

**National Research Council of Canada
Herzberg Institute of Astrophysics
Office of the Director General**

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[S0002-7537(93)00931-X]

This report covers the period from 1999 April 01 through 2000 March 31, while the publications are for the calendar year 1999.

1. MANDATE

The National Research Council (NRC) has the Parliamentary mandate to operate and administer any astronomical observatories established by the Government of Canada. NRC exercises this mandate through its Herzberg Institute of Astrophysics (HIA), which provides astronomical facilities, research, and infrastructure to university scientists and their students.

Later sections of this report describe the Optical Astronomy Program at the Dominion Astrophysical Observatory in Victoria, BC, the JCMT Group at the same location, and the radio-astronomy projects at the Dominion Radio Astrophysical Observatory near Penticton, B.C.

2. INTERNATIONAL COLLABORATION

HIA is responsible for Canada's participation in three major ground-based facilities - the 3.6-m Canada-France-Hawaii Telescope (CFHT) and the 15-m James Clerk Maxwell Telescope (JCMT) on Mauna Kea, and the Gemini 8-m telescopes on Mauna Kea and on Cerro Pachon in Chile. Donald Morton represents NRC on the Gemini Board and the JCMT Board, while Vice President Jacques Lyrette and James Hesser are the NRC members of the CFHT Board.

The Office of the Director General coordinates the assignment of Canadian time on the CFHT, JCMT and Gemini. Jacques Vallée is the Technical Secretary of these committees and is assisted by Brenda Parrish. During 1999 the Canadian Time Assignment Committee for the CFHT consisted of D. Bohlender (HIA), R. Carlberg, S. Lilly (U. Toronto), T. Davidge (HIA), G. Fontaine (U. Montréal), and M. West (St. Mary's U.), while the Time Allocation Group for the JCMT comprised M. Fich (U. Waterloo), D. Naylor (U. Lethbridge), H. Matthews (HIA), R. Pudritz (McMaster), and D. Scott (U. British Columbia). Vallée is also Secretary to the Canadian National Committee for URSI, on which the radio astronomy community was represented by K. Tapping (HIA), followed by D. Routledge (U. Alberta) from 1999 July.

3. STAFF

The professional staff reporting to the Director General, D. C. Morton, are J. E. Hesser, D. Crabtree, P. E. Dewdney, L. Avery, T. Landecker, J. Vallée and M. Storr. Dennis Crabtree returned from 3 years as Deputy Director of the CFHT to become the Group Leader of the Canadian Gemini

Office. He succeeded Andrew Woodsworth, who left HIA to become the new Director General of NRC's Institute for Information Technology in Ottawa.

Andrew Yau transferred to a position in space physics at the University of Calgary.

Kevin Farris joined the Central Services staff as Supervisor of Administrative Services, replacing Michael Albert who left during the reporting period. Sandra Plimley accepted a short term position with the Purchasing Group. Bill Mackwood returned to another short term contract to assist with building maintenance. Sheila Goeckel returned to assist DRAO's Central Services staff for another short term appointment. Hashim Mitha began a secondment arranged with the Innovation and Development Corporation at the University of Victoria to investigate opportunities for technology transfer.

In July 1999 construction began on safety upgrades and an extension to the main Victoria building, as well as a new Visitors Centre adjacent to the 1.8-m dome. Michael Storr became Project Manager for these improvements, in addition to his normal responsibilities as Manager of Operations for HIA. Roy Heppner took an acting assignment as the Construction Coordinator. Diane Crowe accepted an acting assignment as Procurement Officer.

4. EXTERNAL RELATIONS

The Institute receives direct advice on its policies, programs and management from the HIA Advisory Board. During most of the year of this report, the Board comprised C. Wilson (McMaster U.) as Chair, A. Babul (U. Victoria), R. Carlberg (U. Toronto), R. Doyon (U. Montréal), O. Forgacs (retired), R. Green (NOAO), J. Lyrette (NRC), and S. Pineault (U. Laval). Jacques Vallée serves on the CASCA Public Relations Committee, is the HIA institutional representative for CASCA, and is responsible for HIA public relations. In this last role he has organized numerous media briefings and interviews.

