

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

This report covers the period October 1994 to October 1995.

### 1. PERSONNEL

The professional staff of the Observatory comprises T.L. Landecker (Director), R.S. Roger (Deputy Director), P.E. Dewdney, L.A. Higgs, G.J. Hovey, J.D. Lacey, C.R. Purton, K.F. Tapping, A.G. Willis and W. Wyslouzil. P.E. Dewdney is the Co-ordinator of Future Radio Telescope Initiatives for the Herzberg Institute. G.J. Hovey is on study leave at the University of British Columbia, and his position is being filled by D.R. Karpa. C.R. Purton returned in July 1995 from a three-year secondment to the James Clerk Maxwell Telescope (JCMT) Group of the Herzberg Institute in Hawaii. A.D. Gray is a Research Associate. S.M. Dougherty (Research Associate, U. Calgary) began work at DRAO in September 1995 on the Galactic Plane Survey. C. Rogers and S. Sukumar left DRAO in March 1995. G. Moriarty-Schieven left after three years as Research Associate to take up an appointment with the Research Corporation of the University of Hawaii.

T. Burgess, B.R. Carlson and D.D. Wellborn are working on the Space VLBI correlator project (supported by the Canadian Space Agency), and W. T. Petrachenko (Natural Resources Canada, Ottawa) is seconded to the project. J.A. Galt is a Guest Worker. K.F. Tapping completed his Ph.D. at U. Utrecht in June 1995. D. Lyder (Ph.D candidate, U. Victoria) is doing his thesis research at the Observatory and R.J. Smegal (Ph.D. candidate, U. Alberta) completed his degree in April 1995.

J.F. Vaneldik (University of Alberta) spent the summer of 1995 at DRAO. A.R. Taylor (University of Calgary) and H.J. Wendker (Hamburg University) made lengthy visits. Zhang Xizhen and Zheng Yijia from the Beijing Astronomical Observatory, China, spent six and four months at DRAO respectively, under the China-Canada exchange agreement.

### 2. INVOLVEMENT IN THE SCIENTIFIC COMMUNITY

L.A. Higgs was the President (1992-1994) of the Canadian Astronomical Society (CAS), and continues to serve on its Board as Past-President. He also serves the CAS as chair of a committee which allocates travel grants to scientists from the Former Soviet Union, and as a member of the Radio Astronomy Committee. C.R. Purton is a member of the Board of Directors of the CAS. R.S. Roger is the Canadian radio astronomy representative on the Radio-Communication Study Group 7 of the International Telecommunications Union with responsibility for spectrum management for radio astronomy in Canada. K.F. Tapping is the Chairman for Canada of Commission J (Radio Astronomy) of the International Radio Science Union (URSI).

P.E. Dewdney is on the Science Councils of both the RadioAstron and the VSOP Space VLBI projects, and is a member of the Working Group on Global VLBI of URSI Commission J. L.A. 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. K.F. Tapping is participating in the Working Group on Proxy Measures of Solar Activity. G.H. Moriarty-Schieven was Chair of the Canadian Time Allocation Group for the JCMT for 1994-95, and L.A. Higgs is now a member of that group. P.E. Dewdney is a member of the Canadian Science Team for the ODIN satellite-borne sub-millimetre telescope, a joint project of Sweden, Canada and France.

Three staff members are Adjunct Professors at Canadian universities, T.L. Landecker and A.G. Willis at U. Alberta, and P.E. Dewdney at U. Calgary. T.L. Landecker is a member of the Board of Governors of Okanagan University College.

### 3. TELESCOPES

DRAO is operated as a National Facility. Two radio telescopes, the Synthesis Telescope and the 26-m Telescope, are available to outside users. The Solar Radio Astronomy Program provides data to a worldwide community of users as a scientific service. A newsletter concerning new developments of DRAO telescopes and software is now being published at six-month intervals; it is available on request. Information about DRAO is available on the World-Wide Web at "<http://www.drao.nrc.ca>".

