National Research Council of Canada
Herzberg Institute of Astrophysics
Dominion Radio Astrophysical Observatory
P.O. Box 248, Penticton, British Columbia,
Canada V2A 6K3

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This report covers the period from 1998 April 1 through 1999 March 31, while the publications are for the calendar year 1998.

1. PERSONNEL

The professional staff of the Observatory comprises T.L. Landecker (Director), P.E. Dewdney (Deputy Director), T.A. Burgess, B. Carlson, A.D. Gray, L.A. Higgs, A.P. Hoffmann, G.J. Hovey, L.B.G. Knee, B.D. Parchomchuk, K.F. Tapping, B.G. Veidt, B.J. Wallace and A.G. Willis.

Wallace and Knee are Research Associates working on the Canadian Galactic Plane Survey (CGPS).

Gray moved from Research Associate to the position of Operations Manager, responsible for the DRAO telescopes, in April 1998.

S.M. Dougherty (Research Associate, U. Calgary) transferred from the CGPS in April 1998 to become manager of the Space VLBI Correlator (supported by the Canadian Space Agency). Also working on the project are W.T. Petrachenko (Natural Resources Canada, Ottawa) who has been seconded to HIA, D. Del Rizzo and K. Douglas (U. Calgary)(since September 1998). Carlson, who directed the engineering development of the Correlation Centre, moved from this project in April 1998 and joined the HIA staff to work on Future Radio Telescope Initiatives.

R. Kothes joined DRAO in October 1998 as NSERC Visiting Fellow, moving from MPI in Bonn. C. Brunt, formerly at U. of Massachusetts in Amherst, arrived in February 1999 to take up the position of Research Associate with U. of Calgary; he is working at DRAO on the Canadian Galactic Plane Survey.

During the year M. Davies moved to an engineering position in industry (May 1998) and A. Ebbers transferred to the Instrumentation Group at HIA, Victoria (December 1998).

W. Dent and J. Lightfoot (Royal Observatory, Edinburgh) have been at DRAO for lengthy periods contributing to the JCMT Correlator development.

J.A. Galt, J.D. Lacey, C.R. Purton and R.S. Roger are continuing as Guest Workers.

Dewdney, based at DRAO, is the Coordinator of Future Radio Telescope Initiatives for the Herzberg Institute of Astrophysics. Carlson and Veidt carry out engineering research in this area. The activities of this program are reported under the Office of the Director General.

L. Belostotski and A.C. Thorsley are graduate students in Electrical Engineering at U. Alberta. They are both carrying out research work towards M.Sc. degrees at DRAO.

2. INVOLVEMENT IN THE SCIENTIFIC COMMUNITY

Dougherty, Higgs and Tapping are members of the Radio Astronomy Committee of the Canadian Astronomical Society (CASCA). Tapping represents Canadian astronomy in matters related to the management of the radio-frequency spectrum. He is a member of the Canadian delegation to the International Telecommunications Union (ITU), and participates in ITU Working Group 7D (Radio Astronomy). He is the Co-ordinator of Task Group 1/5 carrying out a band-by-band study of the allocations to radio astronomy and he is involved with a Monte Carlo interference study of the allocation between 406.1 and 410 MHz. Tapping is also the Chairman for Canada of Commission J (Radio Astronomy) of the International Radio Science Union (URSI) and is participating in the URSI Working Group on Proxy Measures of Solar Activity.

Dewdney is on the Science Councils of both the VSOP and the RadioAstron Space VLBI projects and is a member of the Working Group on Global VLBI of URSI Commission J. He is also a member of the scientific organizing committee of Division 40 (Radio Astronomy) of the IAU.

Higgs is a member of the Large Telescope Working Group which was established by URSI Commission J, and of a Working Group on Astronomy from the Moon established by IAU Commission 44. Willis serves on the Scientific and Technical Advisory Group for AIPS++.

Landecker is an Adjunct Professor at the University of Alberta (Electrical Engineering), Dewdney is an Adjunct Professor at the University of Calgary and Purton is an Adjunct Professor at the University of Victoria. Landecker came to the end of a six-year term as member of the Board of Governors of Okanagan University College in July 1998. Hovey is a member of the B.C. Science Council (Okanagan). Landecker is a member of the Okanagan High-Technology Council.

Dewdney, Landecker and Higgs served on the Scientific Organizing Committee of the Workshop ''New Perspectives on the Interstellar Medium'' held in August 1998 (Landecker as co-chair). Higgs chaired the Local Organizing Committee for this Workshop, for which HIA was the host institution.

3. TELESCOPES

DRAO is operated by the HIA as a National Facility for Canadian radio astronomy. Two radio telescopes, the Synthesis Telescope and the 26-m Telescope, are available (on a limited basis) to external users. The Solar Flux Monitoring Program provides data to a worldwide community of users as a scientific service. A newsletter concerning new developments of DRAO telescopes and software is published at six-month intervals; it is available on request. Information about

DRAO, including the newsletter, is available on the World-Wide Web at http://www.drao.nrc.ca.

