

# **The International Galactic Plane Survey**

## **Brief to the LRP Mid-Course Review Panel**

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### **Introduction**

The International Galactic Plane Survey (the IGPS) is creating the world's best dataset for the study of the interstellar medium (ISM) of the Milky Way, supporting scientific leadership in ISM research by Canadian scientists, and making the data accessible to the worldwide astronomical community. By using telescopes in the Northern and Southern hemispheres, the IGPS covers 90% of the stellar disk of the Galactic, and the multi-wavelength approach yields images of all the principal constituents of the ISM and provides 3-dimensional images of the neutral gaseous components. The angular resolution, of order 1 arcminute, is unprecedented in a survey of such wide coverage. The major scientific thrust is to understand the ISM and its role in the evolution of our Galaxy, and thereby to improve our comprehension of the evolution of galaxies.

The ISM of our Galaxy consists of multiple phases, neutral gas in atomic and molecular form, ionized gas, and dust grains. The whole is threaded by magnetic fields and a flux of cosmic-ray particles. The Galaxy evolves by processing its diffuse ISM through multiple generations of stars, and the ISM is both the source of the next generation and the matrix within which the physical and chemical tracers of current and past generations appear.

Our location, embedded within the ISM of the Milky Way, provides an unparalleled opportunity to view these processes "close up", but the opportunity comes with a technical challenge, to image large regions of sky with good angular resolution and excellent sensitivity to broad structure. Imaging the major components of the ISM requires observations over a range of wavelengths, primarily radio and infrared, but complemented by observations at shorter wavelengths. To sample the range of spatial scales from parsecs, characteristic of stellar phenomena, to kiloparsecs, characteristic of spiral-arm systems requires an angular resolution of about 1 arcminute coupled with coverage of a large area of the sky.

The DRAO Synthesis Telescope provides this "spatial dynamic range", and sensitivity to the atomic component (the HI line at 21 cm), the ionized and relativistic components (continuum at 21 and 74 cm), and the magnetic field (continuum polarization at 21 cm). Advances in wide-field, synthesis imaging pioneered at DRAO, including the combination of single-antenna and synthesis observations, provided the spatial dynamic range needed. Based on its experience with the telescope, a consortium of Canadian university and HIA astronomers together created the Canadian Galactic Plane Survey (CGPS) in 1994-95 and forged partnerships with a molecular-line group (FCRAO) and an infrared group (IPAC). A five-year grant for the project was awarded by NSERC under its Collaborative Special Projects program in April 1995 with Russ Taylor as Principal Investigator. The project was expanded into the

International Galactic Plane Survey in 2000, and a second 3-year grant was received from NSERC in April 2001, this time under the Collaborative Research Opportunities program.

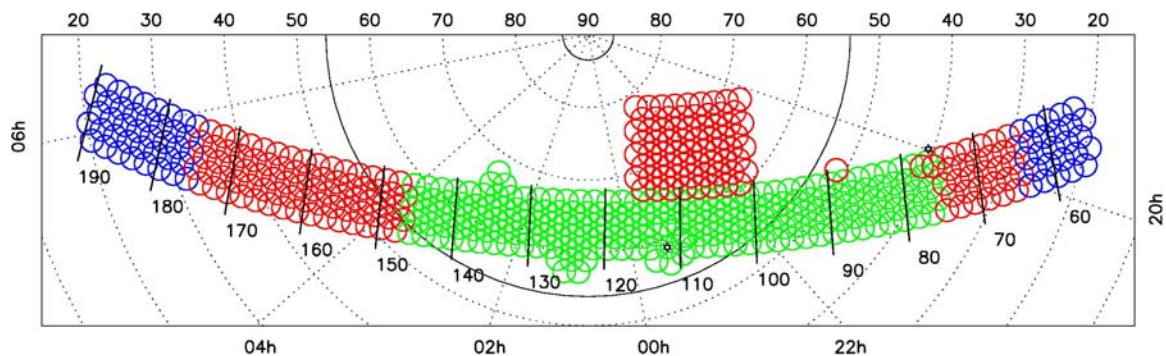
### Development of the Project to 2004

At the time of the first LRP meetings in 1998, the CGPS was well under way. The first important scientific results were in the literature, and the LRP Panel commented

*“The CGPS is an exemplary project for its scientific impact on our knowledge of the Galactic interstellar medium, the extensive collaborative links between NRC and the universities that it has fostered, and the training of a new generation of radio astronomers in this country as witnessed by the significant number of Ph.D. theses that it has spawned. The LRPP finds enthusiastic support for the Galactic Plane Survey from many astronomers and graduate students across the country”*

By 1997 imitators had begun to appear, and in the year 2000 scientists from many countries joined forces to form the International Galactic Plane Survey (IGPS), a systematic attack embracing 90% of the longitude range around the Milky Way. Led by Canada, the IGPS combines data from seven major radio telescopes (the Very Large Array, the Green Bank Telescope, the Five Colleges Radio Observatory 14-m Telescope, the Australia Telescope Compact Array, the Parkes Telescope, the DRAO Synthesis Telescope, and the Effelsberg 100-m Telescope). A new proposal to NSERC under the Collaborative Research Opportunity Program led to the award of funding from 2001 to 2004.