### 4. 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 ( $2^\circ$  and  $8^\circ$  at 1420 and 408 MHz) and good angular resolution (1.0 and 3.5 arcmin at 1420 and 408 MHz) and makes it well suited for studies of the interstellar medium in our own 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 a 256-channel spectrometer to suit galactic and extragalactic observations; baseline coverage is complete 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.

An expansion program, which began in 1985, was completed in 1992. The number of antennas in the Synthesis Telescope was increased from four to seven. The expansion

has resulted in an increase in sensitivity and image quality (dynamic range) and a threefold increase in speed without changing field of view or angular resolution. A 256-channel spectrometer was completed in March 1995. Polarimetry at 1420 MHz is now available. Solar imaging is also possible.

The bulk of the observing time on the telescope is now devoted to the Galactic Plane Survey (see below); applications for other observations are also accepted but only a few can be scheduled. Proposals for Synthesis Telescope observations should be addressed to C.R. Purton (e-mail "crp\@drao.nrc.ca"); proposal deadlines are October 15 and April 15. A data reduction *cookbook* is available.

## 5. 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. 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  $\sim 16\%$ . Proposals for use of the telescope should be addressed to the Director of the Observatory (e-mail "director\@drao.nrc.ca").

## 6. THE DRAO GALACTIC PLANE SURVEY

Taylor (U. Calgary) is leading a consortium of 33 scientists from Canada and other countries who are carrying out a new panoramic imaging of the continuum and H I emission in the galactic plane using the DRAO Synthesis Telescope. Observations began in March 1995, with the intent of mapping completely a strip  $9.3^\circ$  wide in latitude along the plane from  $l = 75^\circ$  to  $l = 145^\circ$ . Images of individual fields will be assembled into a large mosaic image, which will eventually cover the entire survey region. After a proprietary period, the survey data will be made available to the worldwide astronomy community through the Canadian Astronomical Data Centre, operated by HIA in Victoria. Scientific analysis of the Galactic Plane Survey data in Canadian universities is being supported by a grant from the Natural Sciences and Engineering Research Council.

DRAO observations will be complemented by data in other wavebands made available by members of the consortium. These data include high-resolution IRAS data, CO images from a new FCRAO survey, 151 MHz continuum images from Cambridge University, and 232 MHz and 327 MHz continuum images from the Miyun Synthesis Telescope (Beijing Astronomical Observatory). The total of these data will form the basis for a wide variety of studies of the "ecosystem" of the Milky Way. Enquiries about the survey should be addressed to Taylor (e-mail "russ\@bear.ras.ucalgary.ca") or Dewdney (e-mail "ped\@drao.nrc.ca").

Normandeau (graduate student, U. Calgary), working with Taylor and Dewdney designed and carried out a pilot study for the survey involving observations of ten fields covering an area  $8^\circ \times 6^\circ$  which contains the W3/W4/W5/HB3 galactic complex near  $l = 135^\circ$ . This is a region of active star formation where the interaction between the various ma-

ior objects is not well understood. Observations of these ten fields were completed in 1993. Efficient observing techniques were developed in the course of these observations, and data processing techniques are being tested on the data.

Regular observations of Galactic Plane Survey fields began in March 1995.

## 7. COMPUTER SYSTEM

The computer system is built around three IBM RS/6000/550 computers together with two 320H workstations and an SGI Indigo 2, all connected by a local area network with the VMS computers which operate the Observatory's telescopes. Virtually all data reduction programs run under *unix*.

Visualization software is available for working with spectral-line data cubes. *X-windows* software for the production of videos has been developed; this medium is well-suited for the display of H I data cubes by animation through velocity channels. Special techniques have been developed for the animated display of merged data sets that combine H I, CO, IR, and radio continuum.

