission (Bolton 1983; Bohlender 1994).

All known helium spectrum variables follow a period-$v \sin i$ relation (Hunger 1986a). It implies that they are oblique rotators, an idea attributed to Guthnik & Prager (1918) and developed by Deutsch (1958), who applied it to the Ap stars. Problems regarding the non-detection of radial velocity changes in some of the stronger lines have since been addressed and have been attributed to saturation of the line cores (Landstreet & Borra 1978; Hunger 1986a).

The magnetic fields of these stars are also important to our understanding of the oblique-rotator model for helium line variability. All of the known helium-strong and helium-weak spectrum variables have detectable magnetic fields (Bohlender *et al.* 1987; Bohlender 1994; Borra *et al.* 1983). Their fields are variable, with the same periods as their photometric and spectroscopic fluctuations.

The main problem facing the oblique rotator model is how to create and maintain the regions of differing composition in the star. It has been known for some time that helium can settle out of a sufficiently stable stellar atmosphere under the right conditions (Michaud 1970). At first glance, that would appear to allow only the possibility of stars developing helium-poor atmospheres, with the helium diffusing inward towards the core. However, ionized helium diffuses 100-1000 times more slowly than its neutral counterpart under the conditions expected in an early-type star's atmosphere. It follows that the inward rate of diffusion decreases with radius, because of increasing ionization, which can result in the creation of a helium-rich layer with a helium-poor region above it (Bolton 1983). If a radiatively driven stellar wind were introduced, the downward diffusion would then be taking place in an upwardly moving reference frame. That could allow the helium reversing layer to occur higher in the star's atmosphere than might otherwise be possible, its radius being dictated by the balance between the rates of diffusion and mass-loss (Osmer & Peterson, 1974). If the He-enriched or depleted layers were to exist near optical depth ~1, they would affect the helium line strength and mislead attempts at abundance analysis.

Computer models have indicated that helium separation can occur in the atmospheres of hot stars in such a manner (Vauclair 1975, 1991). However, the mass loss rates required are ten or more times higher than would be expected from models for the winds of such stars (Lucy & Solomon 1970). The expected winds would sweep the reversing layer out into space. The key to the dilemma is the magnetic field.

A magnetic field will exert a retarding force on a charged particle moving perpendicularly to it. Thus, the magnetic field provides a mechanism by which the stellar wind might be slowed to the point where the helium reversing layer could be retained (Shore 1993). If we were to assume a simple dipolar geometry for the field, the maximum non-radial component of the magnetic field would occur at the magnetic equator, and the reversing layer would have its minimum astrocentric distance there. The magnetic field would become increasingly radial with increasing magnetic latitude, allowing the stellar wind to flow more freely and the reversing layer to rise progressively. It would result in what would appear to be (and are) differing chemical compositions at different latitudes, as the reversing layer would reside at different radii and hence different optical depths. Such compositional variations would have the appearance of bands or caps. More complicated field geometries could result in the presence of more localized spots, for which some evidence exists (Bohlender & Landstreet 1990; Groote & Hunger 1997).

As the star rotates, the different areas will be swept across the visible face of the star. That produces the observed variations in the helium lines and explains their periodicity. The variability of the metallic lines can be explained by a similar diffusion process, or perhaps simply as a symptom of the helium segregation. The helium enrichment or depletion of different regions may change the temperature structure of the atmosphere, and so might affect temperature-sensitive lines in principle; in practice it is probably not very sensitive to changes in helium abundance (Bohlender private communication). They should demonstrate the same periodicity as the other variations, which is in accordance with observations.

The purpose of this survey is to enlarge the sample of known helium spectrum variables. In the theoretical interpretation there are many free parameters involving the magnetic field, the star, and the geometry, thus allowing a wide range of behaviour. A good statistical look at the phenomenon requires a relatively large sample, which does not yet exist. Though relatively rare, OB-type stars are visible at large distances, thus yielding a large accessible population of potential helium spectrum variables. In addition, the characteristic of being helium strong (easily detectable in classification surveys) or helium weak gives criteria by which to choose candidates for closer inspection. These two factors give us the tools necessary to expand efficiently the sample of known helium spectrum variables. We report below the results of one observing run.

2. Observations and Reductions

The observations were carried out between May 24 and June 12, 1992, with the Helen Sawyer Hogg 60-cm telescope of the University of Toronto Southern Observatory on Cerro Las Campanas in north-central Chile. The Garrison classification spectrograph was used with a glycol-cooled PM512 CCD (Photometrics, Inc.), which is coated with MetaChrome II for improved blue response. A new first-order grating was used in the wavelength interval 4100–4500Å with a resolution of 1.7 Å per 2 pixels. Signal-to-noise ratios of a few hundred are achieved by widening the spectra up to 30 pixels

Table I
The Target Stars

HD No.	Hbg No.	MK type	V	B-V	U-B	Notes
66765	120	B2 V	6.60	−0.14	−0.76	2SB, sl. He-strong, var
117357	828	B0.5 IIIne	9.07	0.20	−0.69	var H emiss., He absorp.
133518	928	B2 Vp	6.30	−0.06	−0.72	He-strong
135038	945	B8 III (p?)	8.37	0.01	−0.39	He-weak?
147880	1138	B5: III (p?)	8.63	0.04	−0.39	He-weak?
149257	1173	B2 Vp	8.46	−0.01	−0.77	He-strong
150136	1188	O5 III (f)	5.54	0.20	−0.76	He "washed out," SB?
164769	1539	B2 IVp	9.23	−0.04	−0.79	He-strong
165207	1551	B2 Vp	8.25	−0.10	−0.76	He-strong
168785	1623	B2 Vp	8.51	0.04	−0.73	He-strong
168941	1624	O9.5 IIp	9.34	0.07	−0.87	He ii 4686 too strong
172854	1650	B3 IIIp	7.69	0.23	−0.30	He-weak

for most of the program stars. The standard procedure is for at least three successive ten-minute frames to be taken of each object, to aid in the detection of cosmic rays. The three frames are then added to make one "exposure." The signal-to-noise ratio per pixel is generally 40-80; after co-adding and binning, the overall signal-to-noise is generally between 100-500.

Despite overall poor weather, observations were obtained on thirteen nights, which were fairly well spaced over the twenty-night interval. It allowed measurements to be taken over more than one period for stars with longer cycles, and also allowed adequate phase coverage for any stars with periods close to an integral number of days.

The program stars were chosen from a survey of southern OB stars by Garrison, Hiltner & Schild (1977; hereinafter GHS). Heidelberg (Hbg) numbers are from Klare & Szeidl (1966). The GHS survey has a limiting magnitude of about 10 in *V*, and provides the MK classifications for the stars observed. GHS include comments on stars with peculiar spectra, including those with abnormal helium line strengths. Photometry for the stars is found in Schild *et al.* (1983; hereinafter SGH).

The comments in GHS were used for selecting our candidates. Seven stars noted to have strong helium lines were chosen as primary candidates. Five other stars having either weak helium lines or other helium spectral peculiarities were chosen as secondary candidates. The stars chosen are in the range $5.5 < V < 9.4$ and are listed in Table I.

Spectra of thirty-nine standard stars were observed, ranging from late O to early A; each was taken at least once during the run. Three primary standards were taken nightly. Also observed as variability standards were the known helium spectrum variables HR 3089, HR 7129 and a Centauri. The subset of standards actually used is listed in Table II.

The spectra were reduced with IRAF 2.9.1, running on a Sun 3/160. From the 900+ frames taken (including reference and calibration frames), 241 finished spectra were produced. All of the stellar exposures consisted of three frames and most are widened by 30 pixels. They were co-added and reduced to one dimension.

The exposures for each object were then stacked to allow visual inspection for large-scale variations. The stacked and difference (from the mean) spectra for the known variables are shown in figures 1ab–3ab. The difference spectra for two of the primary standards are shown in figure 4ab to illustrate the confidence level for constant spectra of good quality. Stacked and difference spectra for the program stars are shown in figures 5ab–12ab. For a few of the candidates only one or two spectra were obtained and no differences were visible, so they are excluded from the series of illustrations. A few of the spectra were in the range 3850–4250 Å, and are not illustrated here. Note that the stacked spectra are not necessarily taken on consecutive nights, so a periodic change in line strength might not appear obvious in the plots; in the first instance we were searching for any changes that occurred. Follow-up observations of the most interesting cases will be necessary to ascertain periods.

3. Discussion

3 (a). Known Helium Spectrum Variables

HD 125823 (a Centauri, figure 1ab) shows dramatic variability in the strengths of all the neutral helium lines in the wavelength region covered, notably 4121, 4144, 4168, 4387, and 4471Å. The Julian dates in figure 1ab are those on which the observations were made. The helium-line strengths at maximum are stronger than in normal stars at B2 V, the peak of helium-line visibility, but they approach invisibility at minimum. However, the Balmer lines show no significant changes. Most of the other strong lines, notably Si ii 4128–30 Å, show no changes. Mg ii 4481Å may vary slightly. Curiously, however, the Fe ii line at 4233Å is faintly present and appears to vary slightly in antiphase compared with helium. The line is not visible in normal early B stars and usually begins to appear only at about spectral type B8. It is not clear if the changes in profile of C ii 4267Å are real, though the reductions have been checked several times and no sources of error were found that could lead to the effect. The line has strong non-LTE effects and is known to be unreliable as a temperature indicator (Hamilton & Garrison 1995).

There has been some disagreement (on the order of a few hundredths of a day) about the period of a Centauri's helium variability. The measured values seem to be increasing slowly with time (Fahey 1984). Such a trend of slowly increasing period is supported by our results. In figure 1 it is clear that the maximum of the helium lines does not occur at zero phase (JD2440083.5 + 8.814, or JD2448782.918) as given by Norris (1971). Our data are more consistent with a period of 8.816 days (JD2448776.076).

The reported variability of HR 3089 (Bohlender & Landstreet 1990) for the helium lines is not very obvious in our data (figure 2ab). C II 4267Å and Mg II 4481Å are easily visible and essentially constant. The blend at 4415-17Å, which may be due to O II, is relatively strong and non-variable. Si II 4128–30 Å is marginally visible. Besides the strong helium lines, however, the spectrum is quite peculiar. There appears to be a strong, non-variable feature at 4072–6 Å, which is possibly O II, but that is usually seen in stars earlier than B1 or above the main sequence at B2. There is also a line at 4444 Å, which may be O II or N II. As HR 3089 is the hottest well-established helium-strong star, the appearance of O II is perhaps not so surprising. A further comprehensive study of high-resolution, high S/N spectra of the star would be very informative.

HR 7129 (figure 3ab), also a known helium spectrum variable, exhibits a clear helium line variation, though it is considerably less dramatic than in HD 125823. The He I lines 4144, 4387, and 4471

TABLE II
The Standard and Comparison Stars

Spectral Type	Luminosity Class			
	V	IV	III	Ib
B1	ω^1 Sco		σ Sco	
B2	22 Sco β Sco C[a]	μ^2 Sco υ Sco	β Lup	
B3	η Hya			
B5	κ Hya[a]	γ Cir	ι Aql	67 Oph
B6	β Sex			
B7	α Leo	δ^1 Tel	HR 6460	
B8	HD 142315		ω Car[a]	
B9	HD 141774	α Del	γ Lyr	
B9.5	ω^2 Aqr			
A0	109 Vir γ Oph		HD 142805	
B2-8p var	a Cen[a]			
He-var	HR 3089[a] HR 7129[a]			
He-weak	HR 5988			
Silicon	HD 147890			
Si-4200	HD 142884			
Manganese	HR 6003			

[a] Nightly standards and known variables.

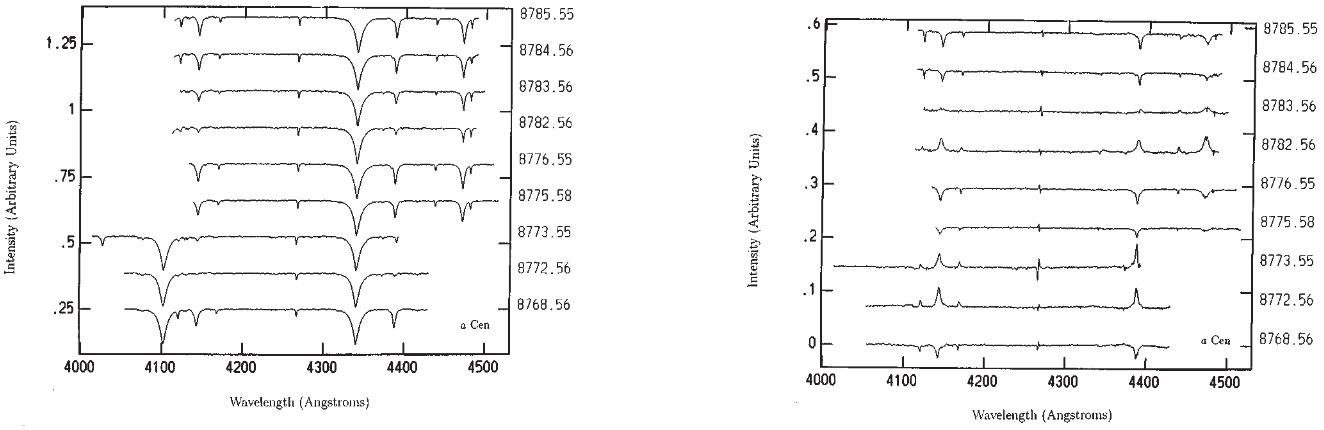

Fig. 1ab — a Centauri = HD 125823 (B2-B9 IIIp). Zero phase is JD2448782.918 for a period of 8.814 days or JD2448776.076 for a period of 8.816 days. In this and following figures the difference spectra are on the right.

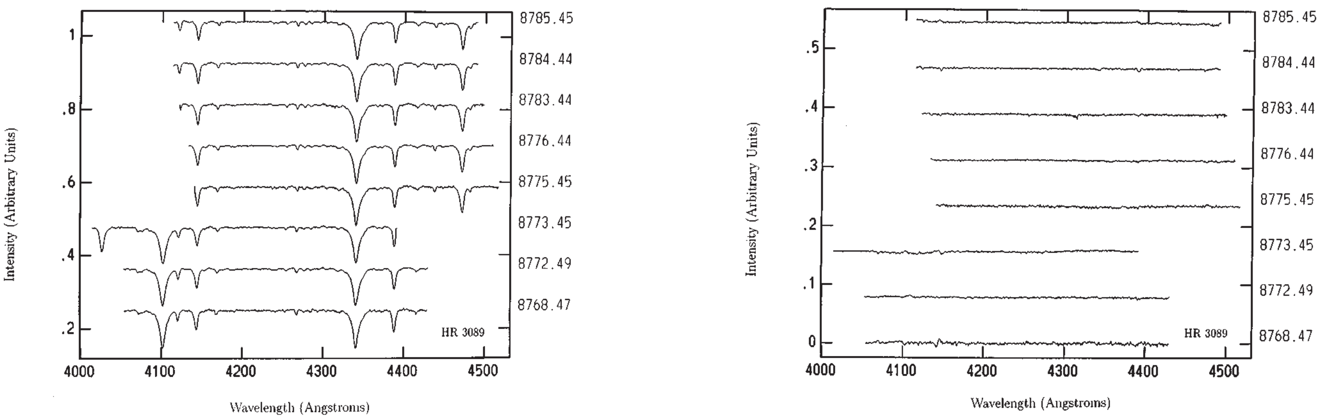

Fig. 2ab — HR 3089 (B2 III). Zero phase is JD2448775.573 for a period of 1.33026 days (Bohlender & Landstreet 1990).

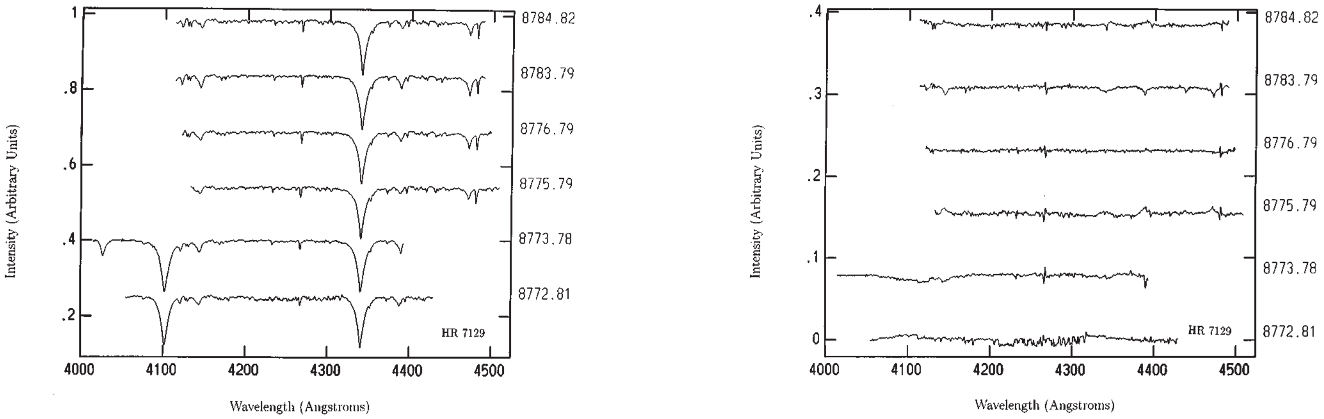

Fig. 3ab — HR 7129 (B8 IV). Zero phase is JD2448774.15 for a period of 3.67 days (Wolff & Wolff 1976).