This report concentrates on the Canadian component of the project, the CGPS. Figure 1 shows the sky coverage of the DRAO surveys. Phase 1 (green) occupied the period 1995 to 2000. Phase 2 observations (red), now nearing completion, cover 2000 to 2004. Phase 3 (blue) is the area now proposed for the period 2004 to 2007 to complete the CGPS longitude portion of the IGPS project. Phase 3 plans also include observation to very high sensitivity of a targeted high latitude region of low HI- and dust-column density in the Galactic halo, the DRAO Planck Deep Field (not shown, but see below for details).



**Figure 1:** The area covered by the CGPS. Phase 1 (1995 to 2000) green, Phase 2 (2000 to 2004) red, Phase 3 (2004 to 2007) blue. The outer frame is labeled with equatorial co-ordinates while Galactic longitudes are indicated within the frame. The heavy curve at declination 54 degrees is the circumpolar limit at DRAO.

## **DRAO Data Acquisition, Processing, and Dissemination**

With the exception of polarimetric data, for which improvements to imaging and calibration techniques are still being researched, the observing techniques and data reduction procedures were developed during Phase 1 and have long since stabilized. Observations are easily kept on schedule. We have essentially completed observing for Phases 1 and 2, and reduction of data is easily keeping up with observing with the Synthesis Telescope. Polarimetric data are supplied to the polarization group within the IGPS consortium, but not much has been made public yet.

Complementary HI data are observed with the DRAO 26-m Telescope. This observing system is also well established. Despite delays due to mechanical problems with the 26-m telescope in 2002, as of April 2004, we have completed observations and processing for Phases 1 and 2, and have completed observations for Phase 3. Data processing for Phase 3 will be complete by the end of April, and the low-resolution data from Phases 2 and 3 will then be made public.

We have a strong collaboration with the Max-Planck-Institut für Radioastronomie in Bonn (MPI). The MPI group is providing complementary single-antenna data needed for true representation of large structures, and has completed 21-cm continuum observations of the entire Phase 1 and Phase 2 regions, including polarization, using the Effelsberg 100-m Telescope. The MPI group has developed techniques for observing wide areas of sky, and the Effelsberg data are unquestionably the best single-antenna data in the world. Processing of the polarization component of the Effelsberg survey is now being carried out in Bonn.