An export package of DRAO software is available; it is principally useful for processing data from the DRAO telescopes, but includes general-purpose plotting and data manipulation programs. The combination of single-antenna data with synthesis images is possible with this software. The package includes 76 different programs, but excludes (for practical reasons) programs related to data acquisition and manipulation of visibility data. It is supported, within the limits of available personnel, on IBM RS6000 (under AIX), SUN (under SunOS) and SGI (under IRIX) computers. Some programs require an IDL licence. Direct enquiries to L.A. Higgs (e-mail "lah\@drao.nrc.ca")

## 8. SPACE VLBI

Canadian collaboration in Japanese and Russian Space VLBI missions is continuing, funded by the Canadian Space Agency. P.E. Dewdney is the Canadian Principal Investigator. The Canadian contributions to this international partnership are being made by DRAO, where the correlator is being built, by the Institute for Space and Terrestrial Science (ISTS) of York University where tape recorders have been developed, and by the University of Calgary where support of scientific users will take place. The Japanese VSOP satellite, to be launched in September 1996, will be the first dedicated Space VLBI satellite.

The correlator system has demonstrated the capability to process ground-based VLBI data on a single baseline, and plans are in place to construct a six-station correlator. Deployment of recorders at appropriate ground telescopes and satellite-tracking stations is now being planned. Enquiries about the correlator system or the program should be directed to P.E. Dewdney (e-mail "ped\@drao.nrc.ca").

## 9. AIPS++

DRAO is a partner in the AIPS++ project, the development led by the National Radio Astronomy Observatory of a new image processing system for radio astronomy. A.G. Willis is contributing to the development of software.

## 10. IMAGE PROCESSING

The Synthesis Telescope employs small antennas, which confer a wide field of view and permit observations of extended structures. However, the small antennas have relatively high sidelobe responses, especially at 408 MHz where the antenna diameter is only  $12 \lambda$ . Imaging in the vicinity of strong sources, such as Cass A and Cyg A, is difficult because of emission received in the sidelobes, and dynamic range problems arise in such areas. Because of differences between individual antennas, standard image processing techniques cannot remove these problems. Willis and Higgs have developed a simple procedure to overcome such effects by calculating the response of the telescope to a model of the source (derived from observations of high angular resolution) and fitting model visibilities to observed visibilities for each interferometer pair. Willis is testing methods to correct other effects arising from differences between antennas.

## 11. RESEARCH WITH THE 26-METRE TELESCOPE

The 26-m Telescope will be used to provide information on large H I structures in the area covered by the Galactic Plane Survey. The information will be incorporated into Synthesis Telescope images (with suitable filtering) to ensure that all angular scales are truly represented in the Survey images. Galt and Tapping are carrying out this program. The relative calibration of the two telescopes will be carefully investigated, and the 26-m Telescope data will be corrected for sidelobe contributions. A wide area of the galactic plane will be sampled at an interval of about 0.3 beamwidths.

In addition the 26-m Telescope is used for a wide variety of OH and H I investigations, and more recently for methanol maser observations. Galt, with Feldman and Polanen (HIA), have searched a number of star-forming regions for methanol maser emission in the 6.6 GHz line. Eight new sources have been discovered and known sources are being monitored to search for intensity and polarization changes.

## 12. A GALACTIC CHIMNEY

Normandeau and Taylor (U. Calgary) and Dewdney have discovered a galactic chimney, a conduit from the disk of the Galaxy to its halo produced by the integrated effect of many supernovae and/or stellar winds. The discovery was made in the pilot study for the Galactic Plane Survey. The chimney has apparently been formed by the stars of the open cluster OCl 352 which lies within the W4 H II region in the Persues Arm. Filaments of H I and a related CO cloud within the chimney present clear evidence of the outflow.

## 13. POLARIZATION OF THE GALACTIC BACKGROUND EMISSION

As a result of the work of R.J. Smegal, who completed his Ph.D. at U. Alberta in April 1995, polarimetry at 1420 MHz is now routinely done with the Synthesis Telescope (Smegal *et al.* 1995).