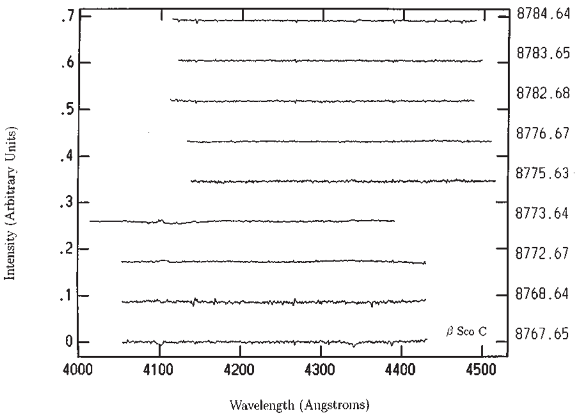

Fig. 4a — β Scorpii C = HD 144218, standard B2 V star.

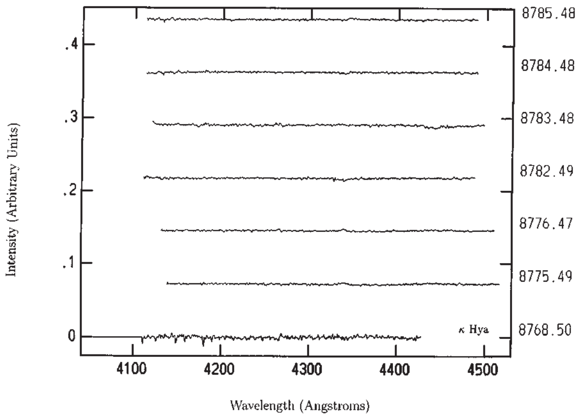

Fig. 4b — κ Hydrae = HD 83754, standard B5 V star.

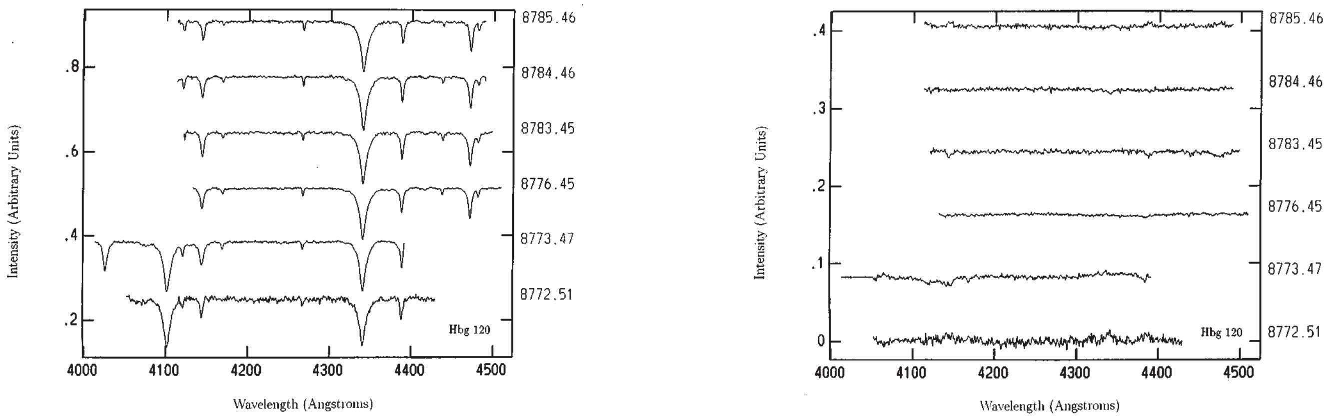

Fig. 5ab — Hbg 120 = HD 66765, B2 V (two-line spectroscopic binary; helium slightly enhanced).

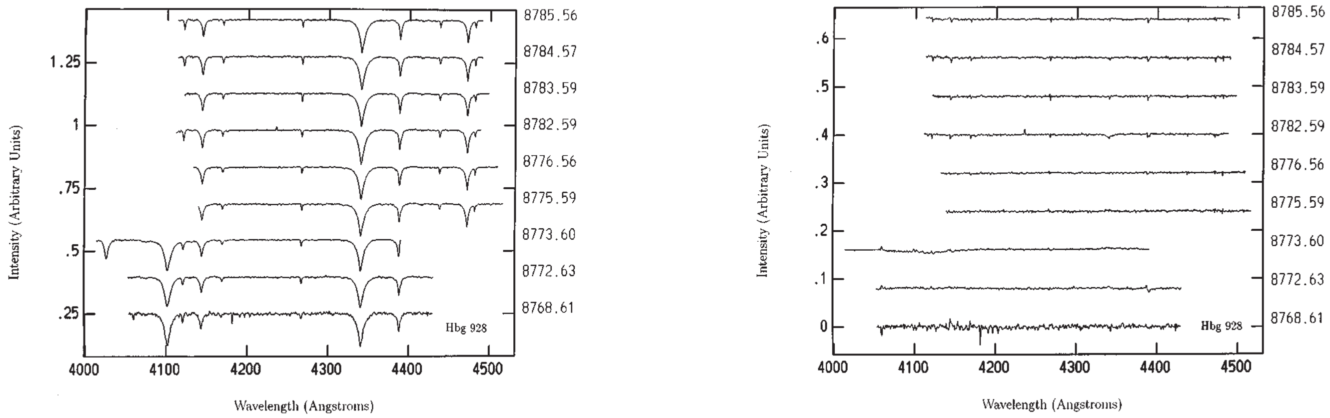

Fig. 6ab — Hbg 928 = HD 133518, B2 Vp (helium-strong star).

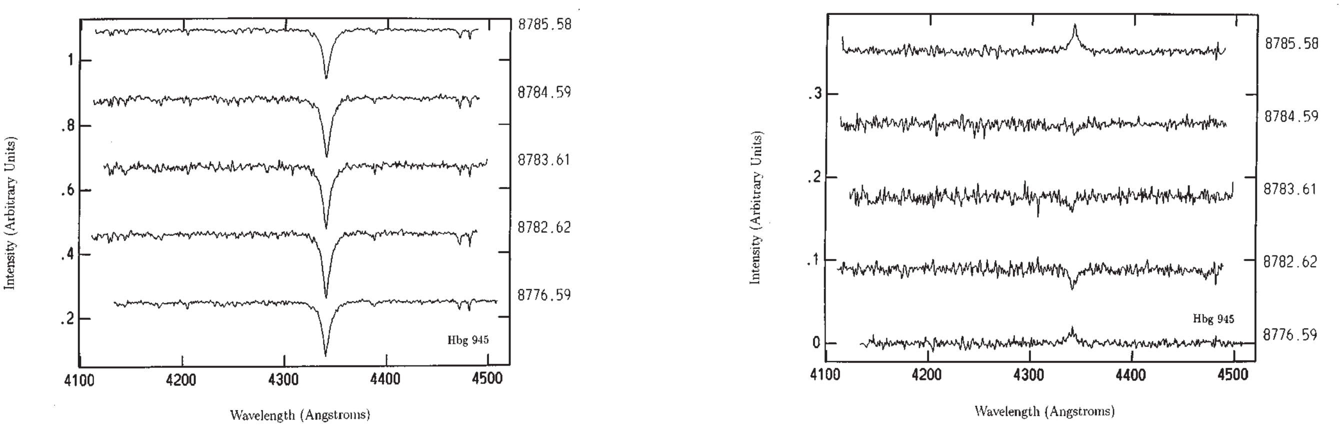

Fig. 7ab — Hbg 945 = HD 135038, B8 III (p?) (hydrogen profiles are peculiar, as in weak-helium star).

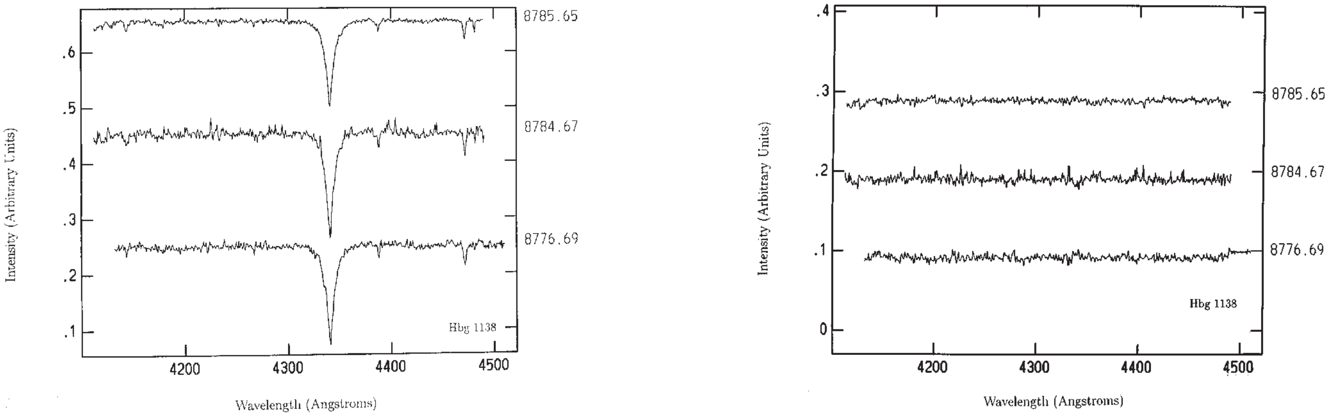

Fig. 8ab — Hbg 1138 = HD 147880, B5 III (p?) (silicon, magnesium weak, hydrogen profiles are somewhat peculiar, marginal helium-weak star).

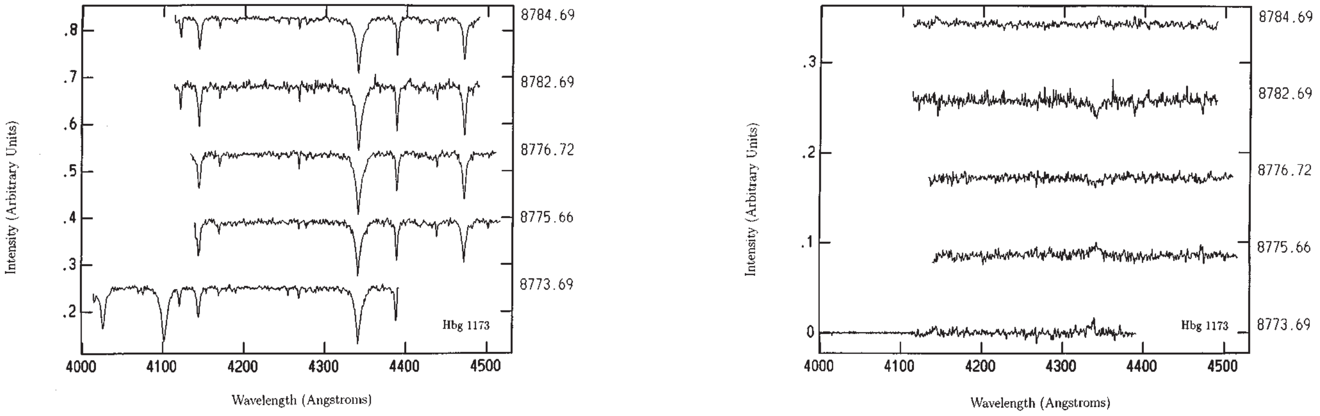

Fig. 9ab — Hbg 1173 = HD 149257, B2 Vp (helium-strong star).

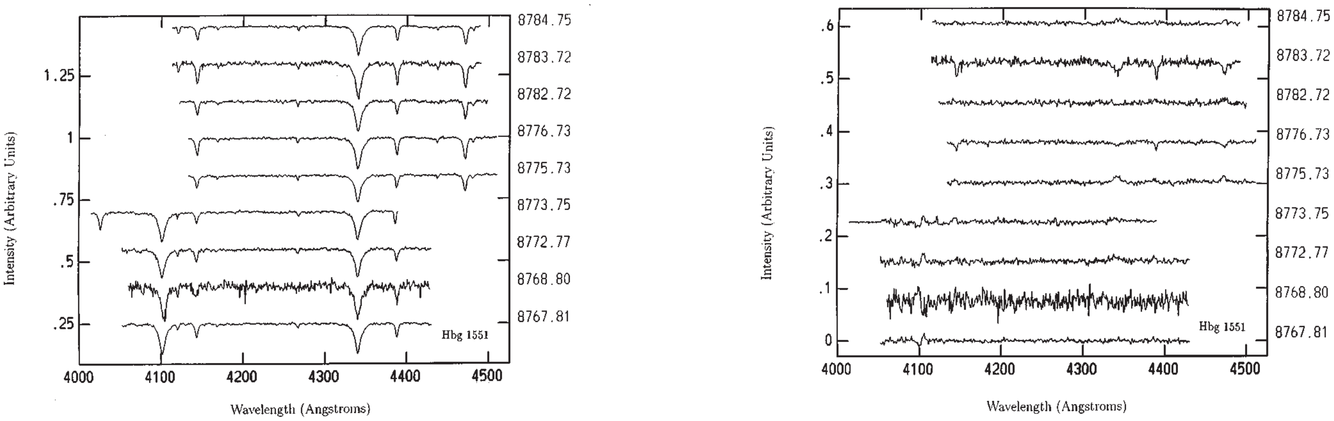

Fig. 10ab — Hbg 1551 = HD 165207, B2 Vp (helium-strong star).

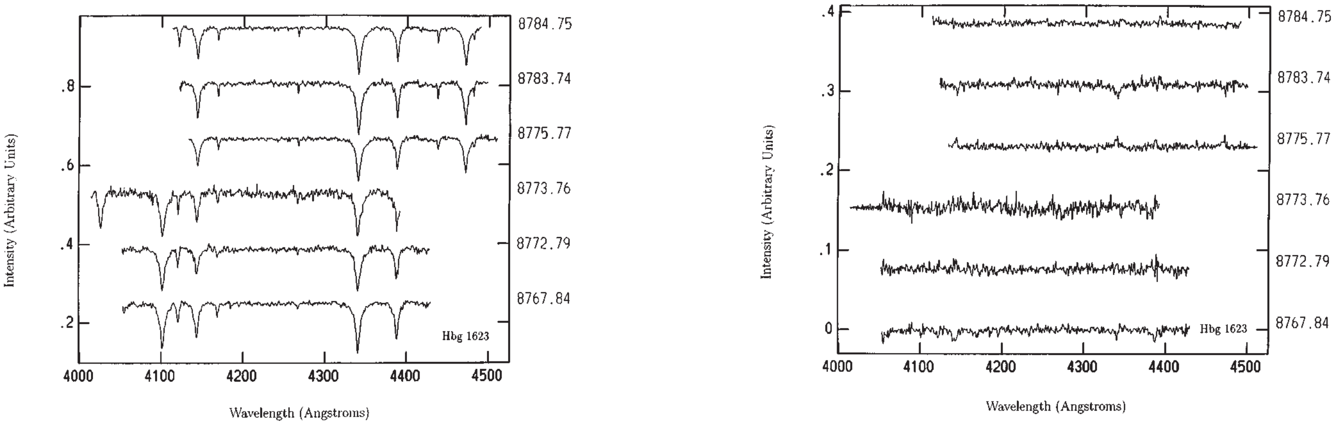

Fig. 11ab — Hbg 1623 = HD 168785, B2 Vp (helium-strong star).

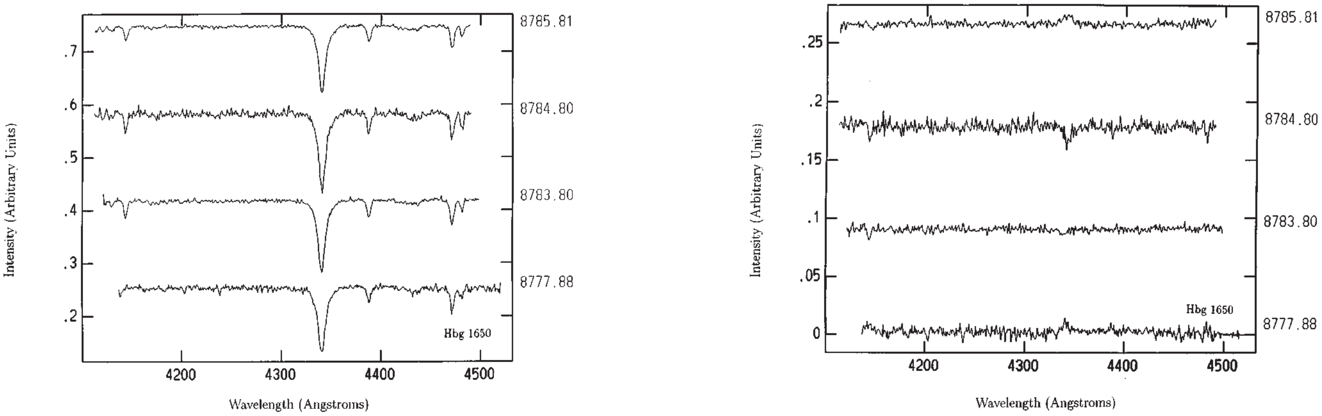

Fig. 12ab — Hbg 1650 = HD 172854, B3 IIIp (helium lines are weak for the rest of the spectrum).

Å lines vary unmistakably, and their maxima seem to coincide well with zero phase. The blend Si II 4128–30Å and an O II line at 4370 Å seem to vary in antiphase with the helium lines. The C II 4267 Å line has been reported to vary (Wolff & Wolff 1976). In our data there is a possible line shift or profile variation, as described above for a Cen (HD 125823), but no apparent variation in line strength. As in a Cen, the hydrogen lines and Mg II 4481 Å appear to be constant in strength, with a possible line profile shift. Other discernable, but apparently non-variable, lines are Fe II 4233 Å (which varies in a Cen), and the O II blend at 4415-7Å.

3 (b) Nightly Standards and the Question of Errors

Three of the non-variable standards (β Sco C, B2 V; κ Hya, B5 V; and ω Car, B8 IIIn) were taken nightly and can be used to estimate the true errors introduced by the reduction process. Differences in the flats used in the first stages of reduction, as well as the effects of the rectification process and the dispersion correction, could lead to apparent variations in the spectra. Figure 4ab is an illustration of the difference spectra for β Sco C and κ Hya.