3.1 The Synthesis Telescope

The DRAO Synthesis Telescope has both continuum (1420 MHz and 408 MHz) and spectral line (H I) capability. Its combination of antenna size (9 m) and baseline (600 m) gives it a wide field of view (2deg and 8deg) and good angular resolution (1.0′ and 3.5′) at the respective frequencies and makes it well suited for studies of the interstellar medium in our Galaxy and in nearby external galaxies. In particular it is a unique instrument for the study of the interstellar H I with arcminute resolution while retaining good sensitivity to extended structure. Channel widths from 0.1 to 3 km/s are available from 256-channel spectrometers to suit Galactic and extragalactic observations; the seven antennas provide complete baseline coverage from 13 to 600 m. Information on broad structures, corresponding to baselines shorter than 13 m, is derived from observations with the DRAO 26-m Telescope (H I line) or from other single-antenna observations.

Currently, the Synthesis Telescope is devoted almost entirely to the acquisition of data for the Canadian Galactic Plane Survey (CGPS). This is a project involving researchers from Canadian universities and several international partners which has been funded for the five-year period, 1995 - 2000.

Although 90% of the observing time on the Synthesis Telescope is currently devoted to the CGPS, a few observations for external users are scheduled each semester; in the three years since the start of the Survey, 25 such observations have been completed, inluding two sessions of solar imaging in mid-summer. Proposals for external observations with the DRAO Synthesis Telescope should be addressed to Gray (e-mail Andrew.Gray@hia.nrc.ca); proposal deadlines are October 15 and April 15. A data reduction *cookbook* is available.

3.2 The 26-m Telescope

The DRAO 26-m Telescope is equipped with receivers covering 1350 to 1750 MHz and 6.6 GHz. All receivers have two polarizations, connected to a digital spectrometer. The main areas of application of the L-band receiver are H I and OH spectroscopy. Recombination line observations are also possible. Pointing accuracy is $\sim$ 1′ rms. The 6.6-GHz receiver has been built for the maser line of methanol. At 6.6 GHz the beamwidth is 7.5′ and the aperture efficiency of the antenna is $\sim$ 16%. The 26-m Telescope is also routinely used to obtain H I data that complement Synthesis Telescope data by providing low-spatial-frequency information. Proposals for use of the telescope should be addressed to the Director of the Observatory (e-mail Tom.Landecker@hia.nrc.ca).

During 1997, the 26-m Telescope was used by Higgs and Tapping to observe some 25000 H I spectra at 12′ intervals over the sky area being covered by the CGPS. These spectra, after correction for ‘‘stray radiation’’ are being used to provide short-spacing data for the H I images observed with the Synthesis Telescope.

A detailed comparison was made between the spectra observed with the 26-m Telescope and the data from the Leiden-Dwingeloo Survey (which is more sensitive but is sampled only at full-beamwidth intervals) in order to assess the significance of stray-radiation corrections. Software was developed to correct for stray radiation; this correction requires detailed knowledge of the antenna radiation properties. Using antenna analysis software (the Numerical Electromagnetic Code – NEC) and empirical modelling of feed-strut scattering and other effects, a model antenna pattern was calculated. This has been used to make first-order corrections for stray radiation, and the resulting corrected data are being used for incorporation with CGPS data from the Synthesis Telescope. A program of actual antenna measurements and more refined calculations to improve the knowledge of antenna sidelobes is in progress.

4. COMPUTER SYSTEMS

The current computing power at the Observatory consists of four 200-MHz dual-processor Sun Ultra clones, along with a number of IBM RS/6000 workstations (two model 320Hs, two model 520s, two model 550s and one 58H), an SGI Indigo 2 and numerous X-terminals and PCs. All the computers at the Observatory are connected by a local area network.

The latest addition to the system (March 1999) is a Beowulf-class computer, a networked assembly of sixteen computers running under Linux. The individual machines are 450-MHz Pentium II PCs. This dedicated parallel-processing supercomputer will be used for prototyping the data-reduction system for the ACSIS Correlator for the JCMT (currently being developed at DRAO), to improve data reduction for the Canadian Galactic Plane Survey, and for the development of data-processing algorithms for future telescopes such as the Square-Kilometre Array. The Beowulf system will also be used by the Canadian Astronomy Data Centre (CADC), a group within HIA at Victoria, for development of their Data Mining project of archival astronomy.

Higgs has continued to support the export package of application software, adding new programs as they become needed. This software package is supported for IBM RS/6000 machines running AIX, Sun machines running Solaris or Sun O/S, SGI machines running IRIX, and, most recently, PCs running Linux. He has also developed a suite of programs to calibrate spectra collected by the 26-m Telescope and to produce low-spatial-frequency data to be combined with H I observations made by the Synthesis Telescope, as part of the CGPS.