Gray, Landecker, Dewdney and Willis, together with Normandeau and Taylor (U. Calgary) are analysing 1420 MHz polarization data from the Galactic Plane Survey pilot project (the W3/W4/W5 region). Several new phenomena

have been identified through their polarization signatures. Extended polarization structures, with sizes up to several degrees, were observed: some have little fine-scale structure, while others have detail to the resolution limit of the telescope. These are apparently produced by Faraday rotation within the interstellar medium acting on the polarized background emission from the Galaxy. The fine-scale structure is shown to lie in the Perseus Arm, and the entire path length through the arm is required to generate the observed Faraday rotation. Such observations serve to probe the ISM, giving information on the distribution of thermal electrons and magnetic fields, and the impact of H II regions and other structures on these components.

Gray and Landecker have made polarization observations of a number of widely separated fields. Fine scale polarization structure is strongest at low galactic latitudes. The correlation of the polarization structures with other ISM constituents is being investigated. In a related investigation, Gray and Landecker have observed the bright supernova remnant G78.2+2.1 to search for a possible increase in the level of diffuse polarized emission in the vicinity of SNRs.

## 14. PHOTODISSOCIATION REGIONS

Blouin and McCutcheon (UBC) with Dewdney, Roger and Purton have mapped the continuum and H I-line emission associated with the nebula Sharpless 185 which comprises two comet-shaped clouds, IC59 and IC63, illuminated by the star  $\gamma$ -Cas. These synthesis telescope observations are compared with far-infrared, optical and CO maps of the region to determine the photochemical evolution of the gas components with respect to ionization, dissociation and thermal balance. The observations in H I and far-IR have also yielded a new example of a dissociating star unrelated to the  $\gamma$ -Cas complex. Blouin's M.Sc. thesis (UBC, 1995) describes much of this work in detail.

## 15. H II REGIONS

Some of the first fields observed in the Galactic Plane Survey are those surrounding the nearby (750 pc) H II region IC1396, which contains a number of dense cometary globules. Moriarty-Schieven together with Xie (U. Maryland), and Patel (CfA) have found that some of the globules have caps of ionized gas (observed by their radio continuum emission) on the side facing the ionizing star, and H I "tails" extending as much as 8 pc. The tails are probably material ablated from the globules by photoionization or dissociation and blown away from the globule by the wind from the central star.

## 16. THE ENVIRONS OF WOLF-RAYET STARS

Arnal (Instituto Argentina de Radioastronomia), St-Louis (U. Montreal), and Roger have used the Synthesis Telescope to observe a number of fields centred on Wolf-Rayet stars where there is evidence that the stars have created cavities and shells in the interstellar medium. This study has particular relevance to the morphology of supernova remnants since WR stars are believed to be direct progenitors of type Ib

supernovae and it is likely that the appearance of the remnants will be determined largely by the stellar-modified environments.

Purton, Dewdney and Lozinskaya (Sternberg Astron. Inst.) have made VLA continuum observations of the WO star WR142. The WO stars are the most advanced massive stars, probably a few thousand years before a supernova explosion. Of the three WO stars known in the Galaxy, WR142 is the closest.

Arnal (Argentina) and Rogers have studied the H I surrounding two WR stars, WR 140 and WR 3. The H I data obtained with the Synthesis Telescope reveal a much more complex and intriguing picture of shell structure than that first detected with the Effelsberg 100m Telescope. The new observations show dual-lobe structures offset from the stellar positions. The incidence of H I shells seen about WR stars is too high to be coincidental, and complex structures such as these will challenge theoretical explanations based on symmetrical stellar winds.

Dougherty, with Williams (ROE), Bode (John Moores U., Liverpool) and Davis (NRAL) have observed WR146 with the MERLIN telescope. The emission is resolved into two components separated by 116 milliarcsec. A thermal component arises from the stellar wind of the star, while a non-thermal component is generated by interaction of the wind with that of a companion identified in the optical spectrum of the system.