The only visible difference is in the amount of noise present in each of the exposures. That is most likely a consequence of differences in signal-to-noise ratio (S/N) in the raw data, because varying sky conditions and exposure times translate into different S/N for each night. Except for the S/N differences, the spectra appear to be very uniform, so it is likely that any night-to-night processing artefacts will be comparatively small. The shift in profile of C II 4267 Å is slightly visible in the spectrogram of β Sco C, indicating that it may be an artefact of the reduction process, though we could not find any obvious errors.

3 (c) Program Stars

The previously unexamined program stars are illustrated in figures 5ab -12ab. Most of the spectra were taken in the 4100–4500 Å region, so that is the only region shown. None of the new candidates shows dramatic changes in the helium lines, such as those in a Cen, though we were hoping to find some. Several show small helium-line variations, indicating that further study is warranted. A few show definite hydrogen or other line variations. To avoid problems resulting from small artificial night-to-night changes tied to the rectification process in IRAF, we consider mainly periodic changes in line ratios. That minimizes the processing "noise." Some lines in some stars are marginally variable. When combined with other line information, the results are strengthened in some cases and rendered inconclusive in others.

Hbg 120 (HD 66765, figure 5ab) seems to have a definitely variable line at He I 4144 Å. The other He I lines at 4121, 4168, 4387 and 4471 Å appear to be marginally variable, all with the same phase, thus supporting the reality of the helium variations. The effect is too systematic to be spurious. GHS list note that the star is a two-line spectroscopic binary. Further investigation is warranted.

Hbg 828 (HD 117357, not illustrated) is faint and heavily reddened. The diffuse interstellar absorption band at 4430 Å is prominent. The star was observed on only two nights and the resulting spectra have relatively low S/N per pixel. Only a few strong lines of hydrogen and helium are discernable, so any apparent variations are probably not real. GHS note that this B0.5 IIIne star has variable emission and 4471 Å absorption.

Hbg 928 (HD 133518, figure 6ab) is a strong helium star that may show marginal helium-line variations. The May 26 spectrogram (JD 2448768.61) is much noisier than others because of poor sky conditions. Its raw S/N per pixel is only about 30–40, whereas the others are consistently above 100. The helium lines, though very strong, do not seem to show gross variations. A few of the lines, namely 4144 and 4387 Å, seem to vary slightly and should be investigated at higher resolution. The Fe II line, 4233 Å, pops up in emission, but only in one spectrogram (8782.59). It is not a cosmic ray and is well above the noise level, so its presence is an interesting puzzle. Bohlender *et al.* (1987) find no evidence for a magnetic field in the star. Pedersen & Thomsen (1977) find no evidence for variability in the He 4026A line. If the star is truly variable, it would be the first case of known spectrum variability in a non-magnetic, helium-peculiar star.

Hbg 945 (HD 135038, figure 7ab) is a weak-helium star, as noted in GHS. The hydrogen line at Hγ is strikingly variable. More complete coverage, both photometric and spectroscopic, would be fruitful. On the other hand, the helium lines are so weak that small variations would be difficult to detect. The S/N is relatively low, but it is clear that there are no gross variations in the helium lines, such as those in HD 125823. The 4471/4481 Å line ratio seems constant within the noise limits, though small variations are not ruled out. Si II 4128–30 Å seems constant.

Hbg 1138 (HD 147880, figure 8ab) is a tantalizing case. GHS note that it has weak silicon and magnesium lines as well as peculiar hydrogen-line profiles and is probably a weak-helium star. Unfortunately, the star was observed on only three nights. The helium lines, especially 4144 Å, may be variable, but more spectra are needed to confirm this.

Hbg 1173, Hbg 1551, and Hbg 1623 (HD 149257, HD 165207, and HD 168785; figures 9ab–11ab) are all helium-strong stars. All have very strong helium lines, with Mg II 4481 Å visible. Significant variations are visible in the hydrogen and helium lines, though nothing as striking as in a Cen is apparent. Hydrogen varies in phase with helium. Follow-up observations are recommended.

Hbg 1188 (HD 150136, not illustrated) is classified as an O5 III(f) star and was included in the sample because GHS noted that the helium lines were peculiar in appearance ("washed out"). The most prominent lines besides Hγ are He II 4200 Å and He I 4471 Å. The diffuse interstellar feature at 4430 Å is one of the strongest features in the spectrum. Only two spectra were obtained, but no gross variations are visible.

Hbg 1539 (HD 164769, not illustrated) has only two exposures, the second being of much lower signal-to-noise ratio than the first. The helium lines are unusually strong, but no gross variations of the helium or other strong lines are visible. GHS note that Ca II is present and broad (as in some shell stars).

Hbg 1624 (HD 168941, not illustrated) was observed only once. It is an O star with helium peculiarities. The peculiarities reported in GHS (very strong He II 4686 Å) are confirmed.

Hbg 1650 (HD 172854, figure 12) is a another good candidate for further investigation of helium variability, though the data here are not complete enough or of high enough quality to unambiguously establish helium-line variability. GHS list the star as having weak helium lines for the rest of the spectrum. The hydrogen lines, however, vary significantly. The equivalent width ratios of He I 4387 Å to Hγ and He I 4471 Å to Mg II 4481 Å show some evidence of variation, but are inconclusive. Curiously, C II 4267 Å is much weaker than in most of the other stars in the sample, whereas it should be at its peak strength.

4. Conclusions

We conclude that four of the stars show small helium variations, two show marginal helium variations, and two show strong hydrogen variations, but further study is needed to confirm the variations and to determine periods. None of the twelve new target stars in our survey undergo the gross variations in helium or metal lines observed in the classical strong-to-weak helium variable, a Cen. Unfortunately, our study was hampered by bad weather. From the eye estimates and equivalent width ratios, a reasonable estimate of the nominal confidence level for the well-observed sequences is about 10% for the strong lines. Indeed, we can see such changes in two of the three known helium variables, but none are visible in the standards, so the small variations observed in many of the survey stars are real. For the poorly observed stars, all we can say is that they do not appear to vary wildly at the times of the few observations.

For smaller scale variations, there are several cases where further investigation is warranted. The helium-peculiar stars are in general not very well understood, so higher resolution and higher S/N studies would produce interesting results in any case. With better data the application of Fourier transform or other mathematical techniques could reveal quantitatively the extent of small variations or variations in the weaker lines.

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A SEARCH FOR THE PARENT CLUSTER OF THE CEPHEID SU CYGNI

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ABSTRACT. We present photoelectric *UBVR* photometry, supplemented by photographic *UBV* photometry and spectroscopic observations for the brighter objects, of a sample of 33 stars in an anonymous field located 17 arcminutes west of the classical Cepheid SU Cygni. The survey represents an attempt to identify members of the parent cluster from which the Cepheid originated. Photographic photometry is also presented for 14 stars that lie within about 15 arcminutes of the Cepheid and are known to be of B or A spectral type. There is no evidence in our data to suggest that the survey field west of SU Cyg contains a previously-overlooked open cluster. On the other hand, there is a group of 14 stars from our survey and that of Turner *et al.* (1997) that does appear to represent the scattered remains of the parent cluster for SU Cyg. If SU Cyg is a member of the group, its luminosity as a "cluster" member is $<M_V> = -3.19 \pm 0.07$.

RÉSUMÉ. Nous présentons des données de photométrie *UBVR* photoélectrique, ainsi que des observations de photométrie *UBV* photographique et des observations spectroscopiques d'objets les plus brillants d'un échantillon de 33 étoiles dans un champ anonyme situé à 17 minutes de l'arc à l'ouest de SU Cygni, une céphéïde classique. L'enquête représente une tentative d'établir l'amas supposé duquel provient la céphéïde. Des données de photométrie photographique sont aussi présentées pour 14 étoiles situées à quelque 15 minutes de l'arc de la céphéïde, lesquelles sont de type spectrale B et A. Il n'y a aucune indication dans nos données suggérant que le champ à l'ouest de SU Cygni contient un amas ouvert qui n'a pas encore été decouvert. Toutefois, il y a un groupe de 14 étoiles dans notre échantillon et dans celui de Turner *et al.* (1997) qui semble représenter les restants de l'amas originaire de SU Cygni. Si SU Cygni est bien un membre de ce groupe d'étoiles, sa luminosité en temps que membre de l'amas est $<M_V> = -3.19 \pm 0.07$. SEM

1. INTRODUCTION

In recent discussions pertaining to the Hubble constant and the distance scale of the universe, it has sometimes been overlooked that the fundamental standard candles used for such research, classical Cepheid variables, are calibrated in various ways, one of the most important being membership in open clusters. The presence of a cluster of stars surrounding or adjacent to a Cepheid is of great potential value since the confirmation of a physical association between the two, usually by means of photometric, radial velocity, proper motion and star count data, allows one to conclude that the distance, reddening and age of the Cepheid are identical to the same values derived for cluster stars.

The region along the Vulpecula-Cygnus border has been examined previously for coincidences between Cepheid variables and open clusters or associations. The $68^d.5$ Cepheid S Vulpeculae, for example, was studied by Turner (1980) as a likely member of the association Vulpecula OB2, about 4 kpc distant, and the variable was subsequently discovered (Turner 1985) to be coincident with a sparse, uncatalogued, open cluster that is probably unrelated to the Cepheid (Turner *et al.* 1986). The spatially-adjacent 45^d Cepheid SV Vulpeculae is suspected by Turner (1984) to belong to an older subgroup of the association Vulpecula OB1, about 2 kpc distant.

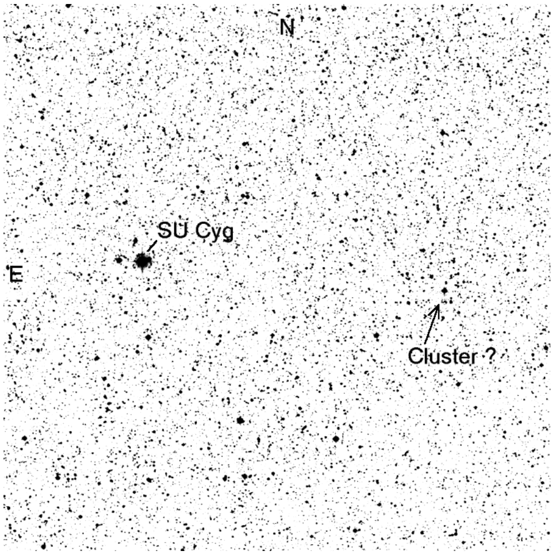

FIG. 1 — A visual image from the *Palomar Observatory Sky Survey* red plate containing the field of the Cepheid SU Cygni (left) and the putative cluster identified by Mandushev (right). The field measures 30 arcminutes on a side. [*Copyright the Digitized Sky Survey (DSS).*]

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The subject of the present paper, SU Cygni [$(\alpha, \delta)_{1950} = (19^h\ 42^m\ 49^s, +29° 08'.6)$], is a $3^d.8$ Cepheid that is also an unresolved triple system (Evans & Bolton 1987, 1990) containing two hot B-type dwarf stars in addition to the F-supergiant Cepheid primary. It was suspected to be located in an open cluster in 1978 by Nancy Evans, who observed the star regularly using the 1.88-m telescope of the David Dunlap Observatory and noted its unusual number of optical companions. The immediate field of SU Cyg was later surveyed by photometric and spectroscopic techniques (Mandushev 1994; Turner *et al.* 1997), but there was no evidence to indicate that any of the stars lying within ~10 arcminutes of the variable are physically associated with it. The optical companions of SU Cyg seem to represent merely a rich concentration of field stars in this populous region of the Milky Way. Given the rich nature of the SU Cyg star system itself, however, one is left to ponder whether or not the parent cluster of the Cepheid, or its remains, is located in a closely adjacent field.

In the course of examining the *Palomar Observatory Sky Survey* (POSS) images of the region surrounding SU Cyg, Mandushev (1994) identified a sparse group of stars lying about 17 arcminutes west

Table I
Photoelectric Observations

Star	*X*	*Y*	*V*	*B–V*	*U–B*	*V–R*	n	Notes
1	−22.09	−4.71	11.13	1.53	1.61	1.11	1	KM-type
2	−21.86	−5.66	12.31	2.21	2.44	1.72	1	M-type
3	−21.38	−5.09	12.86	1.64	1.27	1.26	1	KM-type
4	−20.58	−0.45	12.46	1.09	0.53	0.91	1	K-type
5	−20.60	−2.49	13.29	0.19	0.03	0.33	1	
6	−19.07	−4.27	12.21	0.26	0.22	0.30	1	A-type
7	−18.68	−5.18	13.83	0.43	0.27	0.39	1	
8	−17.29	−6.18	11.14	0.96	0.71	0.81	2	K-type
9	−16.33	−6.01	11.83	0.30	0.18	0.31	2	BA-type
10	−15.03	−6.40	12.22	0.26	0.22	0.28	2	A-type
11	−12.88	−4.30	13.37::	0.65:	0.16:	0.61	2	variable
12	−12.82	−4.05	10.28	1.45	1.36	1.07	2	HDE 332550, K2
13*	−13.95	−3.08	13.19	0.55	0.29	0.33	2	double, FG-type
14	−14.56	−2.25	12.20	1.38	1.50	1.01	2	K-type
15	−10.68	−1.53	13.07	0.31	0.24	0.41	1	
16	−12.16	−0.51	12.28	0.34	0.04	0.45	1	F-type
17	−11.43	−0.17	13.25	1.05	1.01	0.98	1	
18	−10.90	+1.10	*12.84*	*0.60*	*−0.11*	...	pg	double, K-type
19	−11.69	+2.29	11.65	0.43	−0.01	0.46	1	F-type
20	−11.19	+3.71	12.11	2.10	*2.22*	1.67	1+pg	M-type
21	−13.27	+4.95	11.36	0.34	0.10	0.38	1	HDE 332546, A-type
22	−14.09	+3.62	12.60	1.49	1.23	1.09	1	KM-type
23	−15.62	+2.19	12.53	0.19	0.18	0.16	1	A-type
24	−15.40	+0.62	11.26	0.44	−0.03	0.48	2	HDE 332548, F8 V
25	−14.50	−0.65	12.42	0.49	0.04:	0.49	2	variable, G-type
26	−15.33	−0.88	12.45	0.50	0.06	0.47	2	A-type
27	−15.82	−0.82	12.68:	1.31	1.22:	1.01	2	variable
28	−16.53	−1.58	10.05	1.63	1.87	1.18	2	HDE 332549, K5
29	−16.90	−2.19	12.36:	0.20:	0.21:	0.30:	2	A3 V, variable
30	−17.33	−2.77	13.28	2.57	...	1.66	2	M:-type
31	−17.59	−1.10	12.91	0.31	0.25	0.36	2	A-type
32	−17.29	−0.65	12.96:	0.56:	0.10:	0.52:	2	variable
33	−17.07	+0.01	12.72	0.84	0.72:	0.69	2	GK-type

Notes: * Double, $\Delta\rho = 8''–10''$.

of the Cepheid that might be an anonymous, sparse cluster. Figure 1, which shows the field containing the cluster and the region near SU Cyg, is an enlargement from a POSS image. The location of SU Cyg is indicated, as is the putative cluster. Given that the cluster was recognized from the slight enhancement in star densities visible on the POSS, the logical follow-up test for its reality is by means of a photometric and spectroscopic survey of the field. Such a survey is presented here.

2. Observations

An enlargement of the field of the sparse group at $(\alpha, \delta)_{1950} = (19^h\ 40^m, +29^\circ\ 20')$ is shown in figure 2. Of 33 stars selected for photoelectric observation, one (star 18) located near the edge of the field was subsequently dropped from the photoelectric survey when it was found to be a close double. Johnson system *UBVR* observations for the remaining 32 stars were obtained on three nights in October 1994 using the 0.6-m reflector of the Mount Maidanak High-Altitude Observatory of the Tashkent Astronomical Institute, in fashion similar to previous observations described by Berdnikov (1986).

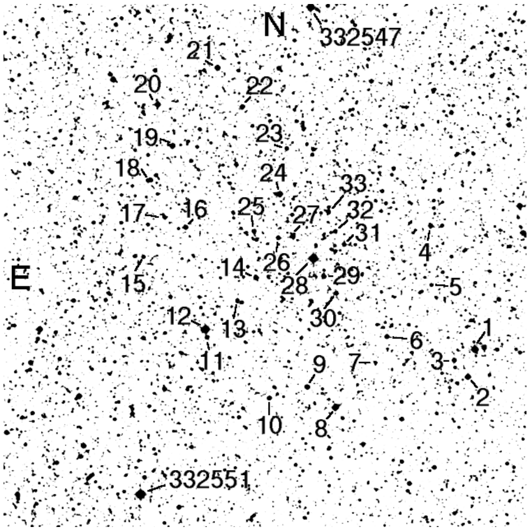

Fig. 2 — A finder chart for the field of the putative cluster identified in figure 1, taken from the POSS red image used for figure 1. The field measures 18 arminutes on a side. Program stars are identified by number, and a few stars from the Henry Draper Catalogue Extension (HDE) are identified.

The identification of potential B-type stars is crucial to any search for a parent cluster to SU Cyg since the Cepheid itself is expected to have been a B3 star during the core hydrogen-burning stage of evolution (Turner 1996). The problem is that certain filter systems can sample the region of the Balmer discontinuity at 3646 Å for late B-type and early A-type stars in a manner that makes it difficult to match the instrumental magnitude and colour observations for such stars to the standard *UBV* system (Moffat & Vogt 1977). Other potential filter mismatches can also lead to systematic errors in such data (Bessell 1990). We were therefore alert to the possibility that non-linear effects might be present in our *UBV* observations, and took care to check for potential systematic effects in the tie-in to the standard system. Since half of the cluster field is contained on the photographic plates used for the study by Turner *et al.* (1997), the plates were remeasured for cluster stars as well as other stars known to be of B and A spectral types in order to confirm the photoelectric calibration and to provide data for other stars that might be associated with SU Cyg. A quadratic trend was detected in the $B-V$ colours and a curvilinear trend, indicating a discontinuity between stars earlier than/later than spectral type G, was detected in the $U-B$ colours. Both trends were subsequently removed from the photoelectric data. The trend in the $U-B$ colours has a different signature from a Balmer discontinuity effect, and may originate in another property of the filter/photometer combination used, possibly a mismatch in the *B* filter relative to that defining the standard system (*cf.* Bessell 1990).