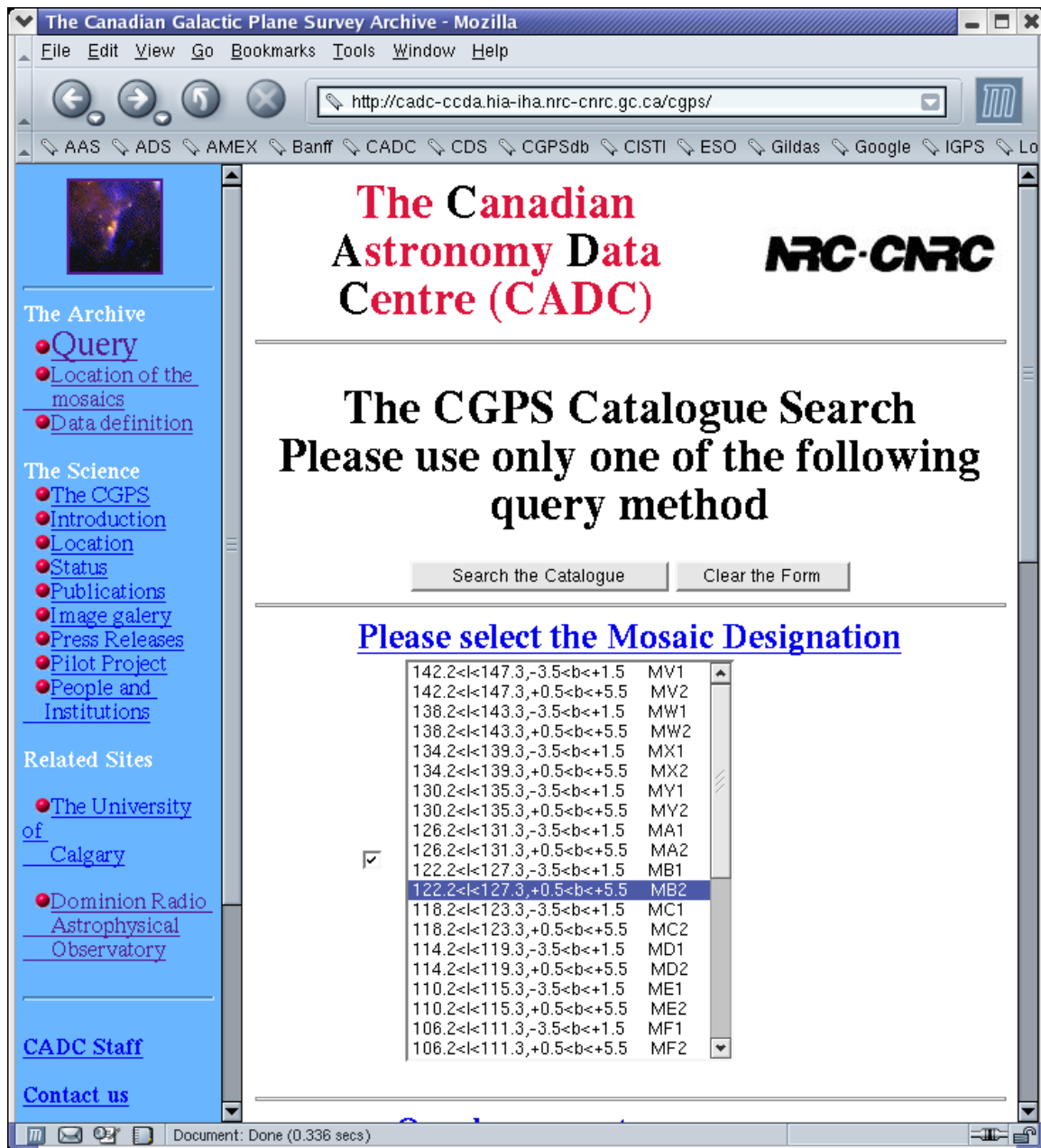
For a variety of reasons “absolute calibration” of the polarization observations cannot be established using Effelsberg observations alone. We have therefore made a polarization survey at 1.4 GHz of the entire Northern sky (May 2002 to May 2003) using the DRAO 26-m Telescope. This work forms a major part of the research of Maik Wolleben, a Ph.D. student from MPI, Bonn, jointly supervised by MPI and DRAO. Observing is slow on this project, and sampling is incomplete. It is nevertheless 100 times better than the previous best data (based on observations made in the Netherlands in the 1960s). Data for the declination range +90 to –30 degrees have been reduced, and will be published in 2004. The data will then be made publicly available. This survey, despite the comparatively crude resolution of 36 arcminutes, is proving to be a valuable astronomical product in its own right, revealing hitherto unknown features and providing valuable information on the Galactic foreground for CMB researchers. Observations will resume in May 2004 to improve the sampling.