## 17. CIRCUM-PROTOSTELLAR ENVIRONMENTS

Moriarty-Schieven has continued a collaborative program of millimetre, sub-millimetre and far-infrared observations and analysis of a complete sample of low-mass protostars in Taurus.

Among the highlights was the detection of a sub-mm continuum “flare” from GG Tau, a T Tauri-type young stellar object (with Butner (DTM-CIW)). They detected a  $\sim 50\%$  increase in the luminosity of GG Tau at sub-mm wavelengths, and only a small increase at mm wavelengths, probably due to a sudden increase in the temperature of the inner circumstellar disk, possibly caused by a massive accretion event.

Moriarty-Schieven, Butner (DTM-CIW) and Wannier (JPL) have been modelling the spectral energy distributions of a large sample of objects in order to set limits on temperature and density gradients in circumstellar envelopes, to estimate the overall dust column density, and to compare with theoretical calculations of low-mass star formation. They have found that the mm/sub-mm spectral energy distributions of young, embedded protostars are significantly different from those of more evolved, visible young stellar objects. This difference is due either to the growth of dust grains in the circumstellar disk and envelope, or to the growth of the disk itself at the expense of the envelope.

Moriarty-Schieven, with Butner (DTM-CIW), Ressler (JPL) and Werner (JPL) are continuing molecular spectral studies of the circum-protostellar envelopes. Formaldehyde  $J=3-2$  K-ladder transitions have been used to derive envelope kinetic temperatures, which in turn have been used to constrain modelling of multi-transition CS observations, in

order to derive envelope density and mass. Moriarty-Schieven, Wannier (JPL), Mangum (U Arizona), Keene (Caltech), Tamura (NAO Tokyo), and Olmsted (U Victoria)) have found that CS is not a good tracer of circumstellar disks. L1551NE, a deeply embedded object near L1551-IRS5 which is potentially an extremely young “Class 0” protostar, was found to possess the CS spectral signature of a collapsing envelope, and to have a bipolar molecular outflow.

## 18. THE ATOMIC/MOLECULAR INTERFACE

Moriarty-Schieven, Wannier (JPL) and Andersson (JPL) have made multi-field maps with the DRAO Synthesis Telescope of the H I gas associated with the L1457 molecular cloud and the Perseus B1-B3-B5 molecular cloud complex. These clouds are nearby ( $\sim 65$  pc and  $\sim 300-400$  pc respectively) and well out of the galactic plane ( $b \sim -30^\circ$  and  $-18^\circ$  resp.), allowing observation and modelling of the molecular/atomic interface region of relatively quiescent molecular clouds. Both cloud regions have extended, dynamic atomic halos.

L1457 is the closest known molecular cloud. Moriarty-Schieven, Wannier (JPL) and Andersson (JPL) have mapped the region in H I and CO at  $2'$  resolution, and a large surrounding region in H I at  $36'$  resolution (with the DRAO 26-m Telescope). There is an extended component of atomic gas, clearly associated with the molecular complex and comparable to it in total mass. The H I structure at small scales consists largely of long, narrow filaments up to  $4^\circ$  in length. The structure at large and small scales suggests that the region has recently been compressed, perhaps by a supernova explosion. The compression may have triggered the formation of the molecular cloud.

Sage (Nature), Mooney (MPIfR) and Roger are exploring the atomic transition zones on the peripheries of molecular clouds which are well observed in the emission from isotopes of CO and CS. The initial study uses Synthesis Telescope observations of two warm clouds with relatively high efficiencies of star formation, but whose inferred  $H_2$  masses differ by more than a factor of ten. The work is directed towards several questions, including determining the extent of the cloud boundaries which may be molecular but which are not effectively traced by CO emission.