The resulting observations are presented in columns four through seven of Table I, and should be relatively free of systematic errors. Because of the small number of observations and non-standard nature of the photometer, the uncertainties in the data are likely to be as large as ± 0.02 or more in some of the magnitudes and colours. The stars in Table I are identified in the finder chart of figure 2, as well as by their displacements (measured in arcminutes) in right ascension (X) and declination (Y) from SU Cyg.

As noted above, photographic photometry of the brighter B and A stars lying near SU Cyg was also obtained using the sample of plates used in the previous study by Turner *et al.* (1997). The resulting photographic photometry is summarized in Table II and should be of comparable quality to the data published in the previous study, with the expected uncertainties in the resulting values of V, $B-V$ and $U-B$ being not much larger than ±0.03, ±0.03 and ±0.04, respectively. Also given in Table II are the displacements X and Y of each star from SU Cyg (as in Table I) and either Harvard spectral types taken from the Henry Draper Catalogue Extension (HDE) or MK types assigned from new spectroscopic observations obtained for this study. Photographic data are also included in Table I where photoelectric observations are lacking, and italics are used to indicate the different origin of the values.

CCD spectroscopic observations were obtained for 10 stars in the field during the autumn of 1994 and in October 1997 using the Cassegrain spectrograph on the 1.85-m Plaskett telescope of the Dominion Astrophysical Observatory. The spectra, which are at dispersions of 60 Å mm^{-1} (6 spectra) and 120 Å mm^{-1} (4 spectra), were recorded with the Observatory's SITe-3 and SITe-1 detectors, respectively, which have wavelength resolutions of 1.4 Å and 2.9 Å at those dispersions. The spectra were obtained primarily for survey purposes, so several are of low signal-to-noise ratio. Most are adequate for spectral classification, however, and the spectral types derived from the spectra are included in the last columns of Tables I and II.

An extremely low dispersion objective-prism spectrum was also available for the field containing and surrounding SU Cyg and the putative cluster from observations obtained in September 1973 using the 0.2-m/0.3-m Schmidt telescope of the Hume Cronyn Observatory of the University of Western Ontario. The classification of individual stars recorded on such plates is made on the basis of

Table II
Photographic Observations

HDE	*X*	*Y*	*V*	*B–V*	*U–B*	Spectral Type
332535	−6.04	+17.32	11.08	0.17	0.16	A2
332536	+4.06	+14.01	10.55	0.44	0.10	A5 V
332537	+7.51	+16.80	10.95	0.31	0.19	A3
332538	+8.28	+13.06	11.25	0.17	0.02	B9 V
332539	+15.00	+2.50	11.36:	0.15:	0.06	B9 Vn
332542	+13.80	−5.89	9.49	0.02	0.04	B9
332543*	+9.11	−3.99	10.56	0.20	0.05	B9.5 Vnn
332552	−11.66	−14.76	10.77	0.34	0.08	A7
332553	−5.63	−11.80	10.43	0.55	0.21	A2 III
332557	+6.44	−9.71	10.38	0.21	−0.19	B8 V
332558	+13.02	−10.91	11.00:	0.40:	0.04	A1
332559	+12.69	−13.13	11.11:	0.16:	0.14	A0
332563	+8.65	−16.92	10.70	0.28	−0.45	B2
332565	−2.73	−16.64	11.14	0.10	−0.32:	B8

Notes: * Star 201 of Turner *et al.* (1997).

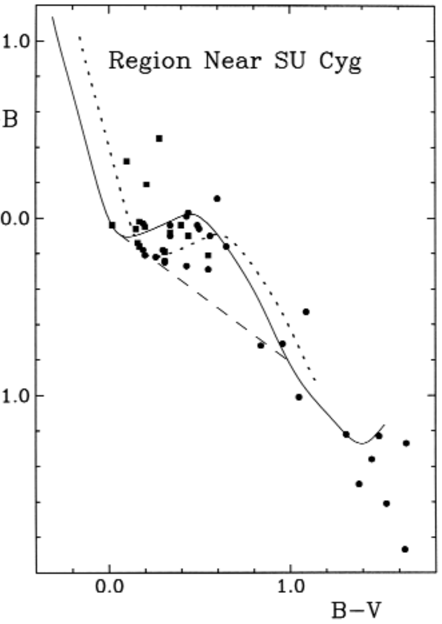

Fig. 3 —Colour-colour diagram for stars in the field of the putative cluster (filled circles) as well as B and A-type stars near SU Cyg (filled squares). The intrinsic relation for main-sequence stars (solid curve) is depicted for a reddening of E_{B-V} = 0.16 (dotted curve) using a reddening slope of E_{U-B}/E_{B-V} = 0.74 (shown as a dashed line originating at spectral type A2).

the length and shape of their spectral images, which, as described in similar work by Morgan *et al.* (1954), depend critically upon the temperature types of the stars and the wavelength sensitivity of the emulsion used — in the present case Panchromatic-X film. Indeed, the sparse group identified by Mandushev (1994) seems to contain a number of stars that are "of early type" — namely of spectral types B, A or F — according to their appearance on our low-dispersion objective-prism spectrum of the field. Classifications derived in such fashion are of relatively low accuracy, but are also listed in Table I for stars whose spectra are present on our objective-prism plate.

3. Interstellar Reddening

Because several fields of the Milky Way containing or adjacent to SU Cyg have been investigated previously (Neckel & Klare 1980; Turner 1980; Turner 1986; Turner *et al.* 1986; Turner *et al.* 1997), the run of extinction with distance towards the Cepheid is known with some confidence. As noted by Turner *et al.* (1997), there is essentially no extinction along the first 200–300 pc of space in the direction of the Cepheid. Beyond that, dust complexes lying at distances of up to perhaps 500–600 pc give rise to minimum reddenings for more distant stars of roughly E_{B-V} = 0.15 to 0.6, depending upon spatial location. The *UBV* reddening relation for the dust in the field has also been established by Turner (1980, 1989), and is described by $E_{U-B}/E_{B-V} = 0.740 + 0.026\, E_{B-V}$. We adopted that dependence here to correct the observations of program stars for the effects of interstellar reddening.

The observed *U–B* and *B–V* colour indices for all stars in Tables I and II are plotted in figure 3. Shown there are the intrinsic relation for unreddened dwarf stars (solid curved line), the intrinsic relation corresponding to an interstellar reddening of E_{B-V} = 0.15 (dotted line), and the reddening law for early-type stars described above (dashed line originating at spectral type A2 — coincident with the leftmost inflection point in the intrinsic relation). The diagram has many similarities to the colour-colour diagram for stars lying in the field immediately surrounding SU Cyg itself (*cf.* Turner *et al.* 1997). There are many cool stars in the sample (lower right in figure 3) possessing colours similar to those of unreddened G and K-type giants and dwarfs, as well as a small population of stars (left central section of figure 3) that have the colours of A and F-type stars of little or no reddening. Although a number of reddened B and A-type stars can be identified in figure 3 on the basis of their colours, there is otherwise no evidence for the presence in our program sample of a large population of stars of similar reddening and spectral type. On that basis it seems rather unlikely that the field of figure 2 contains a well-populated open cluster. Most of the stars appear to represent the general population seen towards SU Cyg.

Figure 4 is a plot of the apparent distance moduli, $V{-}M_V$, for early-type stars in Tables I and II as derived from the adoption of zero-age main-sequence (ZAMS) or spectroscopic luminosities for each star as a function of their inferred reddenings, E_{B-V}. Such a plot is referred to as a variable-extinction diagram. The effect of underestimating a star's luminosity by adopting a ZAMS luminosity for it is to produce a systematic scatter upwards in the diagram. The non-linear response of the *UBV* filters to the continua of stars of different temperature can also result in slightly different colour excesses for adjacent stars that differ in temperature but are obscured by the same amount of interstellar dust. The colour excesses have therefore been adjusted to those appropriate for a star of spectral type B0 viewed through the same amount of extinction.

Since the stars in a particular galactic field are dispersed spatially relative to one another, it is not unusual for stars lying at a common distance to be viewed through different thicknesses of the same dust cloud. The resulting differential reddening generally disperses the stars systematically in colour excess in a variable-extinction diagram so that they fall along a particular relationship $R = A_V/E_{B-V}$ that characterizes the dependence of total visual extinction A_V on colour excess E_{B-V} for the field. In most directions in the galactic plane the dependence is satisfied by a value of $R \approx 3$, but significant variations from this norm are occasionally detected. Various effects can introduce bias, however. A star for which one has adopted a luminosity by the simple assumption that it is a ZAMS object, for example, can have an appreciably greater true luminosity if it is evolved away from the ZAMS, is rapidly rotating, or is actually an unresolved multiple system. The first two effects are particularly important for hot B-type stars, which evolve more rapidly and generally have much larger rotational velocities than cooler stars of spectral types A and F. Such effects must be taken into account when searching for the type of trends in a variable-extinction diagram that are indicative of groups of stars lying at a common distance.

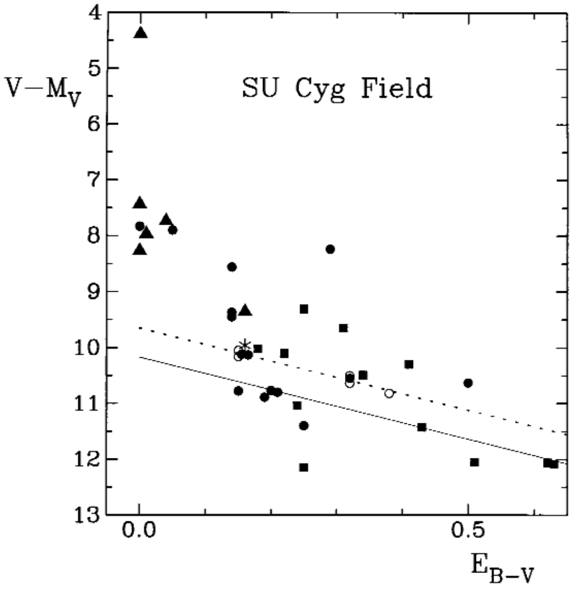

Fig. 4 — A variable extinction diagram for the surveyed objects. The data are plotted according to the inferred or observed spectral classes for the stars: squares for B-type stars, circles for A-type stars, triangles for F and G-type stars and an asterisk for the estimated parameters of SU Cyg. The data for the selection of five stars from Turner *et al.* (1997) are plotted as open circles. The lines are of slope $R = A_V/E_{B-V} = 2.94$, which is appropriate for this section of the Milky Way, and represent fits for the "sheet" of B and A-type stars at 1086 pc discovered by Turner *et al.* (1997) (solid line) and the putative cluster discussed here (dotted line).

For reference purposes we plot in figure 4 lines of slope $R = A_V/E_{B-V} = 2.94$, the appropriate parameter (Turner *et al.* 1997) to use here to correct colour excesses to total visual extinctions, tied to distances of 852 pc (dotted line) and 1086 pc (solid line). The latter corresponds to the distance of the "sheet" of B and A-type stars, possibly coincident with the association of early B stars known as Vul OB4, detected around SU Cyg by Turner *et al.* (1997). The former, taken from the analysis presented below, corresponds more closely with the expected distance to SU Cyg.

A practical method of searching for young stars with a common distance in a variable-extinction diagram is to examine the A-type stars, which are affected less by systematic effects than B stars (see above). In the variable-extinction diagram presented by Turner *et al.* (1997) for stars lying within 10 arcminutes of SU Cyg, the majority of A-type stars clustered at a distance of 1086 pc. Although the remaining foreground A stars were somewhat scattered in distance modulus relative to the main clump, there was a group of five stars with similar distance moduli to that expected for SU Cyg. The data for the few remaining foreground stars were quite dissimilar in their implied distances.

The data for the five A-type stars noted above are included in figure 4 along with the stars from Tables I and II. Several features can be noted. As discussed previously for figure 3, stars in the field of the sparse group and in the larger field around SU Cyg exhibit little or no reddening out to distances of about 450 pc (an intrinsic distance modulus of $V_0-M_V = 8.27$), beyond which all stars are reddened by $E_{B-V} \geq 0.15$. Many of the B and A-type stars in the surveyed region also appear to be coincident with the "sheet" of B and A-type stars at 1086 pc detected by Turner *et al.* (1997). That is not surprising in view of the close spatial coincidence of the separate survey fields. Somewhat to our surprise, however, three of the A-type stars in the present survey coincide closely in distance modulus with the group of five A-type stars discussed above (the data for two of the stars in figure 4 are identical but have been displaced in colour excess to avoid overlap). There are also three B-type stars that have closely similar distance moduli to the same group and three other B stars that might be coincident in distance with the group if their luminosities are ~1^m more luminous than estimated from the adoption of ZAMS luminosities. As just mentioned, the distance moduli for these stars place them very close to the distance at which the Cepheid SU Cyg would be predicted to lie.

In the earlier study by Turner *et al.* (1997), the five A-type stars discussed above (for which the data are plotted as open circles in figure 4) were discounted as companions to SU Cyg on the basis that they were few in number and were also a type of star that forms a common component of the galactic disk. In the present study their identification as potential members of a cluster containing SU Cyg seems to be on a somewhat more secure basis since there are nine other objects that may be coincident in distance with them, namely six stars of late B spectral type and three other A-type stars. The data for the combined subset of fourteen stars, which we refer to as the SU Cyg "cluster," are collected in Table III.

Table III
Likely Members of the Putative Cluster

Star*	$(B{-}V)_0$	E_{B-V}(B0)	$V{-}M_V$	$V_0{-}M_V$	V_0
SU Cyg B	−0.12	0.16	...	...	9.46
332557	−0.09	0.31	9.65	8.74	9.47
332543	−0.04	0.25	9.31	8.58	9.83
21	−0.06	0.41	10.30	9.09	10.15
332538	−0.05	0.22	10.10	9.45	10.60
332539	−0.03	0.18	10.02	9.49	10.83
9	−0.03	0.34	10.49	9.49	10.83
TMW 122	+0.06:	0.15:	10.16	9.72	11.56
6	+0.11	0.16	10.12	9.65	11.74
10	+0.11	0.16	10.13	9.66	11.75
TMW 178	+0.14	0.38	10.82	9.70	11.93
TMW 8	+0.22	0.32	10.50	9.56	12.11
TMW 137	+0.22	0.15	10.05	9.61	12.16
13	+0.24	0.32	10.55	9.61	12.25
TMW 115	+0.25	0.32	10.64	9.70	12.39

Notes: * TMW refers to Turner *et al.* (1997).

4. The SU Cygni "Cluster"

The data for the fourteen stars which possibly share a common distance with SU Cyg were corrected for interstellar reddening, as described above, and plotted in the colour-magnitude of figure 5 along with the data inferred by Turner *et al.* (1997) for the brighter unresolved companion of the Cepheid. The adopted distance to the group was established from the objects least-evolved from the ZAMS, namely the eight A-type stars in the "cluster." They have a mean distance modulus of $V_0{-}M_V = 9.65 \pm 0.06$ s.d., which corresponds to a distance of 852 ± 22 pc. The dispersion in distance is quite small and is fairly typical of what is observed for ZAMS members of open clusters; it is much smaller than the scatter that normally applies to stars in the general field.

The ZAMS conforming to a distance of 852 pc is plotted for reference purposes in figure 5 along with the data for SU Cyg, adjusted to eliminate contamination from its two, hot, unresolved companions. The sequence of plotted stars is very similar to what is observed in many intermediate-age clusters, and the implied main-sequence turnoff at $(B{-}V)_0 = -0.10 \pm 0.02$ (spectral type ~B8) is in fairly good agreement with the value of $(B{-}V)_0$ (turnoff) = −0.12 expected for a group of stars of comparable age to SU Cyg (Turner 1996; Turner *et al.* 1997). The stars do not form a compact cluster, however, but are spread across at least 33 arcminutes of sky — a projected distance of 8 pc at the distance of the group. (Additional "cluster" members may be spread over a larger area, but our survey material is restricted to the region sampled.)

Because the stars do not exhibit any degree of spatial concentration that would give them the appearance of an open cluster (see figure 6), the term "possible cluster" seems to be appropriate. The lack of cohesiveness for "cluster" stars is not unusual for a group with an age of roughly ~16 × 10^7 years, since the majority of open clusters of comparable age have already dissolved into the general starfield of the Galaxy. Indeed, the only clusters of comparable dynamical state to the SU Cyg "cluster" might be Roslund 3, the ellipsoidal ring of B-type stars surrounding ε Ori in Orion's Belt (Collinder 70; Turner 1993) and the Ursa Major moving cluster (Collinder 285), all of which are well advanced towards total dissolution. The SU Cyg "cluster" appears to be further advanced dynamically than either Roslund 3 or the Orion Ring, and is now no longer recognizable as a distinct clump in the sky. The slight enhancement in star density west of SU Cyg that was identified by Mandushev (1994) is neither an open cluster nor a major portion of the group found here.