5. RESEARCH

Morton has continued his efforts to tabulate the most reliable wavelengths and f -values for analyzing resonance lines in astronomical spectra. He completed a compilation for the elements heavier than gallium which will be published in the Astrophysical Journal Supplement Series and he revised his earlier publication for the resonance lines of lighter elements which could appear in spectra recorded by the Far Ultraviolet Spectroscopic Explorer (FUSE). Morton has participated in the analysis of FUSE data on stellar winds and interstellar H₂ with various collaborators. He also has begun a program to analyze HST measurements of interstellar CO for comparison with the H₂ data from FUSE to determine the CO/H₂ ratio on various sight lines.

Vallée, and Bastien (U. Montréal) have a program to detect the presence of magnetism in molecular cloudlets using the JCMT polarimeter with SCUBA. Measurement of the polarization in these elongated clouds should determine the geometry of the magnetic field (at least for the tangential component). Vallée and Greaves are studying gas globulets (Boks) for turbulence, using the JCMT at 345 GHz.

Vallée studied the statistical properties of interstellar clumps, notably the magnetic field strength and the magnetic and turbulent energies as a function of radius, gas density, and other parameters.

6. CANADIAN GEMINI OFFICE (CGO)

During 1999 the CGO prepared to support operations of Gemini North. Jean-René Roy (U. Laval) continued as a member of the CGO in the capacity of Canadian Gemini Project Scientist and Stéphanie Côté and Tim Davidge continued as Gemini Support scientists. Gemini issued a call for proposals for the early scientific use of Gemini in early March 2000. The so-called *Quick Start* semester will run from 2000 August 01 through 2001 January 31. Dennis Crabtree, Roy, Côté and Davidge gave a series of very successful presentations at eight universities to inform the community about Gemini, the instruments available for *Quick Start* and the proposal process. The CGO staff will provide technical evaluation of the 29 proposals received for the approximately 55 hours of observing time.

Côté has extensively developed the Canadian Gemini Office website, which now contains over 120 HTML pages, is fully bilingual and is routinely updated with new material. The site provides all the information necessary to astronomers wishing to submit Gemini proposals, and contains a general public section. Crabtree developed a procedure for converting the Gemini proposals from XML to LaTeX using an XSL style sheet and the IBM Lotus package to allow Canadian proposals to include standard mathematical markup.

Crabtree represented Canada at the September Gemini Instrumentation Forum and the Gemini Operations Forum. Crabtree, Côté and Davidge participated in the Proposal Readiness Review held in Hilo in November and attended the Gemini Science Committee meeting held in Seattle in October as observers.

Crabtree with Bryson (CFHT) created a database of publications based on data collected at the major Observatories including CFHT, JCMT, UKIRT, AAT, NOAO, CTIO, ESO, STScI, and the MMT. Citation numbers were retrieved from the Astrophysics Data System for all publications. Analysis of this database is continuing to compare publication records from various observatories. Crabtree with Brewer (ESO) and Richer (UBC) obtained data with the new CFH12k camera to identify the AGB population in M33.

Côté is investigating the kinematics of nearby spiral galaxies at very large radius using Lyman- α absorption lines in the spectra of background quasars. In an HST cycle 7 program with STIS to observe 8 quasars in the background of nearby galaxies (with redshifts < 6000 km/s). Lyman- α lines were successfully detected in the spectra of 5 quasars at impact parameters up to ~ 160 kpc from the galaxy, and at

wavelengths consistent in each case with the galaxy's redshift. These lines are being used to extend the rotation curves beyond the radius available to H I observations, to constrain the mass profiles of the dark halos. These detections include the lowest redshift Lyman- α lines detected so far in association with nearby galaxies.