## 19. ABUNDANCES IN THE INTERSTELLAR MEDIUM

Wannier (JPL), Moriarty-Schieven, and Schloerb (FCRAO) have mapped the  $C^{17}O$  and  $C^{18}O$  abundance ratio towards three nearby molecular clouds, B335, L134N and  $\rho$  Oph, two of which are active star-forming regions. They have found significant abundance variations in the  $\rho$  Oph cloud. This is interpreted as a variability in the  $^{17}O/^{18}O$  ratio on solar mass scales. This finding has implications for our understanding of the evolution of abundances in the interstellar medium. The two isotopes are produced by separate processes in stellar interiors.

## 20. SUPERNOVA REMNANTS

Leahy (U. Calgary), Roger and Ballantyne (U. Victoria) have made new high resolution images of the Cygnus Loop

in both continuum emission at 1.4 GHz and in the 21-cm H I spectral line. The continuum image, mosaiced from 3 separate Synthesis Telescope fields, is of higher resolution and sensitivity than any previous complete radio image, and reveals hitherto unknown radio filaments. A high degree of polarization (up to 40%) is found in ordered regions of the southern breakout feature of the SNR, and a relatively low polarized fraction is found in the bright northern features.

Pineault (U. Laval), Landecker, Reich (MPIfR, Bonn) and Swerdlyk (U. Guelph) have made a new image of CTA1. The observations confirm that this is a breakout remnant. The low-intensity breakout region, hinted at in earlier DRAO observations, is now seen clearly due to the enhanced sensitivity. Comparison of 1420 and 408 MHz images indicates that the spectral index in the breakout region is significantly steeper. This is confirmed by measurements of integrated flux density at low frequencies.

Landecker and Willis, working with Reich and Fürst (MPIfR, Bonn) and Aschenbach and Egger (MPIfEP, Garching) have used the Synthesis Telescope to observe G65.2+5.7, a large SNR ( $4.2^\circ \times 3.3^\circ$ ) which is very bright optically (in the [O III] line) and in soft X-rays, but faint at radio wavelengths. Optical and radio filaments coincide within the resolution (0.005 of the diameter of the remnant). Radio observations have been compared with new X-ray data.

Landecker and Higgs, working with Zhang and Zheng (Beijing Astron. Obs.) have studied the low-frequency spectrum of the unusual SNR G76.9+1.0, combining observations at 232 MHz (from the Miyun Synthesis Telescope) with higher frequency observations from DRAO and from other telescopes. The object is believed to be a filled-centre SNR; its spectrum is flat below about 1 GHz, and steepens above that frequency. Other filled-centre SNRs exhibit a similar break in their spectra, but at much higher frequencies. G76.9+1.0 is thought to be the first example of a very old filled-centre SNR. Other objects like it may exist, but may have been mistaken for extragalactic radio sources.

Wallace (graduate student U. Calgary), Landecker, Taylor (U. Calgary) and Pineault (U. Laval) have observed various constituents of the ISM around three filled-centre SNRs. G74.9+1.2 (CTB 87) was observed with the DRAO Synthesis Telescope. The SNR lies on the inner edge of a circular shell of H I which appears to have impeded the expansion of the blast wave. The failure to detect a steep-spectrum continuum shell around the SNR strongly suggests that the SN explosion had less than the usual energy.

Wallace has mapped the H I around the Crab Nebula in collaboration with Kalberla (U. Bonn), Landecker and Taylor using the Effelsberg 100-m Telescope. The H I in the immediate environs of the Crab Nebula has been mapped in greater detail with the Synthesis Telescope.

Smegal (graduate student, U. Alberta), Landecker, and Routledge and Vaneldik (U. Alberta) have observed the 1420 MHz emission from the highly polarized SNR DA530. This is the first observation using the DRAO Synthesis Telescope as a polarimeter, and uses the calibration techniques developed by Smegal.

## 21. EXTRAGALACTIC ASTRONOMY

Carignan (U. Montreal) and Purton have observed H I emission from the dwarf irregular galaxy DDO154. Observations with the DRAO Synthesis Telescope and the 26-m Telescope have measured emission from extended structure missed with the VLA in D-configuration (amounting to  $\sim 30\%$  of the total). By combining VLA and DRAO data the rotation curve of the galaxy can be extended beyond the turnover point, establishing the mass of the system, which is more than 90% dark matter, as  $\sim 3 \times 10^9 M_\odot$ . The radius of the galaxy is  $\sim 8$  kpc, about 6 optical radii.