5. Final Remarks

Stellar remnants of the parent cluster for the Cepheid SU Cygni can be detected, but the sample is a poor one at best. The objects included in Table III (exclusive of SU Cyg B) represent only about 31 $\mathcal{M}_\odot$ of stellar matter, with an additional 37% or more of that (≥ 11.4 $\mathcal{M}_\odot$) found in the compact triple system formed by SU Cyg and its two

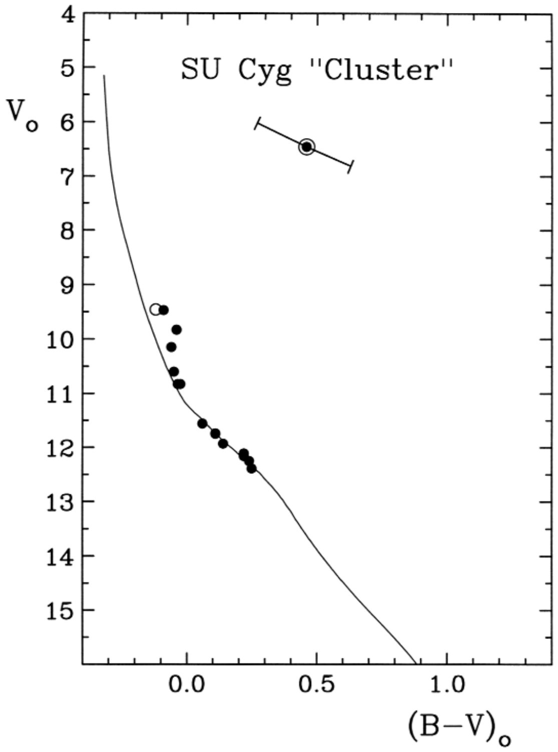

Fig. 5 — A reddening-corrected colour-magnitude diagram for stars in the field of the putative cluster. The range of light and colour variability for SU Cyg as a "cluster" member is indicated. The open circle represents SU Cyg B.

hot companions. The Cepheid triple system seems to represent a massive subgroup of the scattered cluster remains, which is more stable against dynamical disruption than other cluster stars. We are fortunate in being able to glimpse a "cluster" in such an advanced dynamical state. Were it not for the unique characteristics of the Cepheid triple system, there would have been little reason to search for the scattered remains of its parent cluster.

As noted by Burki & Maeder (1973) and Becker (1966), it can be difficult to isolate an open cluster from a random group of galactic field stars on the basis of *UBV* photometry. Evidence for the existence of the SU Cyg "cluster" is therefore not conclusive. Yet it is adequately convincing to provide the basis for further observations, such as radial velocity measures, that might strengthen the case. Contrary to what is expected from a random selection of field stars, the mix of stellar types belonging to the potential cluster is exactly that expected for an association with a classical Cepheid having a pulsational period of $3^d.8$. The group also constitutes the only likely clustering of B and A-type stars towards SU Cyg lying foreground to the "sheet" of B and A-type stars 1086 pc distant. If SU Cyg is a member of the "cluster," its luminosity can be established relative to the mean distance for group stars. We obtain an estimate of $\langle M_V \rangle = -3.19 \pm 0.07$ for the Cepheid as a "cluster" member, where the attached uncertainty incorporates the scatter in the distance for group A-type members, the uncertainty in the Cepheid's reddening, and the uncertain brightness difference between it and its companions. By way of comparison, the variable's luminosity as estimated from the period-luminosity-colour relation is $\langle M_V \rangle = -3.03 \pm 0.07$ (see Turner *et al.* 1997).

Further study of the suggested cluster is also of interest given that very little is known observationally about star clusters once they have dissolved to a stage where they are no longer recognizable as a distinct clump in the sky. Perhaps the only open cluster of comparable status is the Ursa Major moving cluster, which is very much closer and also considerably older. The "cluster" associated with SU Cyg therefore presents the possibility for a case study of an unusual type of stellar group. The nature of stellar motions in such an ensemble and details about its luminosity function are just two areas that might be addressed by means of additional spectroscopic observations and a more comprehensive photometric survey.

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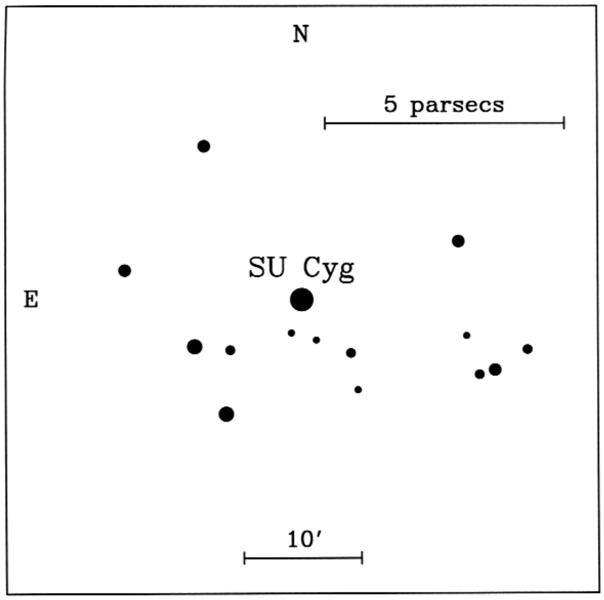

Fig. 6 — The distribution on the sky of likely members of the putative cluster relative to SU Cyg. Both the angular scale and the linear scale corresponding to a distance of 852 pc are indicated.

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Research Note

A PERSEID METEOR SPECTRUM

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Abstract. The spectrum of a Perseid meteor photographed from Courtenay, British Columbia, has been analyzed. Forty spectral lines were identified, including the green forbidden line of oxygen at the beginning of the meteor track. As in other fast meteors, two spectral components with apparent effective temperatures of 4500 K and 10,000 K, respectively, are present in the spectrum. The lines of the high temperature component are particularly conspicuous in flares near the end of the trajectory. That is tentatively explained by the increased strength of the shock wave, but the fact that the lines of the high temperature component are optically thin is also important.

Résumé. Le spectre d'un météore Perséïde, photographié à Courtenay, Colombie Britannique, a été analysé. Quarantes lignes spectrales ont été identifiés, y compris la ligne verte interdite d'oxygène au début de la trajectoire du météore. Ainsi que pour d'autres météores rapides, nous retrouvons deux composants gazeux dans le spectre, avec des températures respectivement de 4 500 K et 10 000 K. Les lignes du composant à haute température sont particulièrement évidentes dans les flambées au bout de la trajectoire. Une explication tentative de ce phénomène pourrait être la croissance de la force des ondes de choc, mais le fait que les lignes du composant à haute température sont minces du point de vue optique est aussi important. SEM

A meteor spectroscopy program has been carried out by one of us (EPM) in Courtenay, British Colombia, since 1972. The program resulted in photographs of several meteor spectra of various quality. Here we present the results of an analysis of one of the best observations obtained, the spectrum of a Perseid meteor acquired on August 13, 1986.

The spectrum was secured during an exposure of 10 minutes duration starting on August 13, 1986, at 01:15 PST (09:15 UT). The camera was a modified F-24 aero with a 2.9/8-inch Pentac lens equipped with an objective prism. A 4 × 5 inch sheet of Kodak Royal Pan 4141 film was used to record the observation. The meteor was photographed from one station only and no data on the trajectory are available.

The spectrum is reproduced here in figure 1. A sudden increase of brightness occurred on the trajectory, followed by almost constant light intensity until the onset of two bright flares near the end. In addition, a single line is present at the very beginning, where other lines are still invisible. It is the forbidden line of atomic oxygen at 5577 Å, with its typical behaviour as described by Halliday (1960).

The spectrum was measured by the two-axis microdensitometer at the Ondrejov Observatory of the Czech Republic. The spectra of the stars α And and β And, recorded on the same negative, were used to determine the spectral sensitivity of the instrument. From a comparison with the stellar spectra and from consideration of the different angular velocities, the meteor maximal magnitude was estimated to be –5 visual and –6 photographic.

The photometric tracing of the spectrum for the terminal flare is presented in figure 2. The spectral dispersion was 210 Å mm^{-1} at 4000 Å and 500 Å mm^{-1} at 5000 Å. The intensity scale was corrected for the spectral sensitivity of the instrument. At 4600–5000

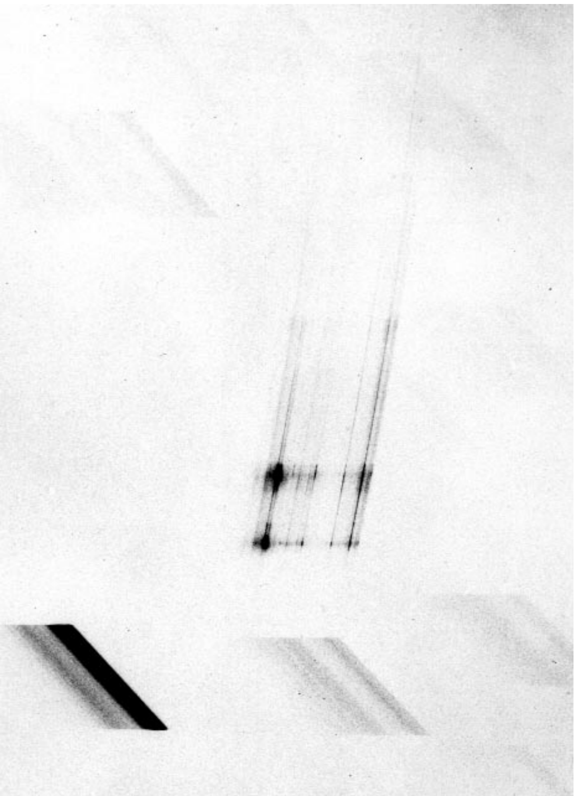

Fig. 1 — Scanned image of the Perseid meteor spectrum negative. The meteor moved from the top to the bottom. Wavelengths increase from left to right. Spectra of the stars β And (left), μ And and ν And are visible below the meteor.

Table I.
Line Identifications

No.	λ_{obs}	Int.	λ_{lab}	Atom.	Mult.	No.	λ_{obs}	Int.	λ_{lab}	Atom.	Mult.
1	3720	2	3720	Fe I	5	21	4428	1.7	4427	Fe I	2
			3723	Fe I	5	22	4481	5.2	4481	Mg II	4
2	3740	2.5	3737	Fe I	5	23	4520	1.1	4523	Fe II	38
			3735	Fe I	21				4515	Fe II	37
			3737	Ca II	3				4520	Fe II	37
3	3750	3	3749	Fe I	21	24	4560	1.1	4549	Fe II	38
			3758	Fe I	21				4559	Cr II	44
			3748	Fe I	5				4550	Ti II	82
			3746	Fe I	5				4556	Fe II	37
4	3830	7	3838	Mg I	3	25	4910	1.1	4924	Fe II	42
			3832	Mg I	3	26	5010	1.6	5018	Fe II	42
			3820	Fe I	20	27	5050	2.0	5041	Si II	5
			3826	Fe I	20				?		
5	3860	5	3860	Fe I	4	28	5180	9.0	5184	Mg I	2
			3856	Fe I	4				5173	Mg I	2
			3856	Si II	1				5167	Mg I	2
			3863	Si II	1	29	5270	2.5	5270	Fe I	15
6	3934	26	3934	Ca II	1	30	5330	2.2	5328	Fe I	15
7	3969	20	3969	Ca II	1	31	5390	2.0	5406	Fe I	15
8	4046	2.7	4046	Fe I	43				5397	Fe I	15
9	4063	2.5	4064	Fe I	43	32	5450	2.7	5430	Fe I	15
10	4071	1.9	4072	Fe I	43				5447	Fe I	15
11	4079	1.6	4078	Sr II	1				5456	Fe I	15
12	4133	2.5	4131	Si II	3	33	5530	1.6	5528	Mg I	9
			4128	Si II	3	34	5600	1.8	5616	Fe I	686
			4132	Fe I	43				5589	Ca I	21
13	4215	1.7	4216	Fe I	3				5587	Fe I	686
			4216	Sr II	1				5594	Ca I	21
14	4227	3.1	4227	Ca I	2	35	5700–				
15	4273	1.8	4272	Fe I	42		–5900			N_2	
			4275	Cr I	1	36	5890	9.5	5890	Na I	1
16	4298	1.3	4303	Fe II	27				5896	Na I	1
			4300	Ti II	41	37	6170	~1.5	6158	O I	10
			4297	Fe II	28				6162	Ca I	3
17	4310	1.1	4308	Fe I	42	38	6350	~2	6347	Si II	2
18	4325	1.2	4326	Fe I	41				6371	Si II	2
19	4383	2.1	4384	Fe I	41	39	6100–				
			4376	Fe I	2		–6400			N_2	
20	4405	1.5	4405	Fe I	41						

Notes. The columns following the line number refer to the observed wavelength (in Å), the intensity (arbitrary scale), the laboratory wavelength (in Å), the atom/ion name, and the multiplet number. The observed wavelengths are given to 1 Å between 3900–4500 Å, otherwise to 10 Å as a consequence of the larger noise and/or lower dispersion.

Å and below 3900 Å the sensitivity is low and the noise is higher than in other regions. A total of 39 spectral lines were identified in the tracing, most of them confirmed by their presence in the first flare as well. The lines are marked by numbers in figure 2 and are identified in Table I.

The spectrum is quite typical of Perseid meteors (*e.g.* Halliday 1961; Cook *et al.* 1971; Borovicka & Betlem 1997) and is very similar to the Perseid meteor of August 12, 1963, discussed at length by Halliday (1968). Both meteors exhibited a sudden increase in brightness early in the trail and two major flares near the end. The

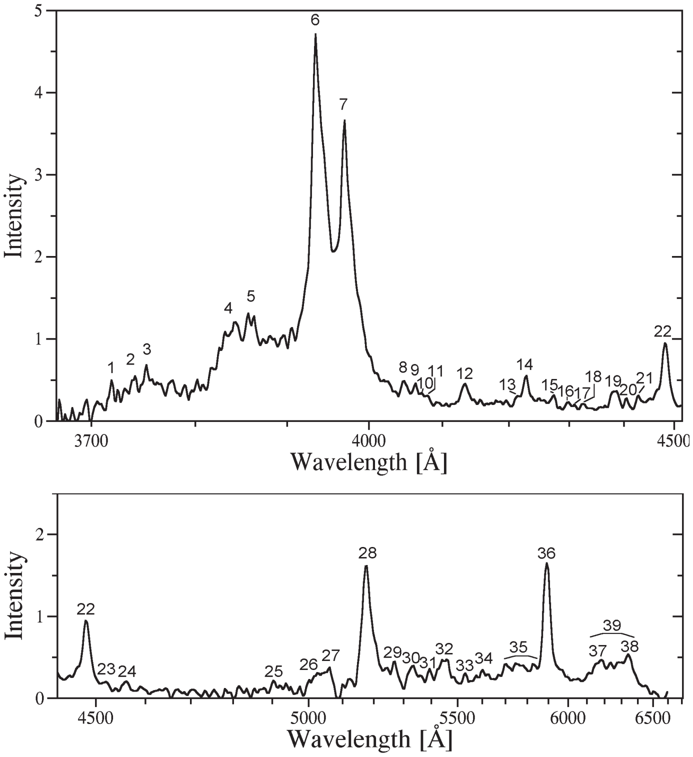

Fig. 2 — Photometric tracing of the spectrum at the terminal flare, 3700–4500 Å (above) and 4500–6500 Å (below). Spectral lines are marked by numbers and identified in Table I. The intensity scale is arbitrary.

height range from the initial brightening to the second flare was 94 km to 82 km for the 1963 event, and data for many other Perseids indicate that comparable values must have applied to the present 1986 Perseid. The brightest lines are the H and K lines of ionized calcium. The other certainly identified species are Na I, Mg I, Mg II, Si II, Ca , Fe , Fe II, and the molecular bands of N$_2$. The contribution of Cr I,, Cr II, Ti II, Sr II, and O I, to some features is probable, but could not be established definitely. The only line with an uncertain identification is line no. 27 at 5050 Å (confirmed to be present in both flares). The Si II (multiplet 5) line is not sufficient to explain the observed intensity even if possible blending with Fe I lines is taken into account.

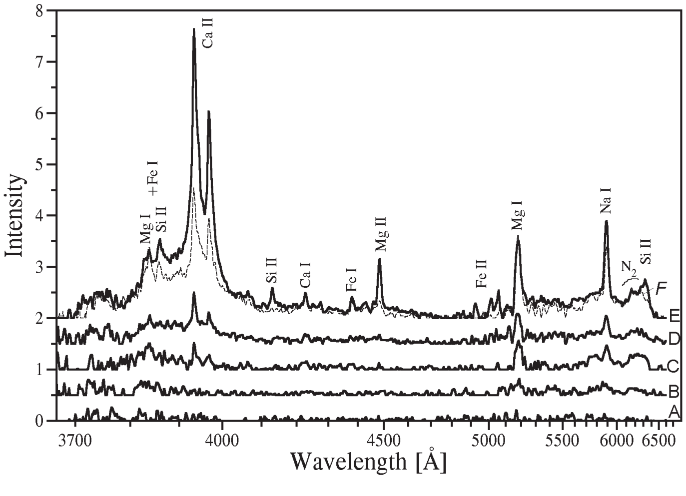

Fig. 3 — The spectrum at six points along the trajectory. For clarity, individual spectra have been offset by 0.5 unit on the arbitrary intensity scale. The spectrum F, however, has the same offset as E. When comparing this tracing with figure 1, note that the intensity scale has been corrected here for the spectral sensitivity of the instrument.

Our identifications are in general agreement with the identification study of more detailed Perseid spectra by Halliday (1961). Halliday did not consider the contribution of Ti II and Cr II, but later he identified both species in ultraviolet meteor spectra (Halliday 1969). Evans & Ridley (1993) misidentified some lines of Fe II as Fe I. A somewhat surprising indication in our spectra is the possible presence of Sr II, which was only a minor contributor in Halliday's spectra. However, Sr II was identified here on the basis of line no. 11, which was not confirmed to be present in the first flare.