5. IMAGE PROCESSING

Willis continues to investigate methods to improve the quality of images produced by the Synthesis Telescope. Since most fields currently being observed by this telescope lie along the northern Galactic plane, and the telescope has a very wide field of view, effects of one of the strong sources Cas A or Cyg A are usually detected in every field. If the Synthesis Telescope field centre is within 5deg to 10deg angular distance from one of these sources, extremely high-dynamic-range images must be produced in order to image

scientifically interesting structure in the field. Since neither Cas A or Cyg A are well resolved by the Synthesis Telescope, Fourier inversion of *CLEAN* components does not produce sufficiently accurate model-visibility functions for comparison with those observed. A better method involves the Fourier transformation of higher-resolution images taken by other telescopes. In order to model bandwidth and integration-time effects with maximum accuracy, a slow Fourier transform procedure must be used. However, this is very time-consuming. In order to compute model visibilities in a reasonable amount of time, Willis has developed a parallel-processing system which will run on the Beowulf computer.

In a paper in *Astronomy and Astrophysics Supplements*, Willis (1999) has described many image processing routines developed particularly for the DRAO Synthesis Telescope. These methods will have many applications in wide-field imaging with aperture synthesis telescopes.

Higgs, working with Gibson (U. Calgary) is developing algorithms for the identification of H I self-absorption features in the CGPS data. Wallace has developed algorithms designed to search the CGPS datasets for small H I, CO and infrared features associated with various kinds of objects, such as dissociating stars.

Willis, Tapping, Gray and Kothes are developing routines for removing solar emission from Synthesis Telescope data. As the Sun advances towards its peak activity, it is becoming a significant source of emission, especially at 408 MHz where the sidelobe level of the antennas is relatively high. In the present approach, solar magnetograms are used as input to a routine which calculates a model radio image of the Sun. This model is used as input to a visibility-fitting technique regularly used in prcessing images from the Synthesis Telescope.

6. AIPS++

The Herzberg Institute of Astrophysics is a partner in the AIPS++ project, the development (led by the U.S. National Radio Astronomy Observatory) of a new image-processing system for radio astronomy. Willis has done beta testing of the initial release of this package and continues to serve on the AIPS++ Scientific and Technical Advisory Committee.

6.1 Correlator for JCMT Focal-Plane Arrays

Detailed design work is proceeding on the Auto-Correlation Spectrometer Imaging System (ACSIS) for the JCMT. ACSIS will provide the processing for spectroscopy with focal-plane arrays. Contributions to the project are also coming from the JCMT Group in Victoria, the UK Astronomy Technology Centre and the Joint Astronomy Centre in Hawaii. This instrument will handle data coming from as many as 32 beams on the sky at the rate of 20 spectra per second per beam. The maximum data rate is 10 Mb/sec. ACSIS includes a processing system for combining fast telescope scans into spectral-line images. The project is headed by Dewdney. Hovey is the project engineer, while the project scientist is Dent (UKATC). Burgess is designing the digital hardware ''core'' of the correlator, and Casorso is designing the sampler. The project passed its Preliminary Design Review in April 1998. Willis joined the project in May 1998, concentrating on the development of data processing software. He has developed a prototype reduction system, based on AIPS++ and has tested it on the Beowulf computer. Lightfoot (UKATC) is also developing software, and is adapting AIPS++ routines to existing calibration techniques in use on the JCMT. Yeung (HIA, Victoria) is working on control software for the IF system, and Force (JAC) is designing IF filters and components.

A large amount of documentation on the design concepts and implementation were produced in preparation for the preliminary design review in April, 1998. Further information can be found on the World-Wide Web at http://www.drao.nrc.ca, under ''JCMT Correlator.''

7. THE CANADIAN GALACTIC PLANE SURVEY

The Canadian Galactic Plane Survey, or CGPS, is a project of a Consortium of scientists from Canada and other countries aimed at increasing the understanding of the many components of the Interstellar Medium (ISM) and their interaction. The project is led by Taylor (U. Calgary). The Consortium now numbers 54, of whom 11 are graduate students and 9 are post-doctoral researchers.

The scales of ISM processes range from the point-like injection of energy from stars to Galaxy-wide phenomena such as spiral density waves. To study phenomena over this vast range of scales the consortium is creating a database of arcminute-resolution images of the main constituents of the ISM over a large area. The survey region is $75° < l < 145°$ and $-3.5° < b < +5.5°$. It images the atomic component of the ISM (through the H I line at $\lambda 21$ cm), and the ionized and relativistic components (through 408 and 1420 MHz continuum images). The 1420 MHz polarimeter is opening a new window on the ISM through studies of the magneto-ionic component.