## 22. INTERMEDIATE VELOCITY CLOUDS

Shaw, Bates, Kemp, Keenan (Queens U. Belfast), Davies (NRAL) and Roger have studied the H I in an intermediate-velocity cloud (IVC) in the foreground of the globular cluster M13 using the 76-m Lovell Telescope and the DRAO Synthesis Telescope. The IVC is found to have a two-component structure with dense cloudlets embedded in an extended diffuse component. The components are probably in pressure equilibrium. Comparisons of the high-resolution H I column densities with optical absorption lines of sodium at the same velocity yields an abundance ratio  $N(\text{Na I})/N(\text{H I})$  of  $\sim 2 \times 10^{-8}$  for the cloudlets.

## 23. JUPITER AND COMET 1993E

Sukumar monitored the emission from Jupiter during the impact of the fragments of Comet 1993e (Comet Shoemaker-Levy) on the planet. Using the Synthesis Telescope at 408 and 1420 MHz, the planet was tracked for about 6.6 hours each day during the succession of impacts in 1994 July. Comparison flux densities were obtained before the impact, and occasional measurements have been made since. Increases in flux densities at both frequencies were recorded, with a subsequent slow decline. These results imply significant changes to the Jovian magnetosphere during and after the impact. Models suggesting energization of relativistic electrons as well as hardening of the electron energy spectrum by cometary dust are broadly consistent with the observations.

## 24. THE PENTICTON 2800 MHZ SOLAR FLUX MONITORING PROGRAM

The National Research Council has been making regular, precise determinations of the total solar flux at 10.7 cm since 1946. The choice of 10.7 cm as the observing wavelength, close to the peak of the spectrum of the slowly-varying (s-) component, together with the continuity, quality and consistency of the data, have resulted in the use of this measurement worldwide as a primary index of solar activity. Since 1990 this program has been located at DRAO. The measurement, known as the Penticton 2800 MHz flux or as the 10.7cm flux, is used in its own right and as a proxy for other quantities which are more difficult to measure. The 10.7cm flux has played a pivotal role in at least 250 papers published in the last five years.

The DRAO Solar Flux Patrol comprises two independent, automated flux monitors, with automatic data distribution by

facsimile and e-mail. Software has been developed to extract flare information from the records. Enquiries about the Solar program should be directed to "solar\@drao.nrc.ca".

## 25. SOLAR ACTIVE REGIONS

Tapping is studying bright, localized sources of the s-component using observations made at 2.8 cm wavelength together with magnetograms and H $\alpha$  filtergrams. Source brightness has been compared with magnetic complexity and the evolutionary state of the host active regions. The brightest sources tend to be in regions which are growing rapidly and are magnetically complex, rather than in those which are simply large or contain large amounts of magnetic flux.

## 26. SOLAR IMAGING WITH THE DRAO SYNTHESIS TELESCOPE

To identify and budget *all* contributions to the s-component, maps of the whole solar disc with arc-minute resolution are needed. The DRAO Synthesis Telescope can map the entire disc in a single operation. However, solar variability and rotation restrict mapping time to one day and, with only one set of antenna spacings, the brightness distribution is inevitably undersampled. Observations are made only when the Sun is at declinations above  $\sim 15^\circ$ .

Burke and Tapping used the Synthesis Telescope to map the Sun in 1992 and 1993 when activity was high. Half of the s-component at 21cm originated in weak, extended emission covering large areas of the disc, roughly coinciding with areas of magnetic network. Observations in 1994, when activity was low, showed no extended emission component: the entire s-component was produced by active region sources. Tapping and Harvey (National Solar Observatory) are continuing this work, and obtained observations spaced through an entire solar rotation in 1995.

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