We decided to model the spectrum by the method adopted previously (Borovicka 1994; Borovicka & Betlem 1997), which uses a superposition of two components of different effective temperature: a main component with $T \approx 4{,}500$ K and a second component with $T \approx 10{,}000$ K. All emission from ionized atoms, O I and N$_2$ belong to the second component. The very different temperatures for the two components appear to be associated with the main column (low *T*) and the presumed surrounding shock wave (high *T*) for the meteor. For the 1986 Perseid, however, they may represent the difference between the initial vapour close to the meteoroid (high *T*) and the cooling vapour in the wake some distance behind the meteoroid and some hundredths of a second after passage of the meteoroid.

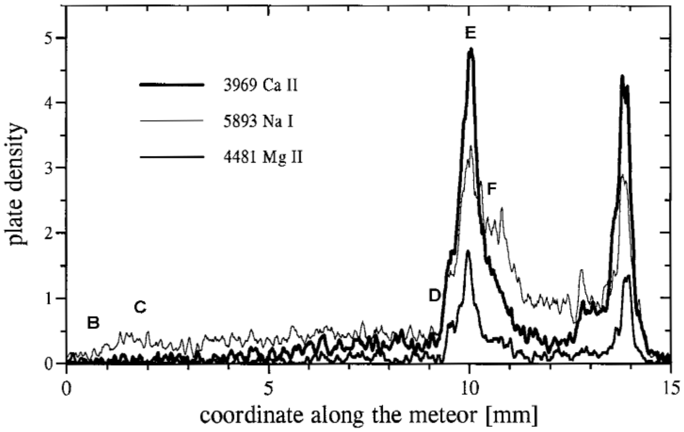

Fig. 4 — Brightness of three spectral lines along the meteor trajectory. The very beginning of the meteor has been omitted. The positions of the scans in figure 3 are indicated.

The method of Borovicka (1993) assumes that local thermodynamic equilibrium applies to the gas. Such an assumption does not necessarily approximate the actual physical conditions associated with the meteor's passage through the atmosphere, but it enables us to draw conclusions about both apparent components. The column density of Fe I atoms in the main component is found to be approximately 4×10^{15} cm^{-1} in the second flare. If we take that number as 1, the column densities of other atoms are Na I $\approx 3 \times 10^{-3}$, Mg I ≈ 3 and Ca I $\approx 5 \times 10^{-3}$. For the second component the column density of Fe II ions is about 4×10^{14} cm^{-1} and the relative numbers for other ions are Mg II ≈ 1, Si II ≈ 3 and Ca II $> 10^{-2}$. All values are only approximate. The apparent cross-section of the second component gas was found to be about half that of the main component gas. Taking into account the probable partial ionization of Fe in the main spectrum, we estimate the mass ratio of the two components to be about 30. That corresponds to a smaller fractional share for the second component than has been found in bright Perseid meteors (Borovicka & Betlem 1997).

The above parameters are valid for the last flare. Nevertheless, the spectrum developed along the trajectory. This is demonstrated in figures 3 and 4. In figure 3 the spectra at six selected points along the trajectory, marked A–F, are given. Point A falls at the beginning of the meteor trajectory, where all emissions are very faint. At point B the lines of Mg I, Na I and N_2 are clearly visible. Point C falls at a point on the trajectory after the sudden increase of meteor brightness where the lines of Ca II are also present, at comparable brightness to Mg I. The spectrum is not very different just prior to the first flare, at point D. At the instant of the flare (point E), the lines of Ca II and other lines of the second spectral component (Mg II, Si II and Fe II) brightened dramatically. The lines then quickly decreased in strength again following the flare (point F).

Monochromatic light curves in three representative lines are given in figure 4. The line of Na I is typical of the main spectral component, Mg II of the second component and Ca II is the brightest multiplet in the spectrum. Only Na I has significant intensity at the beginning. Ca II increases slowly and bursts in the flares. Mg II is bright only in the flares, while Na I decreases less between the flares. Ca II is intermediate in that respect.

The increase in brightness for lines of ionized atoms toward the end of the trajectory and especially in the flares was noted previously by Cook *et al.* (1971). However, an approximate physical analysis of the spectra at different points showed that the mass ratio of both component gases does not change as dramatically in the flares as one could expect solely on the basis of the monochromatic light curves. The share of the second component gas just before and between the flares is smaller than in the flares only to within a factor of two. The reason for the much more dramatic changes in brightness of lines like Mg II in comparison with Na I, for example, is that Mg II and the other lines of the second component, except Ca II, are optically thin while the lines of the main component are optically thick. The changes in column density in the flares produce, of course, more pronounced changes of brightness in optically thin lines. The lines of Ca II are more optically thick than other lines of the second component, but more optically thin than the bright lines of the main component.

The physical interpretation of the observational features listed above is not quite clear. Borovicka (1994) proposed that the high temperature component is produced in the meteor shock wave. The problem with such an interpretation is that the Ca II lines are present at high altitudes. By comparison with other Perseid meteors we can say that the offset for Ca II must have occurred above an altitude of 90 km. At such altitudes the shock wave is not supposed to be developed (Bronshten 1993). It could be argued that the Ca II lines are weakly present also in the low temperature component (Borovicka 1993, 1994). Nevertheless, the N_2 bands and the infrared N I and O I lines (Millman & Halliday 1961) begin even earlier in the trajectory. More observational and theoretical work is needed to fully understand the hydrodynamics and radiation of meteors and the formation of two distinct temperature components.

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Scenic Vistas: How Low Can You Go?

by Mark Bratton, Montreal Centre (reprinted from Skyward*)*

Many deep sky observers consider a good southern horizon essential to satisfactory observing, and certainly if one intends to complete the Messier list an unobstructed view of the southern sky is important. Twenty-two Messier objects are located south of declination −20° and, of them, eleven are south of −25°.

There is also the consideration that many important and beautiful deep sky objects are located in the southern sky and are only visible in our skies for brief periods during the year. Successful observation of such objects is difficult and further complicated by an effect known as atmospheric extinction, which considerably dims faint, extended objects. For instance, the globular cluster M4, located near Antares, is a prominent, resolvable cluster, but hardly as impressive in our skies as such notables M3, M13 or M92. If, however, you travel to southern climes, your opinion would be altered considerably because now, with the cluster much higher in the sky, you are looking through far less dust, grime, humidity and air; the cluster will shine in all its glory.

In dark skies it is possible to aim a telescope at the horizon and observe faint stars just as they come over the rim because they are concentrated, point sources of light. The same cannot necessarily be said of deep sky objects, which are usually diffuse, extended objects. The question is, how low can you go? What is the most southerly deep sky object visible from your region?

In the late 1980s I did almost all of my observing with an 8-inch Schmidt-Cassegrain from my backyard in suburban Dorval. It was a relatively light-polluted environment, though stars as faint as magnitude 4.5 would be visible at the zenith on a good night. I was extremely fortunate in that my neighbours very seldom left outdoor lighting on at night. The houses south of my backyard were all bungalows, allowing me to easily observe as far south as −32°. In June of 1988 I picked up all of the far southern Messier globulars in Sagittarius and Ophiuchus from my location. How much farther south could I go?

Because all the houses in my neighbourhood are single family dwellings, all houses are separated by adjoining driveways. What that meant for me was that a narrow gap existed between my backyard neighbour's house and a stand of trees across the street. Through the gap, for a brief period, I could observe several degrees further south.

On June 14, 1989, I aimed my telescope through this narrow corridor at the Stinger of Scorpius, acquiring a third magnitude star designated G Scorpii. In the field along with the star was the globular cluster NGC 6441, a high surface brightness, concentrated glow with sharply defined edges. Located at right ascension $17^h\ 50^m.2$ and declination −37° 03′, at its highest point it never rises more than 7.5° above the horizon from Montreal.

Almost a month later, on July 11, 1989, I very nearly repeated the feat when I observed NGC 6723, a globular cluster on the border between Sagittarius and Corona Australis. The co-ordinates of the cluster are right ascension $18^h\ 59^m.6$, declination −36° 38′, so it never rises more than 8° above our horizon. Despite being a half magnitude brighter than NGC 6441, NGC 6723 is larger and more diffuse and appeared slightly flattened at its northern and southern extremities. The overall texture of the cluster was smooth and a little brighter to the middle. No stars could be resolved.

Can other members who are near latitude 45° duplicate or exceed these results? The answer would appear to be yes and the time to do it would be now. From June to August, the Milky Way dominates the southern horizon. Many bright open and globular clusters can be found in this region of the sky, and many planetary nebulae as well. Such objects are more readily visible through the thick layer of air at the horizon than galaxies or gaseous nebulae, which generally speaking seem to have lower surface brightness. On the next page is a list of objects even further south, but still above the horizon from that latitude. They are all in Scorpius, except for NGC 6541 which is located in Corona Australis.

If you are successful with any of the objects, I would be delighted to hear from you. ◉

Mark Bratton has had a life-long interest in astronomy, and first became acquainted with the RASC in November of 1966 at the age of eleven. He did not become a member until twenty-five years later. He is currently the editor of the Montreal Centre's newsletter Skyward *and was recently elected as president of the Centre. He is the single parent of an eleven year old boy, Kristopher, and his greatest joy, besides his son of course, is slowly exploring the skies with a 375-mm reflector from the deck of his small country cottage near Sutton, Québec.*

DEEP, DEEP SOUTH OBJECTS FOR CANADIAN SKIES

Name	Right Ascension	Declination	Type	Mag.	Comments
NGC 5986	15:46.1	−37° 47′	Globular Cluster	7.5	Bright, but concentration only moderate
NGC 6124	16:25.6	−40° 40′	Open Cluster	5.8	Rich cluster, brightest star mag. 8.67, concentrated & detached from background
NGC 6139	16:27.7	−38° 51′	Globular Cluster	8.9	Highly concentrated, should cut through murky skies
NGC 6153	16:31.5	−40° 15′	Planetary Nebula	10.9	Probably tough
NGC 6231	16:54.0	−41° 48′	Open Cluster	2.6	Very bright & concentrated
NGC 6281	17:04.8	−37° 54′	Open Cluster	5.4	Few stars, detached.
NGC 6302	17:13.7	−37° 06′	Planetary Nebula	9.6	“Bug Nebula”
NGC 6322	17:18.5	−42° 57′	Open Cluster	6.0	Bright but very low
NGC 6337	17:22.3	−38° 29′	Planetary Nebula	12.3	Probably too faint
NGC 6541	18:08.0	−43° 42′	Globular Cluster	6.1	Bright, concentrated horizon hugger. Tall people have a slight advantage!

At the Eyepiece

Eclipse-Chasing Perfection — the Caribbean

by Alan Whitman, Okanagan Centre

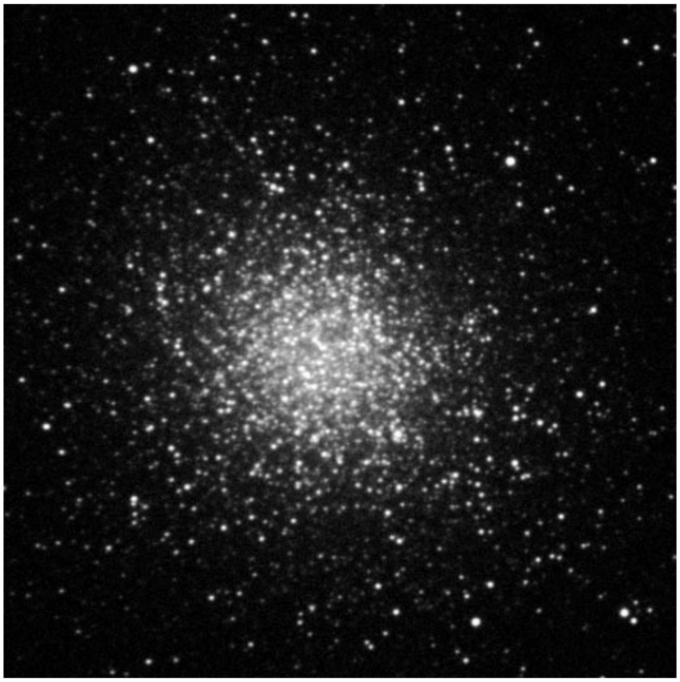
February’s Caribbean total solar eclipse was without compromises: totality was relatively long, the eclipse was in an area with very good weather prospects, and it occurred in one of the most desirable tourist areas in the tropics during the northern hemisphere winter. A popular T-shirt proclaimed, “I *earned* this one. I was in *Siberia* last time!”

Deep lunar valleys sculpted two of the longest diamond rings that I remember. The Sun’s long, luminous, equatorial streamers and the short polar brushes characteristic of its corona at sunspot minimum were spectacularly framed by bright Jupiter and Mercury, as both were near superior conjunction. At the sight of that winged corona, it was obvious to me how the ancient Egyptians developed the idea of their winged sun god, Ra. The few visible prominences were small, as was to be expected for an eclipse at sunspot minimum. The pink chromosphere made a striking appearance for several seconds at third contact, arcing through about 90 degrees.

> “The Sun’s long, luminous, equatorial streamers and the short polar brushes characteristic of its corona at sunspot minimum were spectacularly framed by bright Jupiter and Mercury.”

My wife photographed. Otherwise, for this eclipse she and I just looked with our unaided eyes and binoculars. I try to let the eclipse experience sink in and avoid too much frenetic activity, so I have got into a pattern of viewing with telescopes and binoculars at alternate totalities.

Perfection did not end with the third contact diamond ring — the showpieces of the far southern night sky were on



The great 4th magnitude globular cluster Omega Centauri was obvious to the naked-eye, peaking as high above the southern horizon as Spica does in southern British Columbia. (Photo by Dave Lane, Ram Krishnan, and Greg Palman using a 130-mm Astro-Physics refractor and a CCD Camera designed and constructed by Ram)

display from the darkened decks of the *M.S. Veendam* during February's New Moon. After midnight the huge Eta Carinae Nebula, the brightest patch in the southern Milky Way, culminated 18 degrees above the Caribbean Sea. The nebula is flanked by two very prominent naked-eye open clusters, oblate NGC 3532 three degrees to the ENE and the bright stars of IC 2602, the Theta Carinae cluster, five degrees to the south.

Virginian Kent Blackwell had brought tripod-mounted 1930s-era 20×120 Japanese battleship binoculars. They revealed the chevron-shaped dark lane in the great emission nebula and unveiled the third large galactic cluster near Eta Carinae, unresolved NGC 3114. Kent spotted Comet Hale-Bopp with the giant binoculars. (I said I would look in a few minutes and then frankly forgot — I was too entranced with the Eta Carina area.)

On the night of February 27/28 we sailed east from Bonaire to Grenada along latitude 12 degrees, the southernmost leg of the voyage. Achernar was visible just before it set during evening twilight — it had eluded me longer than any other 1st magnitude star in the entire sky.

That night I used my 4-inch Astroscan and my 7×50 binoculars from midnight until dawn. At 64× the Astroscan revealed the many long star-chains forming NGC 3532's overall football shape. One orange star highlights the cluster. In addition to the three large galactic clusters escorting the Eta Carinae Nebula, the Astroscan found other smaller clusters nearby. The two best were adjacent NGC 3293, enmeshed in faint nebulosity, and bright compressed NGC 3766 in Centaurus, between Eta Carinae and the Southern Cross. The Coal Sack dark nebula was obvious to the unaided eye. My 7×50 binoculars showed several parallel dark bands in the dust cloud, the northern one being the most opaque.

The famous Jewel Box cluster was a disappointment through both the 4-inch Astroscan and the giant binoculars — perhaps a larger telescope is required to allow it to live up to its reputation. The Astroscan showed only 12 stars at 64×, none of them with any noticeable colour.

The great 4th magnitude globular cluster Omega Centauri was obvious to the naked-eye, peaking as high above the southern horizon as Spica does in southern British Columbia. My small reflector resolved the elliptical globular's 11th magnitude stars at 64×. Alpha Centauri's two yellow components were separated by 21 arcseconds, almost the widest that they ever become in their 80-year orbit.

The 7×50s swept up numerous unresolved open clusters from Triangulum Australe through Norma and up into the tail of Scorpius. After all of these fuzzies, the bright gems of M7 were a treat. (M7 was halfway to the zenith on that memorable morning.)

One of my long-time naked-eye favourites is the comet-like structure headed by the wide double star Zeta Scorpii. The wonderful open cluster NGC 6231 forms the "coma" while the adjacent large cluster H12 makes "the comet's tail." Has anyone else noticed this illusion?

The closest globular cluster is NGC 6397 in Ara, at a distance of 9000 light years. I located it easily with the Astroscan's three-degree field of view at 16×, but I had a devil of a time viewing it at 64× — it took me a frustrating half-hour. I would centre it at 16×, change eyepieces, refocus, and it would then be gone because of the rolling of the ship which had increased as morning approached. Only a scattering of 10th magnitude stars was resolved at 64× by the little reflector as the very rapid tropical twilight rolled up the sky.

> "While I had no difficulty navigating the far southern sky, familiar northern constellations held surprises."

While I had no difficulty navigating the far southern sky, familiar northern constellations held surprises. Corvus was well above Spica when rising, which never happens at home. Boötes passed north of the zenith, hanging head down from Arcturus. Conversely, by following the same course, kneeling Hercules was made into an upright figure with his head towards the zenith. No circumpolar stars were visible between low-lying Polaris and the sea.

The evening sky was viewed last, on the 28th, as we sailed from Grenada, heading north from our southernmost port at latitude 12° 03′ N. At the end of astronomical twilight my 7×50 binoculars easily found the Large Magellanic Cloud (LMC), one binocular field above the sea horizon. Only the 3-to-4 degree central bar was visible, but it was unmistakable from having seen it in so many photographs, as was the Tarantula Nebula about half a degree north of the east end of the bar. (The next day several other observers on the *M.S. Veendam* told me that they had also seen the LMC on that evening. On the *M.S. Ryndam* one evening earlier, Sarnia Centre's Richard Weatherston found the LMC with binoculars from one or two degrees of latitude farther north.)