Consortium partners are providing data on the molecular component (^{12}CO data from Five Colleges Radio Astronomy Observatory - FCRAO), the dust component (HiRes reprocessed IRAS data from IPAC at 60 and 100μ and from the Canadian Institute for Theoretical Astrophysics - CITA - at 12 and 25μ), as well as other radio continuum data (151 MHz - Cambridge U.; 232 and 327 MHz - Beijing Astronomical Observatory).

Since the start of the project in 1995, CGPS Consortium researchers have made significant discoveries which change our view of the ISM. The observations have captured in action the flow of material and energy from the disk of the Galaxy to the Halo, through the imaging of large-scale H I features extending to high latitudes. Polarimetry with the DRAO Synthesis Telescope at 1420 MHz has proved capable of detecting ionized material at extremely low densities, and of determining the strength of magnetic fields, which are significant in the ISM but have always been difficult to measure. Stellar winds clearly play a significant role in shaping the ISM, and the CGPS has revealed details of this coupling. However, the structure evident in H I and CO images cannot always be related to specific shaping influences, and consortium researchers have also laid the ground-

work for statistical studies of the turbulent morphology of the ISM. H I in self-absorption is very evident in CGPS images, and consortium researchers have discovered a strong correlation of velocities at which self-absorption features are found with velocities predicted by the theory of the Galactic spiral shock, suggesting that shock compression is leading to the formation of molecular gas, the first stage of star formation. The large proportion of unexpected discoveries, the large angular (and physical) scales over which phenomena occur, and the sheer number of interesting objects along the plane have strongly vindicated the decision to approach ISM studies in the survey mode.

Observations began in April 1995, with a planned duration of five years. By April 1999 141 out of 190 fields had been observed at DRAO, 74% of the Survey region. Observing and data reduction techniques are now well-established, and observing efficiency is very high. In calendar 1998 nearly 47 fields were observed with the Synthesis Telescope, the highest number ever.

Processing of these survey data is being carried out at DRAO and U. Calgary, with individual fields (2deg across at 1420 MHz) being carefully calibrated and registered before being combined into larger ‘‘mosaics’’ (5deg square), which are then released to the Consortium. Data editing and reduction routines have been automated to a high degree, and the focus of the Consortium has moved to data analysis and interpretation. Seven mosaics have now been distributed, with two more very close to distribution.

Data reduction at DRAO and at U. Calgary and scientific analysis in Canadian universities is being supported by a grant from the Natural Sciences and Engineering Research Council. The survey data will ultimately be made available to the worldwide astronomy community – after a proprietary period – through the Canadian Astronomical Data Centre, operated by HIA in Victoria. Enquiries about the CGPS should be addressed to Taylor (e-mail russ@grizzly.ras.ucalgary.ca) or Landecker (e-mail Tom.Landecker@hia.nrc.ca).

An important part of CGPS Consortium scientific activity in 1998 was the Workshop ‘‘New Perspectives on the Interstellar Medium’’ held at Naramata, B.C., in August 1998. The Workshop brought together researchers working on large-scale surveys at all wavelengths, including the CGPS, with those interested in theoretical understanding of the ISM as a whole. The proceedings of the workshop, edited by Taylor (U. Calgary), Landecker, and Joncas (Laval), will be published in 1999 as Volume 168 in the Conference Series of the Astronomical Society of the Pacific.

Planning has begun for a second phase of the CGPS, to cover the period 2000 to 2005. A proposal is being developed to investigate new problems, based on the understanding of the ISM gained during the first phase. Disk-halo interactions, further investigation of the magneto-ionic medium through polarimetry, and star formation are likely to be central themes of the next phase.

8. SPACE VLBI

The Canadian Space-VLBI Correlation Centre at DRAO has been in full-production mode for the past year, operating about 14 hours per working day. Data tapes arrive from the network of twelve ground radio telescopes and five tracking stations around the world that are equipped with S2 recording systems and regularly contribute observations. After correlation, these data are transferred to the Space VLBI Laboratory at U. Calgary where they are calibrated and images are formed. Typically, about ten observations are correlated each month. Some observations involve as many as eight stations – a challenge for the six-station Canadian correlator. Since the VSOP mission began observing in 1997, the Canadian Correlation Centre has handled a total of 153 experiments; 126 have been released to the principal investigators, 12 have been abandoned, and the remaining 15 are in various stages of correlation.

Full-production mode has been attained through an increase in the reliability, and the addition of extra staff. During the Summer of 1998, a major effort was made to fix a number of time-consuming problems with the correlator. Time lost to correlator problems amounted to less than 24 hours in the last year.

