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This report covers the period from 1996 April 1 to 1997 March 31, while the publications are for the calendar year 1996.

1. MANDATE

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

2. HIGHLIGHTS

HIA has now completed its consolidation in British Columbia. The JCMT Group moved from Ottawa to Victoria and re-established its receiver laboratory at the Dominion Astrophysical Observatory. Jacques Vallée also arrived from Ottawa to become the Technical Secretary for the Canadian Time Assignment Committees for the Canada-France-Hawaii Telescope (CFHT) and the James Clerk Maxwell Telescope (JCMT), and Public Information Officer.

The scientific and technical highlights of the year are recorded in the following pages identifying the specific groups within HIA. Particularly noteworthy is the successful commissioning of the adaptive optics bonnette on the CFHT. Now it routinely produces stellar images with about 0.1 arcsec FWHM using a natural guide star. The JCMT Group completed a dual channel receiver for 345 GHz, which is now operational on the telescope with double-side-band temperatures of 100K.

3. STAFF CHANGES

Brenda Parrish joined the secretarial staff in the Director General's office, where she has responsibility for handling the CFHT and JCMT observing proposals, as well as the travel grant provided by the Natural Sciences and Engineering Research Council for users of these telescopes. Also in the administrative area Leslie Dheensaw and Ian McCrea joined HIA in Victoria and Kathy Gibbard moved to the DAO from the DRAO. In Penticton, Bunny Duggan resigned after seven years. Her place was filled by Claudette Campbell for six months and then by Chloe Handley.

4. RESEARCH

Morton has begun collecting atomic data to extend his critical compilation of resonance lines to elements heavier than germanium. The tables will be useful for interpreting spectra of stars and the interstellar gas, and will indicate where further laboratory measurements or theoretical computations are needed.

Morton, in collaboration with Welty and Hobbs (U. Chicago), has observed bright stars with the Ultra High Resolution Facility (R = 1,000,00) on the Anglo Australian Telescope to study the weak interstellar absorption lines of Ca I and Fe I. They will compare these data with observations of other visible and UV lines in the same directions.

Vallée completed a review of the observations of magnetic fields inside and outside the Milky Way, notably on nearby magnetic fields including protostellar disks, dust cores, and interstellar cloudlets. Some of the data presented came from polarimetric observations with the JCMT. Vallée and Bastien of Université de Montréal pursued the analysis of the dark cloudlet near Sh140, using observations at the JCMT. The 1-arcmin (=0.1 parsec) cloudlet contains several pockets of gas, dust, and magnetic fields located along a large open-bowl shape, with a NE to SW axis of symmetry. The goal is to test the various magnetohydrodynamic theories of protostellar collapse in a cluster.

5. CANADIAN GEMINI PROJECT OFFICE

The CGPO under Andrew Woodsworth continued in its role as liaison between HIA and the Gemini Project at the working level. As almost all the major Gemini construction projects are now under contract and progressing well, the emphasis has been on coordination of Gemini instrumentation and software work being done within HIA. Additionally, a significant effort is now being put into planning for the Gemini operations era and how the Canadian Gemini user community can best be supported by HIA. First light on Mauna Kea Gemini telescopes is scheduled for the end of 1998. Work on the Gemini Adaptive Optics System is being managed by Glen Herriot of the CGPO, while Simon Morris acts as instrument scientist. This work, which was restarted in November 1995, has so far resulted in an optical design as well as optomechanical and electronics packaging.

Using spectra obtained with the DAO 72-inch telescope and images in the H and K bands obtained with the CFHT adaptive optics system, Davidge has investigated the stellar content of the inner bulge of M31. He has also used J, H and K images from the CFHT system to probe the central regions of the Milky Way. The main results are that (1) the stellar contents of the innermost regions of M31 and our Galaxy are very similar, and (2) the two nuclear sources in M31 have similar stellar contents, consistent with the 1995 model by Tremaine.

Tim Davidge, a guest worker supported through the University of British Columbia, continued to provide scientific and technical support to the HIA instrument teams and to serve as Executive Secretary to the Gemini Project Scientist team. He also worked with the Canadian Project Scientist to solicit input from university astronomers for future instrumentation initiatives.