Carina's 4th magnitude open cluster NGC 2516, just off the western end of the False Cross asterism, was the last significant object on my "hit list." In the 7×50s it had a one-degree ellipse of bright stars (one of them orange) with an inner swarm of faint stars just inside the southern edge of the ellipse. With my binoculars I swept northwards from the False Cross to the Vela open clusters IC 2391 (resolved) and IC 2395 (fuzzy). The latter is in a quite rich Milky Way field while the former is a prominent naked-eye object.

Above the setting 2-day-old lunar crescent with Earthshine, the zodiacal light rose to the Pleiades, just as it does in Canada in February. One striking difference though — the zodiacal light was tilted *north* of vertical!

The next evening in the dining salon one of our table-mates with a view of the setting Sun said that we had a chance of a green flash. I asked if the Sun was near setting, he replied that it was, I stood and walked two steps to where the Sun was visible, and *instantly* a prolonged two to three second emerald green flash occurred! The dining salon erupted in cheers — the *Veendam*'s passengers were mostly experienced amateur astronomers.

Since it was not a star party but a cruise, the rest of my observing was limited to ten-minute sessions with Canopus and the southern constellations on most evenings, as the Moon waxed and the ship ploughed ever northwards. One other event of note was the naked-eye occultation of Aldebaran by the First Quarter Moon in the Bahamas on March 4th, our last evening on board. It seems serendipitous that the brightest star that can ever be occulted should be eclipsed on a solar eclipse cruise. ◉

Alan Whitman's astronomical interests include deep-sky observing, double stars, asteroid occultations (but the paths always miss his backyard observatory), and eclipse-chasing. He invites observing reports at: awhitman@vip.net

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The Light Side of Research

The Ecstasy and Agony of Research

by Orla Aaquist, Keyano College (Orla.Aaquist@keyanoc.ab.ca)

For some of us, a postdoctoral position is not an option after acquiring a Ph.D. Still, many graduates, like myself, who opt out of the postdoctoral route, envision carrying on some form of research regardless of the job they acquire after graduation. Statistics show, however, that the contrary is true: the desire for research usually departs after four years of teaching at a community college or high school, working for an oil company or driving a taxi cab[1].

Last year, having a brief lull in my busy schedule of working on the family room on weekends, preparing lessons, marking labs and assignments, and attending faculty meetings, I had the absurd notion that I had time for a little research on the side. I can only attribute it to the seven-year itch (I graduated in 1991 and it is now 1998). I have been accused by some, including my wife and children, of being somewhat peculiar at times, and it is not at all unlikely that I have managed to apply the seven-year itch to the wrong affair.

In any case, in the fall of last year I submitted an observing proposal to the Very Large Array (VLA) to measure the expansion rates of a few compact planetary nebulae. I put the proposal out of my mind until January 1998, when it suddenly dawned on me that if my proposal was accepted I might be scheduled to observe during the school term. If I were working at a university, that would not be a problem, because university professors are expected to disappear at inappropriate times during the term in the pursuit of research. I strongly suspect that it is written into their contracts:

> *"To encourage those students who cannot think for themselves to drop my course, I, the undersigned, hereby agree to carry on research away from the institution at least twice during each semester."*

The clause does not appear in my contract, so I was somewhat concerned about the possibility of taking a week's leave-of-absence to set up the experiment. Moreover, I do not have a research grant to help fund my travel and living expenses away from home. It is my understanding that in order to obtain one of them, you have to be actively doing research — there is a Catch 22 here for anyone who would care to pursue it while

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[1] Aaquist, private communication.

I move on to the next issue.

On January 18, my fear became real when an envelope arrived from NRAO with the referees' evaluations of my proposal. I carried it to my office while thoughts raced through my mind. I was preparing myself for one of two possible outcomes: (1) my proposal was rejected, or (2) my proposal was accepted.

When the evaluations arrived, my workload was the one from Hell. To an outsider, teaching 20 hours a week seems like a cushy job, but if you take teaching to heart, you know that at least twice that amount of time is spent outside the classroom preparing lessons, helping students, and marking. So, rejection meant relief from an added burden. Preparing the experiment from Keyano seemed unlikely. I had, at the very least, to go to The University of Calgary to set up the observing file. I needed my old data, which were stored in a storage drawer in a closet in the back of room 314. How could I possibly get away during the term to observe? The disappointments of rejection far outweighed any added burdens of acceptance, however. Rejection probably meant an end to my research efforts in astronomy, and endings are always sad. On the up-side I could get on with other aspects of my life; I could finally find time to write a column for the JRASC on my failed research attempts, find the time to make that semi-professional recording of my astronomy songs, and sell the recording to gullible astronomers (serves them right for rejecting my proposal).

I opened the envelope and read,

> `“Enclosed you will find information about the status of all current proposals on which your name appears. These include … blah, blah … Unless stated otherwise … blah … any time allocated is for only the proposal given, … blah, blah, blah … INTERPRETING YOUR PROPOSAL SUMMARY: The first line contains the … blah … The second line informs you if we have scheduled time for the proposal …”`

What proposal summary? I couldn't find the “Proposal Summary.” There is a second sheet, but it is not titled “PROPOSAL SUMMARY.” It read:

```
AAQUIST, O. Keyano College
AA225 Expansion of compact planetary
nebulae
Time scheduled this config.; will not be
considered further.
```

My heart sank. Well, that was that. But what a strange way of rejecting a proposal. I was expecting something along the lines of, *“We appreciate your interest in observing at the VLA, but due to the submission of so many first rate proposals, many excellent proposals were rejected in the evaluation process.”* Perhaps I was getting the rejection confused with one of my past job applications.

I forced my eyes back on the paper to read the specific referees' reports. I skipped over a couple of lines and read:

```
Referee A Rating = 7    Time rec= 50%
Ref mean 3.4
```

A seven didn't seem like a bad rating. When I give my students a 7 (out of 9), they are pretty happy. But what was that stuff after the rating? I paused to think about it for a moment, but I was too hyper to concentrate much on the details. I read the referee's comments:

> `I am sceptical that the first epoch images have high enough S/N to reliably detect expansion motions of even 30 mas. It appears to me that only 4 or 5, at best, are bright enough to try what they propose.`

Oh, that hurt just a little, but not as much as my student evaluations. Actually, I get excellent student evaluations, but I still cringe when it is time to read them. But why give me such a high mark and such a mediocre comment?

I returned to the section entitled “Interpreting Your Proposal Summary,” wherein I read,

> `“The reports from the referees … contain a numerical rating … the lower the rating the better the proposal.”`

Oh darn. Just like my golf score. Apparently, `Time rec= 50%  Ref mean 3.4` meant that Referee A recommended that only 50% of my proposed observing time be scheduled and that his ratings of previous proposals had a mean value of 3.4. So my proposal, with a rating of 7, did not rank among his top ten. Bummer.

But wait. If Referee A, who gave me the worst mark of the four reports, recommended that I be granted 50% of my proposed observing time, then how come my proposal was rejected? I smelled a lawsuit cooking, but then remembered that I was Canadian. Then, again, since I was observing in the US, perhaps … I better read the fine print more carefully. I returned to the top, and read:

```
AA225  Expansion of compact planetary
nebulae
Time scheduled this config; will not be
considered further.
SCHEDULING COMMITTEE (97DEC05) — We
suspect that not all of the old
observations are good enough for this.
Do some of your best cases.
```

```
O. Aaquist
S. Kwok
CURRENT TIME ALLOCATION:
1 times 8.0 hours in A config at LST near
19.0
Time requested:
3 times 8 hrs in A config centered at
19.0
```

Wow. They gave me 8 hours! I think. I read it again. Yes! They granted me 8 hours.

I read the reports from the other three referees. I smiled stupidly, the same stupid smile I don when I know that I'm about to get sex. I tucked the pages back in the envelope and stuck them in my briefcase. I felt pretty good. ◉

Orla Aaquist is the physics instructor at Keyano College in Fort McMurray. His rather varied career has included periods as an undergraduate at the University of Alberta (B.Sc.) and Queen's University (B.Ed.), a graduate student at the University of Calgary (M.Sc., Ph.D.), a high school teacher of physics and mathematics in Toronto, and "telescope instructor" at the Calgary Centennial Planetarium.

The Night Sky for Dummies

by Tom Cameron, Calgary Centre

It is a piece of cake actually. You just have to understand about right ascension, declination, altitude, azimuth, Universal Time, polar alignment, longitude, latitude, Newtonian mechanics, Kepler's laws of motion and a few other things. How could it possibly be hard to grasp? Perhaps the thing to do is to put it all into perspective. Harvard law school is difficult. Controlling a runaway nuclear reactor is particularly difficult. Understanding what two teenagers just said to each other is well nigh impossible. But there is a way to learn the art form without ruining your eyes trying do perform celestial math computations in the dark or having all your friends think you have turned into some kind of technology nerd.

The simple way to learn the art form is to go outside on clear nights and physically place oneself feet down on the planet Earth. Then you just have to look up and out, towards the starry sphere of stars. That is it. Cool, eh? If you get out a couple of times a month for an hour, you too can help your local astronomy society make the admiring crowds gasp in wonder. (Okay so I made up the part about admiring crowds. Usually you are alone or with two or three other scope-jocks, trolling the universe and trying to catch a glimpse of an elusive comet or some other object that everyone else with a piece of curved glass seems to be able to pick out blindfolded.) A problem will begin to rear its ugly head, however, as you repeat the process of going out a few times a month. It is here that many who take up the odd pursuit begin to falter and lose heart. Most assuredly you will notice the amazing ability of the night sky to move just when you thought you had found a reference point you could depend upon. First of all, when you are looking south, objects in the sky travel to the west all night long. Just like the Sun, most of the stars, especially the ones to the south, seem to set as the night winds along. By morning, stars that were just rising in the east now sit ready to drop out of sight in the west! A couple of months later the whole set of stars appears to have moved substantially to the west and stars that rose in the morning twilight are now overhead at nightfall. The stars seen in the east at sunrise are brand new altogether. The entire thing just gets more curious and more curious. Fear not, budding cosmologists, as we are here to help you understand the simple mechanics that account for why the sky appears to be moving.

A fixed camera and a long exposure shows the motion of the stars caused by the Earth's rotation. This photo of the southern half of Orion, including the belt stars and the Orion Nebula, was taken by a 1st year astronomy student at Saint Mary's University.

You see, all you future comet discoverers, there is a secret to stargazing that all the hip, cool, and trendy amateur astronomers know and are willing to share. (Okay so I made up the part about astronomers being hip, cool and trendy. Most of them, however, are willing to share.) To learn the secret, all you are asked to do in return is make one astonishing, simple leap of faith. When a patent clerk named Albert asked all the physics Ph.D.s on the planet to throw away any previous notions they had about time and simply accept that time was not a constant, he was asking for a true stretch. They did and today thousands of protest marchers have something to keep them occupied. Our leap of faith is much more palatable and only the Flat Earth

Society has raised any kind of fuss worth mentioning. So if the drum roll will please start up, I will stop teasing you with fascinating bits of trivia and let you in on the big secret that every other amateur stargazer seems to have caught on to. The sky is not moving. You are.

Now that I have gone and gotten another coffee and you have finished picking yourself up off the floor I can hopefully elaborate a little. If you are driving your car, say north from Calgary towards Edmonton on highway #2 at about a hundred plus kilometres per hour, you can make a few interesting observations. First, Edmonton is very far north (which will not then help you figure out where the Andromeda galaxy is, although you are getting into the neighbourhood). If you are the village idiot and rapidly accelerating and braking and weaving through traffic, you will definitely know you are moving. If you are on cruise control and at peace and harmony with the universe, aside from the vibrations and the scenery flashing by on the side of the road, you might not even be aware you are moving at all. Now look to the west and have a glance at the magnificent Rocky Mountains. The Rockies appear to be fixed in place at first. That is because from your perspective the mountains are quite far away in the background. If the foreground scenery were to vanish it would be fifteen minutes to half an hour before you noticed that the mountains appear to be moving south and you must therefore be going north.

Now that you have made this interesting observation and turned back towards Calgary, you can hopefully relate the experience to why the starry backdrop of stars appears to travel slowly across the southern sky from east to west. It is because you are standing on the planet Earth, which is always turning from west to east. Aside from some planets, asteroids and other bits of assorted solar system debris, the stars themselves are not at all changing their positions in relation to one another. They, like the Rockies, are way off in the background. Lake Louise, the Columbia ice fields and Marmot Ski Basin all stay in the same general locations from year to year. Great deep sky objects like the Hercules globular cluster and the great Orion Nebula are easy to find because they also reside in exactly the same spot, in relation to the stars, year after year.

A cabby learns the landmarks around a city to an extent where he ends up knowing his way around like the back of his hand. When in doubt, he has only to consult his map. You are now similarly armed but not nearly as dangerous. You simply have a problem to contend with that the cabby does not have to worry about. (Okay, so you do not get the good tips they get, either.) His map does not have to be constantly changed as the night progresses, while yours does. Furthermore, six months from now you are going to be touring a whole new suburb since the Earth on which you are riding is not just turning on its axis but is also making a 365-day tour around the Sun. The Sun is in the middle of the tour and always lights up the side of the Earth facing it. That is referred to in academic circles as "day." It stands to reason that the far side of the Earth facing away from the Sun is in the dark, which should be referred to as "night." At night the stars we are facing can be found on a map. But six months later the part of the map we need is for the other side of the fish bowl. The stars and the deep sky objects in residence have not gone anywhere at all. Your viewing position has changed radically, but if you can grasp this twist of the ballet you will soon be on your way to navigating the universe. The best way to accomplish this is to take my advice about going outside. Just repeat after me, "A few hours a month, a few hours a month, a few... "

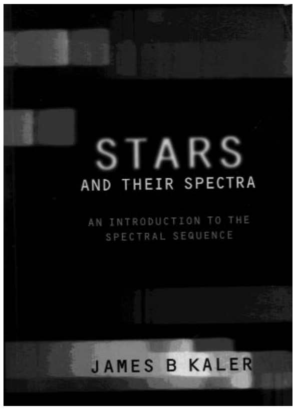
The sensation of a turning planet Earth is actually one that can only be truly appreciated using a telescope fixed on a star-filled field. If you have the right kind of telescope, you can line up an axis on the mount to run parallel with the axis of rotation of the Earth. An electric motor can then be turned on and the telescope will turn opposite the Earth's rotation to stay pointed at the same patch of sky all of the time. If you turn off the drive mechanism or use a telescope without such a mount, it will not be long before the Earth, with you on it, has travelled far enough to the east for the stars you were looking at to have moved out of view. Actually this type of event happens to experienced stargazers all of the time, though not always intentionally. You can recognize such an occurrence by the resulting short wavelength outburst of profanity that usually accompanies the loss of the field of view. At higher magnification with the resulting smaller field of view, you can virtually experience the sensation of the Earth turning in space while looking through the eyepiece. At that point you will begin to receive threatening letters from the Flat Earth Society as they truly fear such a revelation may become too widespread.

All that R.A., Dec, Alt, Az, and Universal Time stuff is not really needed if all you actually want to do is hop on the carousel for a quick look see. What you actually need is a set of seasonal sky maps, readily available at many sources like your local club and also regularly published in all the astro magazines. They will let you know what part of the giant fishbowl is up for viewing on a given night. Then you will need a good (defined as charting all stars down to, say, at least 8th magnitude) set of overall star maps displaying all the nifty non-stellar objects to be found hidden amongst the dark night sky. Then follow the Calgary Observers Group battle cry — "Get off the couch!" Get out, go outside at least a night or two a month, and get used to the regular progression that the stars make across the sky. (Oops, I forgot, the correct description should have something to do with your ride on the surface of the Earth as it spins and slowly circles the Sun.) Learn the 20 or 30 bright marker stars and become familiar with 30 or so of the most easily recognized constellations. Your eyes and perhaps a pair of binoculars will do nicely to start as there is not much point in sinking big bucks into a scope if it is apparent that you are mechanically impaired as far as the evening sky is concerned. It is no different than walking your dog regularly, playing cards with friends now and then, or getting in your car to go pick up little Johnny from his lesson. If you visit a place often enough, the landmarks become familiar. Never lose sight of the fact that some people find doing things like income taxes, brain surgery or going to Edmonton easy. Before you know it, you too will be learning the ancient incantations, the same ones used with little success to ward off clouds by observers around the globe. You may never have to learn how to calculate semi-conducting, non-existential, hyperbolic orbital curves; however you can easily learn how to poke around the dark night sky and catch a glimpse of the same universe that holds most of us spellbound. ◉

Tom Cameron got his first Sears Discoverer telescope at age eleven while growing up in the shadow of Mount Kobau. His interest in stargazing waned a few years later, but was rekindled in 1991 with the purchase of a Celestron C4.5. He has been a member of the Calgary Centre for the last five-years, and gets out three or four times each month to observe. Writing about his experiences landed him a job as editor of the Calgary Centre's newsletter; he also serves on the Centre's council.

Reviews of Publications

Critiques d'ouvrages



Stars and their Spectra: an Introduction to the Spectral Sequence, by James B. Kaler, pages xvi + 300; 17.5 × 24.5 cm, Cambridge University Press, 1997. Price US$24.95. ISBN 0-521-58570-8

Spectroscopy is one of the astronomer's most useful techniques, yet the popular press rarely mentions the word. The study of astronomical spectra provides a very powerful tool for astrophysical insight; if spectra were not available, we would know very little about the universe and how it works. The Hertzsprung Russell (HR) diagram, which shows the relationship between spectra and absolute brightness, is one of the first and most notable examples of the use of a scatter plot in science, and contains a remarkable amount of information about astrophysics. There is clearly a need for a book that explains how astronomers use spectroscopy and the HR diagram in terms that can be understood by the amateur astronomer or educated public. Kaler's book fills the need well.