Almost all the data correlated at DRAO are from the VSOP Space-VLBI mission, the majority from the VSOP Survey of the cores of radio-bright AGN, a project in which Canadian astronomers are playing a leading role. A number of VSOP general observing time experiments are also sent to DRAO to take advantage of several unique features of the Canadian SVLBI correlator, namely the ability to ‘‘fast-dump’’ correlation coefficients up to a rate of 1 kHz, useful for pulsar studies, and the spectral-resolution ‘‘zoom’’ mode that can resample spectral line data from a resolution of 15.6 kHz by a factor up to 32 times, giving a resolution of 488 Hz. The zoom mode is especially appealing for spectral line observations with VSOP since the on-board receivers have a wide bandwidth of 16 MHz.

The VSOP mission has been producing data from the spacecraft HALCA and ground-based radio telescopes on a daily basis for the past two years. However, the mission has not been without some tense moments. In particular, HALCA ran into difficulties in August 1998 when the spacecraft stopped transmitting its status, due to a problem with the on-board Data Handling Unit. In October 1998, HALCA was re-booted but failed again in November. Finally, on 1998 December 10, HALCA was successfully restored to full-working order, and following a full system check out, the normal observing schedule restarted on 1999 January 6.

The interruption to the normal observing allowed the correlator group to tackle a number of test programs on outstanding VSOP mission problems. Del Rizzo carried out a large number of correlation tests for a team at the Japanese Institute for Space and Astronautical Science attempting to understand a timing-delay problem in some HALCA data that has been apparent since the start of operations in 1997. Del Rizzo was recently cited by the mission for his significant contribution to resolving this problem.

In addition to Space VLBI experiments, the S2 correlator at DRAO is designed to support frequency-switched geodesy experiments. The Geodetic Survey Division (GSD) of Natural Resources Canada (NRCan) is testing the S2-geodesy system using the 46-m antenna at Algonquin Park, Ontario

and the Canadian Transportable VLBI antenna (CTVA), presently located at DRAO. The initial shake-down observations have been successfully completed, and the first geodesy observations are scheduled for July 1999. These observations are part of a program to establish accurate positions at over a dozen fiducial stations across Canada. These VLBI positions will represent the highest level of accuracy in the Canadian Spatial Reference System, the basis for all precision surveying in Canada.

9. FREQUENCY PROTECTION

The ongoing problems with interference from the GLONASS navigation satellites herald a situation which will become far worse over the coming decade. The rapidly growing number of new satellite-based communication, broadcasting and other services, using ''constellations'' of tens or hundreds of satellites will, if improperly managed and regulated, make ground-based radio astronomy difficult or impossible.

As Canada's provider of observing facilities for radio astronomers, the National Research Council (NRC) is playing an expanding role in preserving and protecting frequency space for radio astronomy. DRAO is the centre of NRC's effort to protect radio astronomy.

There are two main facets to this effort. Firstly, NRC works with Canadian frequency managers and with the world radio astronomical community to contribute to the regulatory and planning process. This involves attending national and international meetings, and coordination with the national community of radio astronomers. Secondly, the community must explore technical methods for increasing the immunity of current and future radio telescope systems to man-made interference and removing the effects of interference from the data.

Tapping has been recognized by the Canadian Astronomical Society as the representative for Canadian astronomy in matters concerning the radio spectrum. He is currently participating in two major efforts, a band-by-band review of the maximum levels of interference that other services are allowed to radiate into bands allocated to radio astronomy, and a plan for band allocations for radio astronomy between 71 and 275 GHz. The first item results largely from pressure from the satellite communications industry, while the second reflects growing commercial interests in higher frequencies. Tapping continues to participate in meetings of ITU Study Group 7 and Task Group 1/5.

Galt has built a monitoring receiver for signals from the IRIDIUM system of communication satellites. These satellites transmit in the range 1616.0 to 1626.5 MHz, very close to the band 1610.6 to 1613.8 MHz where radio astronomy has a primary shared allocation. This radio-astronomy band includes one of the satellite lines of OH and has been used extensively for measurements of emission from OH-IR stars and other objects. The monitor uses a horn antenna and a sensitive receiver, and has wide sky coverage. The program monitors the level of IRIDIUM transmissions and their use of the band, and aims to determine the temporal and spectral characteristics of these signals. This work is an initial step in an effort to develop techniques that will permit successful radio astronomy observations in an interference-contaminated spectral environment.

10. THE 2800-MHZ SOLAR FLUX MONITORING PROGRAM

The Solar Flux Monitoring Program, now in its 54th year, continues to provide accurate measurements of the emission from the whole Sun at 10.7 cm wavelength. This flux is a key indicator of solar activity and finds many applications in diverse fields, including solar physics, solar-terrestrial relations, space weather, atmospheric drag predictions for satellites in low-earth orbit, and radio communications, among others. It is incorporated into two indices used for modelling the upper atmosphere, the International Reference Ionosphere (IRI) and the Mass-Spectrometer-Incoherent-Scatter (MSIS) Index.