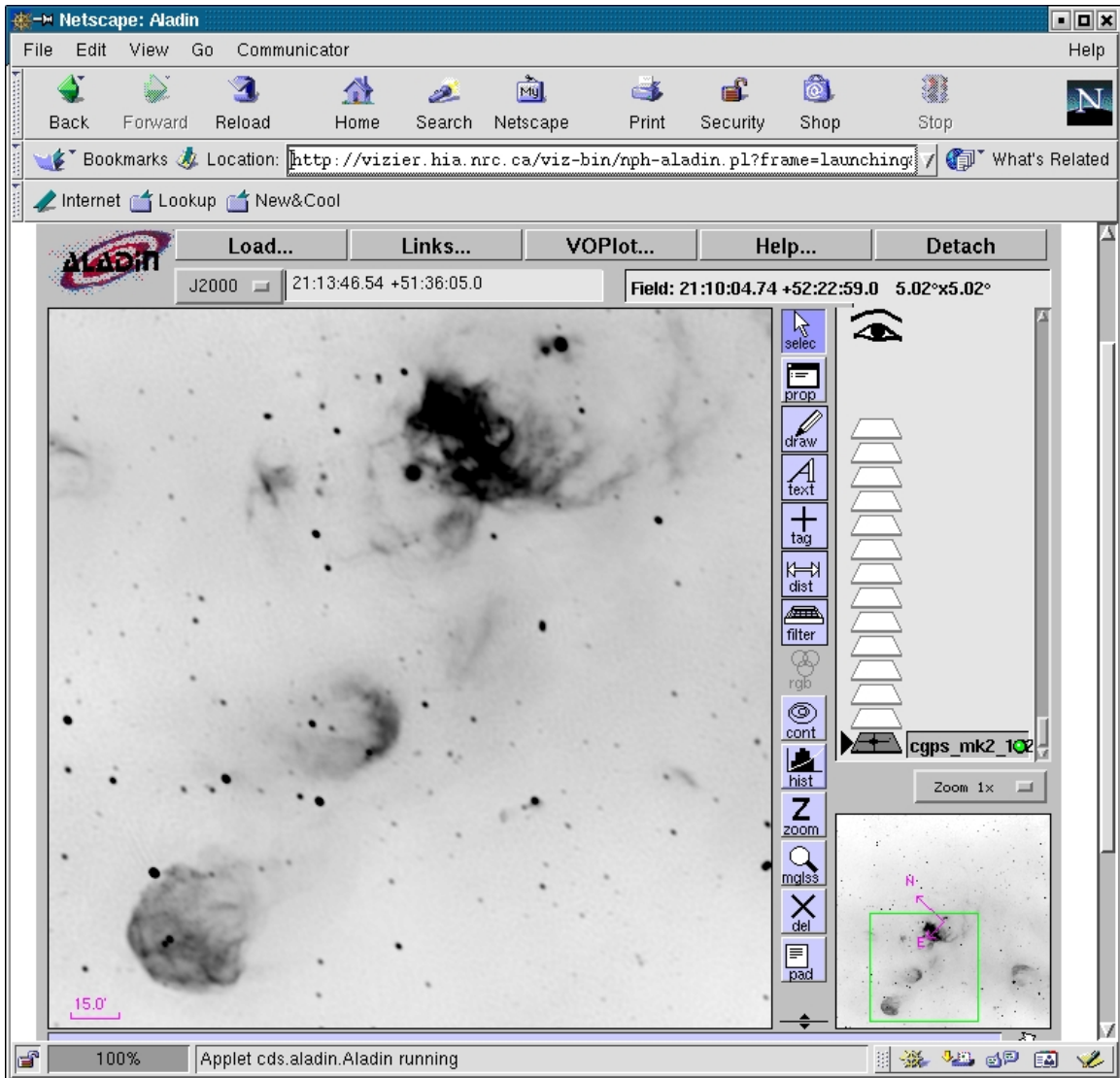
We have been awarded time on the FCRAO 14-m Telescope to obtain complementary CO data from FCRAO for the Phase 2 high-latitude region (see Figure 1) and for the longitude range 145 to 175, greatly expanding the CO database (the region 100 to 145 was observed as part of Phase 1 of the CGPS). The new observations are being made by Chris Brunt, former CGPS Research Associate, who moved to FCRAO in July 2003.

We have completed processing of the infrared data for 12 and 25 microns for Phase 2. (60 and 100 micron data were already available).

CGPS data are published in the form of “mosaics”, each covering about 5 x 5 degrees. Of the 32 mosaics in the Phase 2 region, sixteen 21-cm continuum mosaics and nineteen HI-line mosaics are on the point of being released publicly through the CADC. Nine 74-cm mosaics are in the same state.

In collaboration with the CGPS consortium, the CADC has developed a superior user interface for the CGPS data, illustrated in Figure 2. All of the CGPS high-resolution data products, covering the major components of the ISM, are available at the CADC site in Victoria. Most significantly, all are on a common grid to facilitate comparison. This work pioneers at the CADC a user interface with visualization to 3-dimensional data sets, a facility that will become increasingly important as ALMA and other future radio astronomy array telescopes begin to produce data





*Figure 2: An example of the CADC web-based interface to CGPS data (top) and a preview of an image (bottom)*

## Resources and Management

The CGPS has been funded by HIA and NSERC. The NSERC grants were obtained through the Collaborative Special Purposes program (1995 to 2000) and the Collaborative Research Opportunities program (2001 to 2004). HIA funds come from its A-base, and from an allocation from LRP funds (April 2002 to March 2007).

NSERC grant amounts were

1995/96	\$171,141
1996/97	\$150,000

1997/98	\$150,000
1998/99	\$162,464
1999/00	\$162,464
2001/02	\$254,960
2002/03	\$242,960
2003/04	\$242,960

Current staff resources involved in producing the CGPS/IGPS data sets are shown in the following table. The location of staff and the source of the funds that pay them are indicated.

DRAO Telescope operations and maintenance - Note 1	2.4 FTE	HIA
Computer support - Note 2	0.3 FTE	HIA
Data reduction (at DRAO) - Note 3	2.0 FTE	LRP
Data reduction (at DRAO) - Note 4	2.0 FTE	NSERC
Data reduction (at U. Calgary) - Note 5	2.0 FTE	NSERC

Note 1 - Operation of the telescope has long been standardized, and development work on hardware and software is minimal. Staff required for operation was reduced accordingly over the period 2000 to 2004. It is not possible to reduce below this level.