I'm delighted to see this book in paperback finally. The hardback edition was published in 1989 and was reviewed by Chris Corbally in this journal (JRASC, 84, 358). The paperback is a new printing, but not a new or revised edition. There is no preface to indicate what changes have been made or whether or not any sections have been updated; I suspect not. The only indication of any changes at all is on the copyright page, which merely states "(with corrections)." On the other hand, the book is so well written that it remains an excellent book even as it was written ten years ago.

A preface would also be useful to indicate the target readership. The level is uneven. Some terms given without explanations will mystify even the educated scientist; others will be much too simple for any reader. As far as I can tell, few if any of the criticisms by reviewers of the 1989 edition have been addressed, which is a pity because it is a good book and could be a great book.

The opening chapter is an excellent summary of the information available about stars. It is followed by a very clear discussion of atoms, spectra and the spectral sequence. The major part of the book is a series of chapters discussing the characteristics of each type of star, beginning with the coolest stars, class M, progressing through the ranks to the hottest, class O. Peculiar stars are discussed along the way, but some extraordinary stars (*e.g.* central stars of planetary nebulae, interacting binaries, and supernovae) do not fit naturally into any category, so they get a chapter of their own. In the last chapter Kaler brings it all together with a romp through the HR diagram, tracing the paths of stellar evolution.

I wish the author had given better references. The subject is complex and the readership is likely to be at a high enough level to want to know more. Kaler often does not give full references, or even publication dates, rendering it unnecessarily difficult for the curious to explore further. The intelligent amateur will want to read more. It also would be very helpful to have some general references for further reading given at the end of each chapter. This lack of proper references, even general ones, detracts from the usefulness of the book, in my opinion.

The reproduction of stellar spectra for illustrations is a lost art, even for an experienced press like Cambridge. Many of the illustrations are dark and contrasty, so it is difficult to see some of the features referred to by the author. In addition, some of the illustrations taken from original papers have been cut up and pasted, which does not do justice to the symmetry and integrity of the original illustrations. Astronomers use negatives or tracings in their work, so it would have been best to illustrate them accordingly, in my opinion. This is not just a personal bias; negatives and tracings actually show the features better.

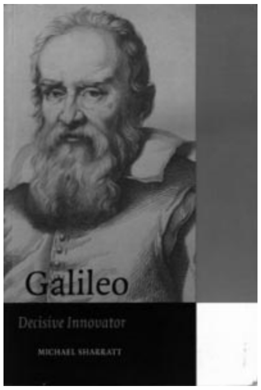
In spite of the above comments, I highly recommend the book to educated amateurs and scientists who want to know more about how spectra are used in astronomy. It also would make interesting casual reading for professional astronomers, who might enjoy interesting summaries of the "personalities" of their favourite stars.

I like very much the final two sentences of the book; they summarize well the author's poetic sensitivity. "Before leaving, look again across the HR diagram presented here, and ponder once more this remarkable array of stars. And, tonight, if it is clear, go out to examine the real thing: all the classes arrayed for you, splashed wondrously across the darkened sky." This informative book is an excellent read, bridging the gap between purely popular-level entertainment and dense professional texts.

Robert F. Garrison

Robert F. Garrison is the Society's Second Vice-President.

Galileo: Decisive Innovator, by Michael Sharratt, 274 pages, 15 cm × 23 cm, Cambridge University Press, 1996. Price $72.45 hardback, $27.45 paperback. ISBN 0-521-56671-1



As every geologist knows, the steep-sided rocky plugs that dot the American southwest and form the backdrop to many a cowboy epic are actually the remains of ancient volcanoes, chiseled by wind down to their bare, unyielding cores. In similar fashion time erodes our collective memory of the past, forming a vacant expanse where big names stand in isolation, progressively stripped of context.

As names go, they don't get much bigger than Galileo. His figure looms large in science history not only because of his seminal discoveries in astronomy and physics, but for defending Copernicanism — and for failing so famously to escape the consequences. Galileo's trial before the Inquisition in 1633, during which he was required to publicly affirm belief in a stationary Earth, is the stuff of high drama. Even a cursory stroll through the ages cannot avoid making reference to that grim episode.

Unfortunately, popular accounts of Galileo's life are often oversimplified to the point of inaccuracy, depicting Galileo as a lone champion of empirical truth against a dark tide of religious tyranny and superstition. It's an image that plays well in the television age, but it is a misrepresentation. Galileo, who may have perceived the mathematical architecture of nature better than anyone since Archimedes, was equally aware of the social framework in which he lived and worked — and was ambitious for success on its terms. That his efforts instead earned him condemnation and bitter poverty in his later years is an outcome of the complicated personal and political culture that encircled him. While the principal conflict of Galileo's career certainly involved clashing interpretations of nature and Holy Scripture, on another level it was all about protocol.

In *Galileo: Decisive Innovator*, Michael Sharratt offers an effective and manageable remedy to the standard schoolbook portrayal of Galileo. Effective, because it outlines Galileo's contributions with an emphasis on ideas rather than anecdotes. Manageable, because it is a succinct account that restricts itself to the salient features of Galileo's arguments and the key events and relationships that shaped his life.

Through the first four chapters, Sharratt chronicles Galileo's progress from a young, somewhat disaffected academic to a teacher and scientist of remarkably original insight. Born and educated at Pisa, Galileo first found "a proper home for his ability" as a professor of mathematics at Padua. Living there in reduced circumstances, in a household crowded with a young family and a steady stream of student boarders, his scientific creativity flourished. The projects and problems that concerned him, well documented here by Sharratt, reveal a resonance with the commercial and cultural hum of nearby Venice; for Galileo the city was both a catalyst for new ideas and an open doorway to the whole of renaissance Europe. In the same period he acquired some of the closest and most important friends in his life, including Giovanfrancesco Sagredo, an enlightened aristocrat who would secure Galileo a raise in salary, as well as student-turned-collaborator Benedetto Castelli. It is through the eyes of men such as these, Sharratt reminds us, that we can see Galileo most clearly: brilliant, proud, anxious, and a born innovator.

Sharratt duly treats the arrival of the telescope, a Dutch invention, as the transformational event in Galileo's life. Quickly improving on its design, Galileo was among the first to point the telescope skyward — and at age 46 he was equally ready to apply a little showmanship in support of a promotion. Astronomy would never be the same. Galileo's numerous discoveries with the telescope, documented in his booklet "The Starry Messenger" propelled him to celebrity status, bringing him into contact with Clavius and Kepler, among others, and ultimately securing him a prestigious new post as mathematician to the Grand Duke of Tuscany. There were, however, other outcomes to Galileo's astronomical revolution, thanks especially to his observations of the phases of Venus and the moons of Jupiter. No longer just a "soft" supporter of the Copernican system, the telescope turned Galileo into its most conspicuous advocate, setting him on a collision course with the Church.

In the latter chapters of the book, Sharratt guides the reader step-by-step through Galileo's most influential works, including his great Copernican treatise the "Dialogue Concerning the Two Chief World Systems" and "Discourses Concerning Two New Sciences," which documents his investigations into materials and kinematics. Between the Dialogue and the Discourses comes the trial, an affair that shattered Galileo's life and kept him under house arrest through his old age. Sharratt, himself a Roman Catholic priest, methodically deconstructs the legal underpinnings of the case, but more importantly identifies the true issues and personality conflicts that led to the trial.

What this book does best — and where it will be of most use to those interested in reading beyond the more Disneyesque versions of Galileo's life — is to clearly identify whom Galileo thought he was actually fighting. Not the Church, but the scientific mainstream of his era, a stifling paradigm of natural philosophy whose practitioners, rather than systematically observing nature, sought recourse in Aristotle. Ironically, even though it was the Dialogue that led to Galileo's downfall, it was the Discourses that would prove to be the more potent vehicle of change. Within its pages Galileo firmly laid down a new approach to physics, doubly grounded in empiricism and mathematics, replacing Aristotelian rhetoric forever and setting the course for Newton and beyond. Before Galileo, mathematics was regarded as an abstract sideline; after him, there could be no serious physical science without it.

While no biography of Galileo this brief can claim to be comprehensive, Sharratt succeeds in restoring the man behind the myth. If time erodes memory, competent history is a breakwall. Unlike a geological formation, the more context that surrounds this giant of the past, the more clearly we see him.

Ivan Semeniuk

Ivan Semeniuk is book review editor of the Journal.

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The Cambridge Illustrated History of Astronomy, edited by Michael Hoskin, pages 392, 21 cm × 26 cm, Cambridge University Press, 1997. Price US$39.95 hardcover. ISBN 0-521-41158-0

The Cambridge Illustrated History of Astronomy provides a great review of the science of astronomy, from earliest times to the present day. Written by a host of expert contributors and loaded with full-colour illustrations, it introduces the subject in a way that is accessible to general readers, and detailed enough to serve as a textbook for an undergraduate course.

The authors of The *Cambridge Illustrated History of Astronomy* are Michael Hoskin, J. A. Bennett, Christopher Cullen, David Dewhurst, Clive Ruggles and Owen Gingerich. Different eras are covered by different authors. The chapters are organized in chronological order, running from Astronomy in Antiquity through to Astronomy's Widening Horizons. Each chapter also contains many clearly marked supplementary sections investigating tangential topics. A short, but interesting feature at the end of the book is a time-line of astronomical history, starting in 3500 B.C. with the first construction of megalithic structures in Europe, through to the arrival of the Galileo spacecraft at Jupiter in 1995. Also included are a comprehensive glossary, reading list and an excellent index. The fact that the book is written by several authors, each with his own style, does make for some disparity in the different chapters, but it is a small sacrifice to pay for the diversity of opinions and knowledge.

The sections that I particularly enjoyed and learned from were those on Islamic Astronomy and Medieval Astronomy (both co-written by Michael Hoskin and Owen Gingerich). Islamic Astronomy includes more detail than I expected and has an excellent "tangent" section on the astrolabe. Medieval Astronomy revealed that the failings of the Ptolemaic system were annoying scholars long before the Renaissance, making for an excellent lead-in to the Copernican Revolution.

The Prehistoric Astronomy chapter, by Clive Ruggles and Michael Hoskin, is definitely Eurocentric, as the authors are careful to point out. "This History will concentrate on the emergence of the science of astronomy as we know it today. The historical record shows this development to have taken place in the Near East and, more particularly, in Europe." Those interested in pre-European American or African Astronomy should look to other sources, although there is a good section on the Maya and a nice "tangent" section on Chinese astronomy.

The authors are quite skeptical of claims to astronomical sophistication amongst early peoples. The skepticism is strong enough to make me wonder if this was not the true reason they stuck to European pre-History. Little enough is known about pre-historic European peoples and they are so removed from the present era that skepticism about their sophistication is unlikely to offend anyone.

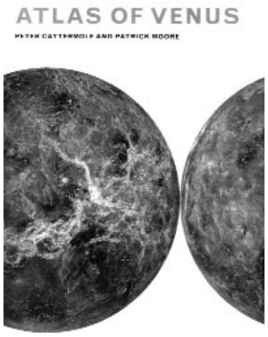
The detailed history ends with the emergence of modern Cosmology in the first half of the twentieth century. The final chapter begins by posing the question, "where does history stop and astronomy begin?" and goes on to review the major problems of astronomy today. Even so, it stops just short of some of the big stories of recent years — possible Martian microbes and extra-solar planets. Still, it is interesting to watch the pattern of a constantly evolving science continue into the present day.

Unlike many of the classic history of science texts, this one presents its story mindful of new ideas about the way science progresses. It offers a far more open-minded look at the past. For example, where it was fashionable to present Galileo as a martyr in earlier texts, here he is presented as an excellent scientist with an underdeveloped sense of diplomacy. While that is certainly not a new trend, it is nice to have a comprehensive history of astronomy written in such a manner.

The purpose of *The Cambridge Illustrated History of Astronomy* is to tell the story of how the science of astronomy has arrived at its present state. It does that very well. At its relatively inexpensive price and with its lovely illustrations, the book will make an excellent addition to any library, astronomical or not!

Kirsten Vanstone

Kirsten Vanstone is Astronomy Assistant at the Alexander F. Morrison Planetarium in San Francisco, and an astrohistory enthusiast.



Atlas of Venus, by Peter Cattermole and Patrick Moore, pages xv + 143; 22.5 × 28.5 cm, Cambridge University Press, 1997. Price US $29.95 hardcover. ISBN 0–521–49652–7

A recent brief review in a popular astronomy magazine described this book as "more than an atlas." The reviewer meant that the "atlas" contained not just maps but also an excellent summary of the exploration and geology of the planet. I take the opposite view: this is "less than an atlas." It does contain a very good summary of our knowledge of Venus and its exploration, but it is sadly deficient in maps. As such its title is misleading.

That said, the book is more than adequate as an introduction to the planet. Three initial chapters describe observations of Venus in ancient times and in the telescopic era, from the mythology of various cultures to pre-space-age speculation on the nature of the planet's surface. Three more chapters recount the exploration of Venus by spacecraft. All these introductory chapters are well written, concise and thorough, though the treatment of synthetic aperture radar imaging is rather weak. Most of the remainder of the book is devoted to the geology of Venus. The plains, volcanoes, craters and uplands are described and well-illustrated with many Magellan radar mosaics. Passing quickly over the one page Chapter 12, in which we learn that astronomy from the surface of Venus would be difficult, we encounter a series of appendices containing basic information concerning the planet and its exploration. The largest of these, 25 pages long, is a list of Venusian place names and their meanings.

The book is presented in a manner that should be accessible to amateur astronomers or students in introductory-level courses. The jargon of modern space science, a mix of astronomy and geology, is not so obtrusive as to be much of a problem, though it does appear in places and is not always properly explained. There is no glossary. For instance the geological term "facies," meaning variations from place to place within a single layer of rock, is used to refer to crater ejecta on page 82 without any explanation, and in fact is misused as if it were merely a synonym of "deposits." This problem is mostly found in the geological section of the book, which is a simplified version of a longer and more technical text by the first author. A glossary would have helped. The map of spacecraft landing sites on page 38 is incomplete and far too small to be useful.

The cartographers of the U.S. Geological Survey have mapped many worlds in detail, and Venus will soon be added to the list, but their Magellan-based maps of Venus are still "in press" and were not available for the atlas. In their place are various small illustrations culled from the scientific literature, useful but not extensive or systematic enough to warrant the title "Atlas," and one set of globe-spanning images. These are beautiful, and some readers may recognize them as being the basis for a globe of Venus currently available through a popular astronomy magazine. They combine a black and white representation of the global Magellan radar mosaic, showing craters, hills, lava flows and so on, and colour-coded elevations. Blue is low, pink and white high. They portray the world in six mutually perpendicular views, very attractive but too small to be very useful. A few place names are added, but not many, and the absence of a latitude-longitude grid means that the names in the appendix cannot be associated with features on the maps. The names that are given are not easy to associate with a specific feature — the name "Lada Terra" is not placed on Lada Terra, and which crater is Stuart? The lack of a colour key for elevations is reprehensible. I would have used the six views to give a global overview of the planet, with colour key and better name placement, and then enlarged the central portion of each to fill a two-page spread for a detailed portrayal of topography, place names and spacecraft landing sites. With that addition the book could justifiably be called an atlas. I recommend this book as an adequate, not-too-technical description of Venus, suitable for many libraries and interested individuals, but we still await a good atlas. ◉

Philip Stooke

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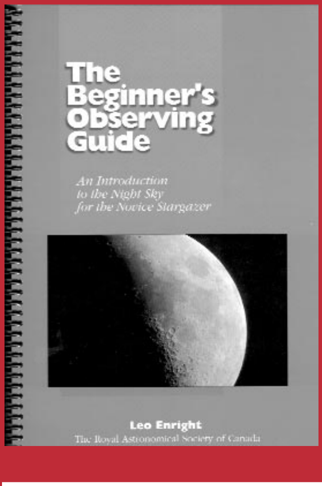

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A History of the Royal Astronomical Society of Canada

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

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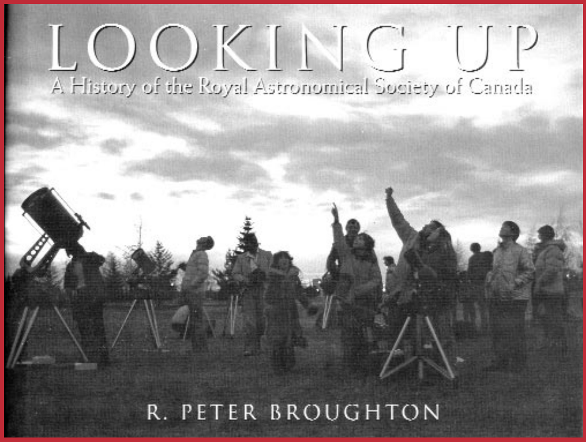

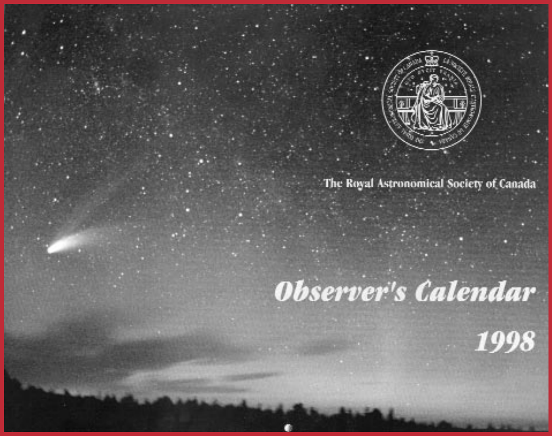

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