The operation of the two identical flux monitors at DRAO is largely automated, from data acquisition through to data distribution. The distribution of data in monthly, mailed reports will continue for at least one more year, but users are being encouraged to access the data via FAX, e-mail or from the DRAO web site.

Queries regarding the Solar Flux Program should be addressed to Tapping (e-mail Ken.Tapping@hia.nrc.ca).

11. RESEARCH ACTIVITIES

11.1 Interstellar Medium

Knee and Wallace have been searching the data from the CGPS to probe the relationship between star formation in molecular clouds and the atomic component of these regions. They have catalogued a large number of filamentary, streamer- or cone-like H I structures which in many cases appear to be associated with star-forming molecular clouds. In some cases, the velocity shift between the molecular gas and the streaming H I is astonishingly large, many tens of kilometres per second. These may be examples of regions forming intermediate mass stars with substantial stellar winds; the stars are not massive enough to photoionize molecular gas, but instead photodissociate and accelerate it in the form of very elongated structures. The formation of streamer-type H I structures in star forming regions may have consequences for the observed filamentary structure of the general H I interstellar medium.

The best studied as yet of such H I flows is a multiple streamer or cone emanating from a hitherto unknown star-forming molecular cloud in the Perseus Arm some 2.2 kpc distant. Several hundred solar masses of H I are moving at a few kilometres per second in enormous 50 pc long streamers from a compact (a few pc) elongated molecular cloud containing about 100 solar masses. Remarkably, the probable driving star of this flow, a luminous B-type star, has been identified. A combination of photodissociation and wind entrainment of gas appears in quantitative terms to be capable of creating the observed flow over a time of order ten million years, comparable to the star-forming lifetimes of typical molecular clouds. The H I streamers thus appear to be remarkably long-lived.

11.2 Polarization of Galactic Emission

CGPS images of the radio emission at 1420 MHz show a profusion of polarized features which have no counterpart in total intensity. These features arise when smoothly distributed background Galactic synchrotron emission suffers Faraday rotation in an ionized medium threaded by a magnetic field. The interferometer is not sensitive to the broad, smooth total intensity of the emission, but the fine structure in the ionization, and particularly in the magnetic field, creates fine structure to which the cross-polarized channels of the interferometer respond. The observations are valuable for the information they give on this ''Faraday screen.'' The polarimeter has very high sensitivity to ionized gas (emission measure as low as 1 cm^{-6}pc), and the data can yield valuable measurements of the magnetic field strength.

The first papers analyzing this phenomenon in the CGPS data were published in the last year. In a publication in *Nature* (Gray *et al.* 1998), a peculiar polarization-angle feature is described; it is about 2deg in size and coincides with the W 5 H II region. This is interpreted as an inter-arm enhancement of electron density, although its origin is unknown. Its presence provides a challenge for theories of the ISM, which do not currently predict features of this type. In a second paper in the Astrophysical Journal (Gray *et al.* 1999) other polarization structures in the W 3/W 4/W 5/HB 3 complex are analyzed. Depolarization arises from the very high rotation measures and rotation-measure gradients in the H II regions themselves. An extended low-density ionized halo around the H II region W 4 is detected, and a magnetic field of 20μG is measured at the inner boundary of the W 4 halo.

Gray has also been collaborating with Peracaula (postdoc), Brown (Ph.D. student) and Taylor (all three from U. Calgary) on issues related to the reduction and interpretation of CGPS polarization data. They have mapped the instrumental polarization across the field of the Synthesis Telescope, and have used this information to correct images. Mosaiced polarization images many degrees in extent, with arcminute resolution, have been prepared. Faraday rotation images, using data from the four individual continuum bands of the telescope, are also being generated. Brown is working on Faraday-rotation effects in thermal filaments. Brown and Taylor (U. Calgary) and Dewdney are using Faraday rotation of small-diameter sources seen through the Galactic plane to derive information on the orientation of the Galactic magnetic field; very few studies have been made at the extremely low latitudes being considered in this work.

11.3 Star Formation

Knee and Sandell (NRAO) are making large-scale maps of the submillimetre dust continuum emission in the NGC 1333 star-formation region using SCUBA on the JCMT. At present they have obtained 9′ by 14′ maps in the 850-μm and 450-μm bands. In addition to revealing the outflow-driven multiple-cavity structure of the cloud, several new submillimetre protostellar objects have been discovered. The youngest stellar objects in the cloud show a distinct tendency to cluster. Comparison between the properties of the submillimetre sources and their molecular outflows should shed light on the evolutionary status of the objects and also on how the high level of outflow activity in the cloud ''feeds back'' to modify the star-formation activity.