Note 2 - Support of the computer system at DRAO used by CGPS/IGPS occupies about 15% of the effort of the two computer system administrators, or about 0.3 FTE.

Note 3 - LRP funds of \$100K per year are used to support one NRC Research Associate position (\$60K) and one NSERC Visiting Fellow position (\$30K supplement by \$10K from central NRC). The work now involves 30% of the time on data reduction and 70% of time for research (in the early days of the Survey the split between these tasks was 50%, 50%).

Note 4 - One of the two NSERC Research Associate positions at DRAO has been vacant since August 2003, and cannot be filled until new NSERC funding is awarded. The job requirement in these positions is 30% data reduction and 70% research.

Note 5 - One Research Associate position at the University of Calgary has data reduction obligations for CGPS data (from DRAO) and one position has data reduction obligations for VGPS data (the VLA component of the IGPS). IGPS data bases and project archives, as well as the project website are maintained at Calgary (The CGPS and VGPS public sites are at [www.ras.ucalgary.ca](http://www.ras.ucalgary.ca)).

In addition to the above complement, four postdoctoral positions in Canadian universities are funded 50% from the NSERC grant, with the balance covered from local funds. At present, the four CGPS postdocs are at the Universities of Calgary, Manitoba, Western Ontario, and Toronto.

Expense of maintaining the DRAO telescopes in FY2003/04 was \$20K. Computer costs associated with CGPS/IGPS operations were \$10K.

The project is run by a management committee with five permanent members and three members elected by the consortium. Permanent members are

Russ Taylor (Principal Investigator - Calgary - Management Committee Chair)  
Peter Dewdney (DRAO)  
Gilles Joncas (Laval)  
Tom Landecker (DRAO)  
Peter Martin (Toronto).

Elected members (May 2003 to May 2004) are

Shantanu Basu (Western Ontario)  
Roland Kothes (DRAO)  
Nicole StLouis (Montreal).

### **The Consortium**

The CGPS/IGPS consortium is large. The current database contains 83 people. Of these, 54 are in Canada, at 15 Canadian institutions. Of those with home institutions outside the country, the largest contingent is 17 based in the United States. The balance are from Germany, the UK, Australia, and Argentina. All 83 participants are not equally active, but the publications since the year 2000 based on CGPS data have involved 51 consortium members. The CGPS/IGPS consortium has annual science meetings each spring at which typically 40-50 people attend. The next meeting will be at DRAO in May 2004.

### **Training the Next Generation**

This project is having a significant impact on the next generation of astronomers in Canada. Within Canadian universities 24 graduate students have been involved with the surveys, 12 M.Sc. and 7 Ph.D. theses have been completed, and 4 Ph.D. and 2 M.Sc. projects are in progress. In the course of the project 14 postdoctoral fellows and research associates have been employed in Canada, and 5 of those are now in tenure-track positions in Canadian astronomical institutions.

One of our graduate students, Jo-Anne Brown of the University of Calgary, has just been awarded the 2004 Plaskett Medal for her thesis “The Magnetic Field in the Outer Galaxy”.

### **Scientific Impact**

Major scientific advances made by Canadian astronomers based on the CGPS and IGPS data include the following.

- The systematic mapping of cold atomic gas in the spiral arms, leading to a new appreciation of it as a significant component of the ISM. There is almost as much gas in cold atomic form as in molecular form. The occurrence of cold gas in the Perseus Arm appears to be related to passage of the spiral arm shock through diffuse gas. We are apparently tracing the compression of the diffuse medium to dense cold gas, perhaps the first step on the path to star formation.
- The opening of a new window into the magneto-ionic medium through observations of the polarization of the diffuse Galactic emission. The polarized sky bears little