6. FUTURE RADIO TELESCOPES

Peter E. Dewdney is the co-ordinator of Future Radio Astronomy Initiatives for the Herzberg Institute. He is based at the Dominion Radio Astrophysical Observatory (DRAO), where he is assisted by B. G. Veidt.

Over the past year, Dewdney was a member of the NRC Planning Committee for a New National Radio Astronomy Facility, chaired by Dr. E. R. Seaquist (University of Toronto). The Committee has now completed its work under the mandate from NRC/HIA to provide recommendations for Canadian participation in a major radio astronomy facility in the next decade. In its final report ''Canadian Radio Astronomy in the 21st Century - the Challenge,'' the Committee has a) outlined all the current options for future international collaboration, b) investigated Canadian university, government and industrial strengths in the technologies required for radio astronomy at different wavelength bands, c) assessed the scientific benefits of potential new telescope facilities, d) provided recommendations for new directions for Canadian Radio Astronomy, and e) provided recommendations on how to proceed in attaining the main goals.

As its highest long term priority the report recommends adopting the Square Kilometer Array (SKA) as the next generation radio telescope for which Canada would provide national facility support within an international collaboration. An international technical collaboration has developed which will carry out feasibility studies for various methods of implementation for the SKA. This has been formalized in a Memorandumof Agreement entitled ''Technology Study Program Leading to a Future Very Large Radio Telescope,'' signed by the Director General of HIA.

The SKA will consist of an array of antennas which will have to be constructed much less expensively than can be achieved using standard techniques. A potential solution to this problem, the Large Adaptive Reflector (LAR), is a long focal-length parabolic reflector fixed on the ground and an airborne platform to support the focal receiver. This technique promises the construction of very large antennas at a relatively low cost per unit of collecting area. Preparations are under way to collaborate extensively with universitites and industrial partners in a more detailed feasibility study of the LAR.

As its highest near-term priority, the report recommends that NRC take a leading technical role in linking the James Clerk Maxwell Telescope to the forthcoming Submillimeter Array (SMA), a project of the Smithsonian Astrophysical Observatory. Research is underway to determine how best to measure the phase changes imposed on submillimeter wavelengths, and contribute to collaboration with the SMA project. The Director General of HIA is also representing Canada in a new working group of the Megascience Forum to address issues of international concern in the field of radio astronomy, and to strengthen intergovernmental contacts among officials who are responsible for planning investments in radio astronomy in the next 10-20 years. The three areas of attention will be a) the Square Kilometer Array, b) the millimeter arrays, and c) protection of the radio spectrum.

7. SOLAR TERRESTRIAL PHYSICS

Following a decision by NRC management in 1994, HIA has now almost completed its involvement in solar-terrestrial physics, both on the ground and in space. The Institute is particularly grateful to Group Leader Fokke Creutzberg, who has encouraged each staff member to remain scientifically active and publish the important results from recent missions.

Fortunately, the University of Calgary, with support from the Canadian Space Agency, was able to accept the staff involved with the Thermal Plasma Analyzer for the Japanese Panet-B mission to Mars. Andrew Yau, as Principal Investigator, has provided scientific and technical assistance to the industrial contractors developing the flight instrument and software. Also, under his direction, the Calgary team has completed key parts of the ground-support software and has begun the instrument calibration. The payload is scheduled for launch in August 1998. Meanwhile, the Suprathermal Mass Spectrometer, which HIA built for the Japanese Akebono satellite, has completed 8 years of successful operation.

Some staff now have contract work with the Canadian Space Agency and others are continuing as guest workers in Ottawa. Victor Gaizauskas is using the photographic archive of solar chromospheric activity accumulated from 1973 to 1992 at the Ottawa River Solar Observatory to examine solar prominences existing at different phases of the solar cycle and in different magnetic environments, specifically inside and around clusters of sunspots, between unipolar magnetic areas created after clusters decay, and at high latitudes marking the Sun's polar caps. Conducted in collaboration with an international team of eight solar observers and theorists, this work is aimed at improved physical models to explain the creation, support and eventual destabilization of prominences.

David Anglin completed a paper titled ''Trapped energetic ions in Jupiter's inner magnetosphere'' which was accepted for publication in the Journal of Geophysical Research. Because of the intense ion and electron fluxes in the region, there were many inconsistencies in earlier Pioneer and Voyager measurements, particularly with respect to pitch angle and ion streaming. The new HIA results significantly clarify the situation and improve our understanding of the physical processes which control the acceleration and transport of ions in Jupiter's inner magnetosphere.