Côté is studying nearby dwarf galaxies with collaborators Skillman (U. Minnesota) and Miller (Gemini). The dwarf galaxies of the Centaurus A group (an *active* group where most main members are active galaxies) were imaged in H α at CTIO, and all of them yielded detection of H II regions. This is different than what was seen in the Sculptor Group (a loose *quiescent* group), where less than half of the dwarfs showed current star formation. This suggests that the group environment plays a role in dwarf-galaxy evolution.

Davidge continued to investigate low latitude Galactic globular clusters at infrared wavelengths. Using broad-band and narrow-band images obtained at CFHT and CTIO, he estimated the metallicities and distances of the highly reddened clusters Djorgovski 1, Liller 1, and HP 1. This investigation found that, contrary to previous studies at visible wavelengths, Djorgovski 1 is not metal-rich, but is actually one of the most metal-poor globular clusters in the inner spheroid. These data also indicate that Liller 1 has a metallicity comparable to that of other metal-rich clusters, such as NGC 6528.

Davidge also completed a survey of all known metal-poor ($[Fe/H] < -1.3$) Galactic globular clusters within 3 pc of the Galactic Center. The principle goals of this study, which uses broad and narrow band images recorded at CTIO, were to estimate the reddenings, metallicities, and distances of these clusters based on the properties of bright giants. The clusters are uniformly distributed throughout the inner spheroid.

Davidge used near-infrared images obtained with the CFHT adaptive optics to investigate the stellar content of the central regions of the Local Group spiral galaxy M33. These data reveal that the nucleus of M33 has near-infrared photometric properties that are similar to SWB type 1 and 2 clusters in the Magellanic Clouds. Moreover, the bulge of M33 has a low metallicity, indicating that it could not have formed from material originating from the surrounding disk. Finally, these data indicate that there was a widespread burst of star formation in the inner disk of M33, that terminated 1 - 3 Gyr in the past.

7. SQUARE KILOMETER ARRAY (SKA)

Peter E. Dewdney, formerly the Co-ordinator of Future Radio Astronomy Initiatives for HIA, is now serving as Group Leader for the SKA. Since planning for contributions to various future radio astronomy projects is complete, there is no further requirement for the previous position. Dewdney will continue to assist L. Avery of HIA, who has become Canadian Project Manager for ALMA. The SKA work is assisted by B.G. Veidt and B.R. Carlson, who are based at the Dominion Radio Astrophysical Observatory (DRAO) with Dewdney. In addition to the work directly on the SKA, this Group is designing correlators and receivers. Dewdney and Veidt also advised an industrial firm in the development

of a technical proposal for a prototype ALMA antenna, and they investigated a possible contribution in the area of cryogenic equipment for cooling receivers.

Dewdney continues to be active with university and international colleagues in promoting the SKA in the international arena, and in developing the Large Adaptive Reflector (LAR) as potential technology for the SKA. The SKA is now seen as the next generation radio telescope for cm and dm waves.

An International SKA Steering Committee (ISSC) has been established with membership from Australia, Canada, China, India, Europe and the U.S. The ISSC has held two meetings, the first at the URSI meeting in Toronto in 1999 August, and the second in Munich in 2000 March. A Memorandum of Understanding formally establishing the ISSC is in draft form and is expected to be signed by all participating organizations during 2000. It includes funding commitments for the activities of an International SKA Secretariat. Prof. A. R. Taylor (U. Calgary) is currently serving as the interim executive secretary of the ISSC. The original international agreement, "Technology Study Program Leading to a Future Very Large Radio Telescope," continues to be in force until it is replaced by the ISSC agreement. With partial funding from the National Research Council, Taylor served last year as SKA International Project Scientist with responsibility to put together the SKA science case.