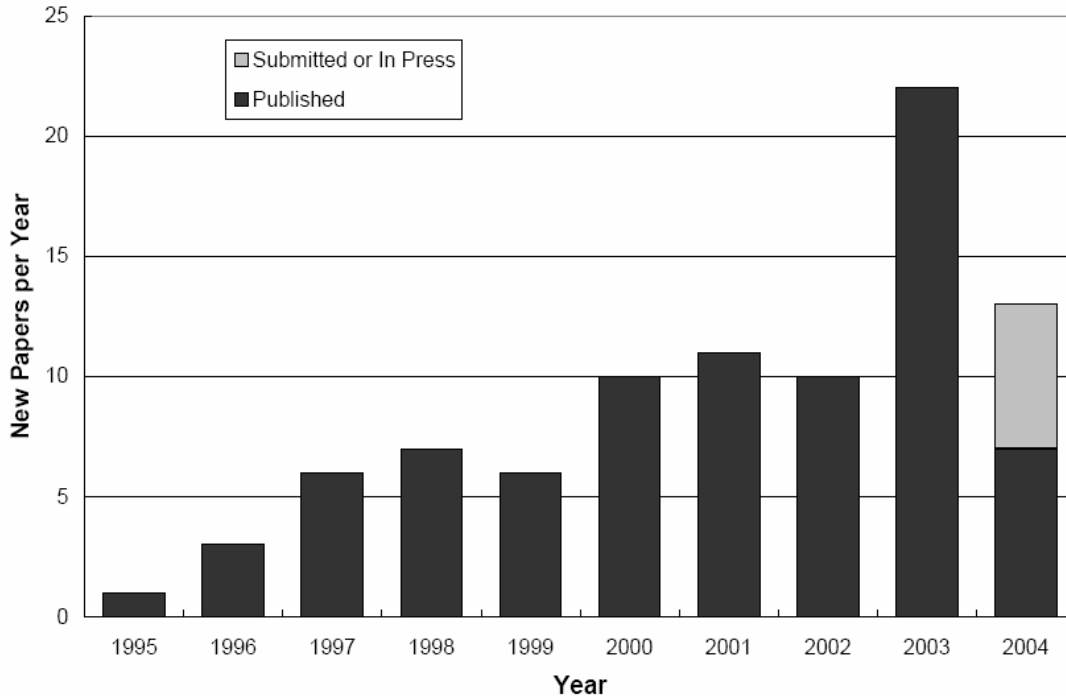
resemblance to the sky seen in total-power images. The images are dominated by small-scale structure produced when the synchrotron background suffers Faraday rotation on its passage through the foreground ionized medium. These polarization images reveal previously invisible structures in the ISM and shed new light on the ionized gas in the Galactic disk and on the uniform and random components of the magnetic field.

- Measurement of the Faraday rotation of compact extragalactic sources seen through the Galactic disk has led to a detailed mapping of the Galactic magnetic field. This is arguably the best (and possibly the only) way to determine the field configuration in the disk. The combination of data from Northern and Southern hemispheres has provided new insights into the structure of the global field and its relation to the mass distribution in the Galaxy.
- The discovery of two examples of the interaction of the Galactic disk with the Galactic halo. One, a Galactic chimney, is a conduit for radiation and material into the halo, driven by a cluster of massive stars at its base. The other, a "mushroom cloud" of atomic gas, is either an example of buoyancy in the exponential disk, or evidence of impact of a high velocity cloud which has penetrated the disk. More recent data from the high-latitude extension (part of Phase 2) appear to provide evidence of a Galactic fountain in molecular and atomic gas.
- The invention of a new method of determining distances based on a model of the distribution of matter in the disk of the Milky Way. The model is based on a wide array of previous knowledge of the distribution of Milky Way constituents. A relationship is established between line-of-sight velocity and distance that does not rely on any kinematic assumptions. Measurement of column density to an object, obtained from CGPS data, leads to an accurate distance. Distances so established are much more reliable than kinematic distances in the outer Galaxy, where the Perseus arm shock is a major perturbation of the velocity field. This tool is being exploited to improve distances to HII regions and supernova remnants, and to determine the structure and of the outer Galaxy and to refine knowledge of the Galactic velocity field.

The impact of the project is seen in its publication record. Figure 3 shows the count of papers in refereed journals from Canadian members of the CGPS consortium using CGPS or IGPS data since the inception of the project. In Calendar year 2003, the total productivity was 22 papers. In 2004, we already have 12 papers accepted, in press or submitted (to the end of March). To put these numbers into perspective, the Canadian astronomy community has produced about 350 papers in refereed journals per year in recent years (Dennis Crabtree, personal communication).

A quick check of citations using the ADS database shows 632 citations to 82 CGPS papers. Since the majority of papers have been published in 2003 and 2004, the true impact of many papers cannot be assessed yet. The most frequently cited CGPS papers have gathered 30 to 50 references. For the years 1997 and 1998, where one might expect to obtain a reasonable measure of influence from citations figures, the average citation rates per paper were 20 and 17 respectively.

### CGPS Refereed Journal Publications versus Time



*Figure 3. Publications by CGPS consortium members based on CGPS data. This is not a cumulative histogram; it shows the number of new publications each year. Records are not complete for the current year.*

Two major international conferences organized by the CGPS/IGPS group are a significant contribution to the literature. The two meetings were held in Penticton in August 1998 and October 2001. Both events culminated in publications in the ASP Conference Series.