Purton and Matthews (JCMT Group) are analysing DRAO Synthesis Telescope H I data for the star-forming region NGC 7129. Tentative results suggest the presence of a compact photo-dissociation region, and an expanding H I shell.

Knee, as part of a large consortium of HIA and other Canadian astronomers, has embarked on a large program of JCMT SCUBA submillimetre and molecular spectral line mapping of extended regions of nearby star formation regions such as Taurus, ρ Ophiuchi, and Orion. The advent of SCUBA allows for the first time systematic and unbiassed mapping of the dust distribution inside molecular star forming regions; this along with complementary spectral line maps are expected to provide a wealth of new information on the structure, dynamics, and star formation activity in molecular clouds. One highlight of this programme is the discovery of intriguing filamentary and arc-like dust structures in the ρ Ophiuchi cloud, as well as a previously undetected far-infrared point source, probably a very young protostellar object.

Knee and collaborators have been investigating the physical properties of low-mass pre-protostellar molecular cores using observations from the ISO satellite. The main aim of the programme is to find evidence for protostellar activity and/or collapse from far-infrared (100 and 200 μm) imaging of Bok globules using the ISOPHOT imaging array. These observations have for the first time detected and resolved very cold dust emission from a number of globules. The coldest dust (traced by 200 μm emission) correlates much more closely with optical obscuration and is much more spatially peaked than the 100 μm emission. This suggests that the 200 μm emission is a much better probe of the mass distribution of cold globules than the 100 μm emission which suffers from confusion along the line of sight.

11.4 Non-thermal emission in WR stars

Dougherty has continued work on non-thermal radio emission from Wolf-Rayet systems in collaboration with Williams (Royal Observatory, Edinburgh). A high percentage of the WR stars exhibiting non-thermal emission are in binary systems, where the emission is thought to arise in a wind-collision zone where the stellar winds of the WR star and a massive companion interact.

In collaboration with de Bruyn (NFRA), van der Hucht (SRON Utrecht) and Setia-Gunawan (Groningen), VLBI observations have been obtained to probe the structure of the non-thermal emission region in WR 146. Also in WR 146, the stellar winds of both the WR star and the OB companion have been detected at 22 GHz with the VLA. The parameters of the two winds can now be deduced independently of distance, a very uncertain parameter.

With Chapman (ATNF), Moffat (Montreal), and Leitherer (STSCI) AT observations of the short period WC6+O8.5 binary WR11 reveal that non-thermal electrons from deep within the stellar wind envelope may be escaping to large radii along the contact discontinuity between the two stellar

winds. High temporal resolution observations with the AT throughout the orbit have been obtained to pursue this possibility.

11.5 B[e] stars

Dougherty, in conjunction with Clark (Sussex), Waters and Fender (Amsterdam), has made radio observations of the cluster Wd1 in Ara which reveal a very bright, extended radio nebula around the B[e] star Ara C. It is suggested that this emission arises in a stellar wind from the B[e] star and a relatively young detached shell. High sensitivity observations of the Wd1 cluster reveal a number of non-thermal radio sources associated with super and hyper-giants in the cluster. These are unexpected and apparently unique.

11.6 Supernova Remnants

The Cygnus Loop is a relatively nearby supernova remnant with structure thought to be determined by the details of the interstellar cavity into which the remnant is expanding. Leahy (U. Calgary) and Roger are examining the H I emission in three mosaiced fields observed with the DRAO Synthesis Telescope to search for evidence of interactions of the SNR shock with the surrounding neutral gas. Comparisons of X-ray, far-infrared, and radio continuum emission with the H I indicate a number of features with evidence of cavity wall interactions. Estimates of the atomic gas density decrement in various parts of the cavity interior have also been made. Similar studies are planned for the SNR IC 443 using observations already completed.

Wallace, Landecker, Taylor and Kalberla (U. Bonn), using the DRAO Synthesis Telescope and the Effelsberg 100-m radio telescope, have studied the H I around the Crab Nebula. The Effelsberg data, which cover a 4deg $\times$ 4deg area, indicate that the Crab Nebula lies in a low-density region of the ISM, while the higher-resolution DRAO data show no evidence of H I which might be interacting with the SNR.

Landecker, Routledge (U. Alberta), Reynolds and Borkowski (N. Carolina State U.), Smegal (SETI Inst.) and Seward (Center for Astrophys.) have observed the SNR DA530 using both the DRAO Synthesis Telescope and ROSAT. The radio appearance of the remnant suggests this is a very ordinary SNR. However, the X-ray emission is extremely weak, and only non-equilibrium shock models can give an interpretation of the observed X-ray emission that is consistent with reasonable parameters for the supernova explosion. The H I observations show that the remnant lies within a shell of atomic gas, probably a bubble formed by stellar winds, and the X-ray models suggest an extremely low ambient density, consistent with this interpretation. The estimated distance is 3.5 kpc. The extremely low density has led to the weak X-ray emission, and has also resulted in slow evolution, so that the remnant, although it is about 5000 years old, is only now entering the adiabatic phase of its evolution. Compared to SN1006, which has a similar size, radio brightness and morphology, the ratio of radio to X-ray flux is 100 times higher, and the efficiency of generation of radio synchrotron emission (about 0.4%) is higher than that of some historical SNRs. DA530 joins a small group of SNRs at high galactic latitudes with unusual features.