The Canadian technical contribution to the SKA is research on the Large Adaptive Reflector (LAR), a potential solution to the SKA's cost and performance constraints. The LAR is a long-focal-length paraboloid which requires an airborne platform to support the focal package and substitutes small surface deformation for the mechanical tilting of the reflector. The airborne platform under development is an aerostat held in position by six tethers. An overview of development progress to date is contained in Carlson *et al.* (2000) and interim results of work on the steady-state stability of the aerostat system are reported in Fitzsimmons *et al.* (2000). Both papers will appear in Proceedings of "Astronomical Telescopes and Telescopes 2000," Munich SPIE. On-going simulations of the entire multi-tethered structure are being carried out by M. Nahon's group (U. Victoria), including the incorporation of a control system.

A group led by S. Stiemer (UBC) has begun an initial study of the structure needed for the LAR focal package, in cooperation with U. Stuttgart. This group also continues work on the reflector structure. A group led by D. Routledge (U. Alberta) is extending the study of a panel measurement system begun by Carlson. Development of large actuators for the adjustment of the surface is on-going at AGRA Coast, a firm associated with the LAR development. A working model of the design is expected to be completed during 2000.

Veidt is concentrating on the LAR feed system, a large prime-focus phased array, designed to provide multiple beams over an area approaching one square degree. Receiver and combining network designs are now being developed, including a digital combining system based on the WIDAR correlator design (see below). Laboratory receiver models are planned for 2000. As part of the receiver development, a

group led by L. Bauwens (U. Calgary) is developing the technology for optimized pulse-tube cooling.

T. Landecker (HIA) and his student, Leonid Belostotski, have successfully constructed a demonstrator two-way microwave system for transferring the local oscillator signal to the focal package and for determining the distance from the center of the reflector to the focus.

A. Willis and A. Gray (HIA) have begun dynamic range studies of the SKA using the LAR concept. The AIPS++ framework is being extended to handle the variable field-of-view imposed by the LAR.

Significant progress in the next phase of the LAR development will require funding to field test some critical components. The technical reports and other information can be accessed on the Web at <http://drao.nrc.ca/science/ska>.

It is proposed that Canada build a new correlator system of the Expanded Very Large Array (ELVA) as part of an NRAO - HIA agreement under negotiation for collaboration in radio astronomy. A novel correlator design for this purpose is described in Carlson and Dewdney (2000) in *Electronics Letters*. The WIDAR (Wideband Interferometric Digital Architecture) design will provide high spectral resolution at the widest bandwidths and high spectral dynamic range, leading to improved performance of the telescope where interfering signals are present. In addition, the WIDAR design permits accurate digital delay, eliminating the need for a quasi-analog delay system for fractional-bit interferometer delays. The version proposed for the ELVA will have a total bandwidth of 16 GHz in eight 2-GHz bands (or four polarization pairs). At full bandwidth up to 16000 spectral channels per interferometer pair are available, providing a spectral resolution of 128 kHz across 2 GHz. The maximum, spectral resolution possible is about 0.1 Hz in so-called "radar mode." Carlson has carried out extensive tests of the WIDAR design by developing a software version of the correlator for a single interferometer baseline, and feeding it with simulated inputs, including strong interfering signals.

8. SOLAR TERRESTRIAL PHYSICS

In Ottawa, Vic Gaizauskas continued his collaboration with members of the PROM (Prominence Research: Observations and Modeling) team. His current research centers on the formation and destruction of long solar filament channels that border global-sized patterns of unipolar magnetic flux as they expand and migrate poleward out of super-clusters of sunspots concentrated near the solar equator. From large-scale chromospheric images taken at the Ottawa River Solar Observatory (ORSO), he can assign an orientation and direction of twist to axial magnetic field lines along filament channels. These assignments test the parameters included in a new model of prominence formation, involving global flux transport, devised by theorists on the PROM team. Simulations conducted so far with magnetic measurements coincident with ORSO observations and parameters constrained by ORSO data have been successful in replicating the elementary magnetic geometry of prominences. These results are a significant step on the way to understanding the formation

and stability of huge structures involved in the transfer of solar mass and magnetic energy into the heliosphere.