“New Perspectives on the Interstellar Medium”, edited by A.R. Taylor, T.L. Landecker, and G. Joncas, ASP Conference Series, volume 168 (1999).

“Seeing Through the Dust: the Detection of HI and the Exploration of the ISM in Galaxies”, edited by A.R. Taylor, T.L. Landecker, and A.G. Willis, ASP Conference Series, volume 276 (2003).

### Recent Developments on the International Scene

Imitation is the sincerest form of flattery. Largely as a result of the CGPS and IGPS, the Survey idea has caught on in ground-based Galactic studies. In Galactic astronomy surveys are on the drawing board for Arecibo after it is fitted with a seven-element focal-plane array, and for the Allen Telescope. Neither of these is likely to be competition for the IGPS for some years to come.

The need to use observations with single antennas to complement observations with synthesis telescopes has finally sunk into the radio astronomy community. These techniques were

pioneered by DRAO in the 1970s and 1980s and have been refined to a high level by the GCPS/IGPS. As an example, the Green Bank Telescope is now being used extensively with the VLA. This combination is playing a significant role in the IGPS.

The strong interest in cosmology is fuelling a great interest in the IGPS data products. Since all cosmological observations are necessarily made through a foreground of the Milky Way, good observations of high angular resolution play an important role in deconvolution of many CMB measurements.

### **Telescope Enhancements**

Two projects are ongoing, aimed at improving the sensitivity of the DRAO Synthesis Telescope at 21 cm by a factor of nearly two. The target is to reduce system noise from the initial value of 60 K to 35 K. The improvements are to be achieved by a reduction of receiver noise by about 17 K and ground noise by about 8 K. Two engineering graduate students, Teresia Ng and Angel Garcia from the University of Alberta, have been working on the two aspects of the problem. Teresia Ng has completed her thesis on the antenna work, and implementation of changes has begun. Angel Garcia is close to success in her amplifier work. By January 2004, system noise has been reduced to approximately 45 K. This has been verified by measuring noise on images.

Improved sensitivity is never wasted, but it will not make much difference for HI observations in the Galactic plane where the peak line temperature can be 80 K. However, at low column densities and in continuum work, particularly polarimetry, the improvement will be substantial. The result will help us achieve the goals of Phase 3 (see below).

### **The IGPS 2004 to 2007**

The IGPS Consortium has submitted a letter of intent to NSERC's Special Research Opportunities program. This proposal will be submitted very soon, with the request for funding to begin in August 2004. The proposal, under the title "*The Galaxy from the Inside Out*", closely tied to two space projects in which Canada has a formal partnership, the Planck and Herschel missions.

The *Herschel Space Observatory* (HSO) is one of the Cornerstone Missions of ESA's Horizons 2000 program. With a mirror diameter of 3.5 meters it is the largest space infrared telescope ever launched into space. It is equipped with three detector systems for operations in the far-infrared to submillimetre wavelengths (60 microns to 670 microns), allowing high sensitivity imaging of emission from dust and molecules. Diffraction limited resolution over this band corresponds to 5" – 40". ESA has established a program of large-scale, legacy observing projects with the HSO called Key Programs. An international collaboration has formed to carry out a Herschel Galactic Plane Survey project as a HSO Key Program. This project will combine a large-scale HSO survey of the disk of the Milky Way Galaxy with the IGPS to provide an unparalleled complete picture of the interstellar medium in the plane of our Galaxy. The HSO observations will cover approximately 1500 square degrees and require about 80 days of observations with the HSO. The end product will be multi-wavelength, high-resolution images of emission from the dust in the disk of the Milky Way. The intention is to cover the entire disk of the Galaxy, but highest priority target region will be those areas for which complementary imaging of molecules and atomic gas will be available on the ground. This corresponds to the northern hemisphere region of the IGPS – the CGPS.

The Planck spacecraft is an all-sky imaging telescope with the primary purpose of measuring the structure of the Cosmic Microwave Background (CMB) radiation at arc-minute scale angular resolution. The CMB image from Planck will have the highest angular resolution yet achieved, yielding measures of the structure of the intensity and polarization of the radiation field on scales not yet charted. The Planck mission achieves its goal of mapping the CMB by carrying out all-sky surveys of radiation at multiple wavelengths shortward of 1cm. Observations at DRAO will provide the Planck mission with high angular resolution images of the low-frequency radiation from the Galaxy. Precise deconvolution of the "foreground" radiation from the Galaxy is a critical step toward extracting the images of the CMB, which are seen through the Galactic ISM. The Planck data rely on the spectral signature of the radiation from the components of the ISM to identify the foreground emission from dust and gas. However, at the lower frequencies the angular resolution of the Planck instruments is very poor, thereby limiting the knowledge of the structure of foreground radiation. As part of the Canadian Planck Science program we will carry out DRAO synthesis observations of a small number of regions in the Galactic Halo. A small fraction of the time will be spent on a few fields with intermediate column density of atomic hydrogen, which will explore the physical transition from high column density regions and very low density ones. Most of the time will be devoted to the DRAO Planck Deep Field – a very deep integration of a region of very low foreground atomic hydrogen and dust emission. This direction is our cleanest window to the extragalactic universe. The DRAO PDF will provide detailed, high resolution information on the foreground emissions in this window. The combination of Planck data on dust in the halo and the DRAO data of the gas and magnetic fields will be used by the Canadian consortium and the Planck ISM working group for studies of the structure, energetics, and physical states of matter in the Galactic halo.