11.7 Low-Frequency Galactic Radio Emission

Roger and Landecker, together with Swerdlyk, have brought to completion a project of long standing, the mapping of the Galactic radio emission using the 22-MHz telescope which operated at DRAO in the 1960s and 70s. C.H. Costain, who died in 1989, was centrally involved in this work. The images cover all right ascensions between declinations $-28°$ and $+80°$, about 73% of the sky. The resolution of the telescope is $1.1° \times 1.7°$ secant(zenith angle). The maps show the large-scale features of the emission from the Galaxy, including the thick non-thermal disk, the North Polar Spur and absorption due to discrete H II regions and to an extended band of thermal electrons within 40° of the Galactic centre. Comparison with data at 408 MHz shows that the brightness-temperature spectral index of most of the Galactic emission lies between 2.40 and 2.55. A region along the outer rim of the North Polar Spur shows a slightly higher spectral index than its surroundings. The mean synchrotron emissivity at 22 MHz deduced from the measured emission towards seven extended opaque H II regions is $\sim 1.5 \times 10^{-40}\mathrm{Wm}^{-3}\mathrm{Hz}^{-1}\mathrm{sr}^{-1}$; this is slightly higher than values obtained in previous estimates.

11.8 Perseus Arm Superbubble

Wallace, Dewdney and Landecker have discovered a superbubble in the Perseus Arm of the Galaxy, using the CGPS data. It is about $5° \times 8°$ in size (physical size 200×300 pc). The shell which defines the boundary of the superbubble can be seen very clearly in H I, ^{12}CO and infrared data from the Survey. The quantities of atomic and molecular gas in the shell are about 3×10^5 and 10^5 solar masses respectively. There is evidence of many young stellar objects in the shell from infrared data. The formation of the supershell may have led in turn to the formation of molecular gas and then to the formation of new stars. The structure of the H I shell is irregular, implying that it is being disrupted by stellar winds and supernovae arising from new, massive stars formed at its periphery.

11.9 Solar Research

Solar research at DRAO, conducted by Tapping, is focussed on the nature and origins of the slowly varying component of solar activity. The research has two facets: models for the sources and emission processes, and making long-term observations of the distribution of emission over the solar disk. Collaborators include Burke (McDonald Dettweiler, Vancouver), Harvey (NSO), and Zwaan (U. Utrecht). A key component of this work is the ability of the DRAO Synthesis Telescope to provide full-disk images of the Sun with arcminute resolution.

Since 1992, images have been obtained at every solstice (except 1997). The sources at 21-cm wavelength can be accounted for in terms of free-free thermal emission from trapped plasma in loops overlying the plage bodies of active regions. The brightest sources occur in the regions which

have the most complex magnetic structure, at the point in their evolution where they are reaching maximum size. This suggests that the plasma traps decay and require dynamism to sustain or replace them. The mapping program will be continued until at least the next solar maximum.

The demonstrated relationship between solar activity and terrestrial phenomena such as global warming underlines the importance of considering the Sun in addressing environmental questions. One project at DRAO is aimed at examining the relationship between solar activity, as indicated by the 10.7-cm flux index and short-term variations in the Sun's energy output.

12. GRADUATE STUDENTS

Thorsley is working on extending the holography efforts pioneered by summer and co-op students working with Gray over the past three years. A major limitation of previous efforts was that celestial sources are too weak to adequately probe the outer portions of the patterns of the Synthesis Telescope antennas in a reasonable time, so Thorsley has built a transmitter to operate from local hill-tops, devising observing strategies to make the necessary observations at low elevation in the near-field of the array, and implementing iterative methods for reconstructing the far-field pattern from incomplete near-field measurements.

Belostotski's project is related to the LO system of the proposed Square Kilometre Array (SKA) telescope. He has designed a distance-measurement system which will determine the separation of the apex of the reflector and the airborne focus package to high precision. The system simultaneously supplies the signals from which the coherent local oscillator signals for the telescope can be derived.

Del Rizzo, who is enrolled in the M.Sc. program at York University where he is supervised by N. Bartel, is studying pulsar emission using VLBI observations.

Parchomchuk is pursuing her M.Sc. degree through the Open University (London). The focus of her course work has been computer-human communication, and she has embarked upon a thesis project developing a user interface for data from the Canadian Galactic Plane Survey when it becomes public through the CADC.

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