Donald McDiarmid, in Ottawa used CANOPUS magnetometer and radar data from the ground to investigate a particular auroral MHD pulsation feature seen in auroral radar data. These data have been used previously to estimate the radial dependence of the cold plasma mass density in the magnetosphere. He is simulating the generation of these data to establish that these estimations are valid. McDiarmid also is the science policy consultant for the Canadian Association of Physicists and is its Director of Professional Affairs.

During the period of this report, David Anglin in Ottawa, started a paper on the convective flows observed in Jupiter using the 1992 measurements of energetic particle anisotropy made with the HIA High Flux Telescope (HFT) on the Ulysses spacecraft. The preliminary results of the analysis indicate that the flows on the dusk side vary dramatically with radial distance and peak flows may be super rotational. He continued the general scientific data processing of the HFT data so that results through to the end of 1999 are now available on the Ulysses Data Archive at ESA and from NSSDC. At the COSPIN Science Workshop held in February 2000, Anglin agreed to help with the development of software to perform anisotropy analysis using all the COSPIN sensors on Ulysses, including the HFT. The goal is to use this information to better understand the acceleration of energetic particles by interplanetary shocks from the sun.

Andrew Yau, who is now based at the University of Calgary, successfully completed the tenth year of continuous operation of the Suprathermal Mass Spectrometer (SMS) instrument on the EXOS-D (Akebono) spacecraft in March 1999. The extended science data base, which will cover a full 11-year solar cycle by March 2000, will be a unique base for the study of ionospheric ion composition and outflow.

9. STAFF PUBLICATIONS (CALENDAR YEAR 1999)

- Blais-Ouellette, S., Carignan, C., Amram, P., Côté, S. 1999, Accurate Parameters of the Mass Distribution in Spiral Galaxies. I. Fabry-Perot Observations of NGC 5585, *AJ*, 118, 2123
- Côté, S., Broadhurst, T., Loveday, J., Kolind, S. 1999, An H I survey of LSB galaxies selected from the Apm survey, *Proceedings of the IAU 171*, "The Low Surface Brightness Universe," ASP Conference Series, 170, 307
- Davidge, T. J., & Courteau, S. 1999, The Central Regions of M 81, *AJ*, 117, 2781
- Davidge, T. J. Courteau, S., 1999, High Angular Resolution JHK Imaging of the Centers of the Metal-Poor Globular Clusters NGC 5272 (M3), NGC 6205 (M 13), NGC 6287 and NGC 6341 (M 92), *AJ*, 117, 1297
- Gaizauskas, V. 1999, Solar Activity Complexes, *Encyclopedia of Astronomy & Astrophysics*, Macmillan/IOP
- Gaizauskas, V. 1999, Solar Filament Channels, *Encyclopedia of Astronomy & Astrophysics*, Macmillan/IOP
- Jorgensen, A. M., Spence, H. E., Hughes, T. J., and McDiarmid, D., 1999, A Study of Omega Bands and Ps6 Pulsations on the Ground, At Low Altitude and At Geostationary Orbit, *J. Geophys. Res.*, 1041, 570, 5J
- MacKay, D. H., Gaizauskas, V., and van Ballegoijen, A. A. 1999, Magnetic Flux Transport and the Formation of Dipped Magnetic Field Lines, *ESA, SP-448, Conference Proceedings*
- St-Germain, J., Carignan, C., Côté, S., Osterloo, T. 1999, H I in the Field of the Dwarf Spheroidal/Irregular Galaxy Phoenix, *AJ*, 188, 1235
- Vallée, J. P. & Bastien, P. 1999, Magnetism in Interstellar Nurseries at 760 microns, *ApJ*, 526, 819
- Welty, D. E., Hobbs, L.M., Lauroesch, J. T., Morton, D. C., Spitzer, L., and York, D. G. 1999, The diffuse interstellar clouds toward 23 Orionis, *ApJS*, 124, 465

Donald C. Morton