The observations with the DRAO Synthesis Telescope will be carried out over the period April 2004 to March 2007. This program will (a) complete observing of the strip along the Galactic plane accessible to DRAO, and (b) include the high latitude observation and the DRAO Planck Deep Field designed to complement Canadian involvement in the Planck. In addition funds will be requested for the incorporation of all IGPS data from all telescopes into one common database at the CADC.

The extension of the CGPS will take coverage to longitude limits of 55 (towards the inner Galaxy) and 190 (past the anticentre) – see Figure 1. When this is completed, the area covered by the CGPS will be about 1400 square degrees. Because these regions lie at low declinations they cannot be observed around the clock, and the Deep Field observations, which will be at high declination, form an effective counterpart. An efficient full-time schedule can then be implemented and completed in March 2007, a few months before launch of Herschel and Planck.

These extensions to the CGPS will, as in the Survey to date, feed data to a number of science groups working in Canada. We give just a few examples.

- The anticentre region contains a significant part of the Perseus Arm, the closest spiral arm beyond the one we live in. The angular resolution at the distance of the Perseus Arm corresponds to a physical scale of parsecs, smaller than the stellar separation. The Perseus Arm is the only Galactic arm for which we have a reasonably comprehensive model (the two-arm spiral shock model which Roberts proposed in 1972) and extending our sample of it is a high priority. The postulated shock ridge is closely traced by cold

atomic gas, detected in the CGPS by its absorption of more distant, warmer gas at the same velocity (HI self-absorption). Understanding the flow and evolution of ISM material through a spiral arm passage is of crucial importance and we have the opportunity to study these processes in detail. Significantly, the Northern sky, accessible to the CGPS, is the only part of the entire Galactic plane where CO observations of comparable resolution and adequate sensitivity are available (from the FCRAO 14-m Telescope).

- In the anticentre the circular motion of the HI is compressed into the velocity range near zero, and we have a good chance of detecting the non-circular motions generated by the spiral-arm shock. Furthermore, the anticentre contains very interesting polarization structures. From earlier CGPS research we have established a framework for interpreting these polarization observations. The simpler structure towards the anticentre will aid correlation with other ISM constituents.
- At longitudes near 175 degrees the line of sight should become perpendicular to the regular magnetic field. At this point the Rotation Measure should change sign because the line-of-sight field component reverses. Pinpointing this direction, through observations of Rotation Measures of extragalactic sources, will allow the local field direction to be established with better precision than by any other method.
- At the other end of the Survey, at longitude 55, the line of sight becomes tangential to the Sagittarius Arm, and interesting results from point-source Rotation Measures are also expected, providing data on the field in the next inner arm.

### **Beyond 2007**

By 2007 the portion of the Galactic plane visible at DRAO will have been observed and the DRAO observational contribution to the IGPS will be complete. Programs at Arecibo to image large areas outside the Galactic disk will be underway and SKA demonstrators such as the CLAR will be on the horizon, with potential for extremely fast surveys of the entire sky beginning around 2011 (note that Arecibo and the CLAR will have slightly lower resolution).

We do not anticipate a Phase 4 of the CGPS project. Remaining areas where the DRAO Synthesis Telescope could contribute to Galactic research and extend the work of the survey might be targeted observations of particularly interesting regions of disk-halo interaction and/or further probing of halo regions. Such activities could be carried out in response to a normal observing proposal process.

The principal legacy of the survey will be a database of major significance for ISM research for many years. Beyond that, the ideas embodied in CGPS/IGPS will drive the thinking for new surveys such as those planned with SCUBA and ACSIS on the JCMT and those envisaged for Arecibo, the EVLA and Galactic science with SKA demonstrators such as CLAR.

The CGPS/IGPS has been the major thrust of astronomical research at DRAO for the last decade, and the temporary funding provided to the project by the LRP and by NSERC has sustained DRAO science over that time. It is important that DRAO research be put on a firmer long-term footing to underpin implementation of the CLAR.