Don McDiarmid has continued his studies of the Earth's magnetospheric pulsations observed from satellites and from the ground. He established for the first time that the azimuthally polarized Pc 3-4 pulsations at geosynchronous orbit sometimes show convincing field-line resonance structure in the ground data.

Don Wallis continued to improve the accuracy of the data from the magnetometers and riometers in the CANOPUS ground-based array across north-western Canada. He also analyzed data from the Langmuir probe on the OEDIPUS C tethered rocket to ascertain the altitude dependence of electron temperatures and densities on the tether current.

8. PUBLICATIONS

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This report covers the period from 1996 April 1 through 1997 March 31, while the publications are for the calendar year 1996.

1. HIGHLIGHTS

The Canadian Network for Observational Cosmology team has found that red and blue galaxy subsamples in rich clusters of galaxies at $z \approx 0.30$ yield identical mass profiles for the clusters, indicating that these are clusters in equilibrium.

From analysis of their critical compliation of peculiar velocities for 3600 galaxies, Courteau, Willick (Stanford University) and collaborators find that light traces mass on all scales, and argue that Ω is likely to be greater than 0.2 on scales larger than galaxy clusters.

Comparison of the spectral properties of more than 400 galaxies observed in the Canada-France Redshift survey out to redshifts of 1.3 indicates that star formation rates in galaxies were much higher in the past, but that the star formation was generally more sustained than episodic in nature.

Oke, Postman (STScI) and Lubin (Carnegie Obs.) find that two galaxy clusters with $z = 0.84$ and 0.89 have spectral energy distributions consistent with models of age 0.1 - 2 Gyr, as measured from the first burst of star formation. Galaxies with age 0.1 - 0.5 Gyr always have [OII], while by about 2 Gyr such oxygen emission is either absent or very weak.

Van den Bergh, Abraham (Cambridge U.) and Glazebrook (AAO) continued their study of the morphology of galaxies contained in the Hubble Deep Field (HDF), which are typically located at redshift $z \sim 1$. Grand-design spirals are almost absent, probably indicating that the assembly of giant spirals from their ancestral objects had not yet been completed, while merging and interacting galaxies are significantly more common. The HDF contains a class of head-tail (tadpole) galaxies that do not appear to have local analogs.

Richer (U. British Columbia) and collaborators, including Hesser and Stetson, have identified a sample of some 260 white dwarfs from HST observations of the globular cluster M4. They show how the properties confirm basic tenets of stellar evolution and current white-dwarf cooling theory.

From radial velocity studies of 22 R-type carbon stars over 16 years, McClure showed that none of them exhibit variability attributable to binary motion, and suggested that they are close binaries which coalesced.

Harmanec (Ondřejov Obs.), with collaborators at U. British Columbia, U. Victoria, and elsewhere has discovered bipolar jets in β Lyrae from an international campaign.

Balam (U. Victoria) has developed automated procedures for near-real-time reduction of multiple exposures from the Plaskett 1.8-m telescope that allows moving objects as faint as $V \sim 22$ to be detected, even when the orbital motions characteristic of Earth approaching asteroids limit exposure duration to a couple of minutes.

The CFHT Adaptive Optics Bonnette was successfully commissioned during the year. It is a user-friendly system which delivered diffraction-limited images almost immediately.

The Gemini Multiple Object Spectrograph went through a successful Critical Design Review, and construction in the UK and Canada is commencing. The Gemini Data Handling System had a successful Preliminary Design Review.

2. STAFF & VISITORS

New appointments to staff during the report year included André Anthony, Dr. David Bohlender, Gordon Broom, Dr. Stéphane Courteau, Colin Ganton, Sharon Hanna, Dr. David Schade, Gurjeet Singh, and Doug Stajduhar. Dr. Grant Hill took up an NSERC Visiting Fellowship in July, and Dr. Frank Grundhal arrived in December from the University of Arhus under a Danish National Research Council fellowship. Dr. Dennis Crabtree was seconded to CFHT for a three-year term, while Dr. Graham Hill retired after almost 30 years of service to return to his native New Zealand, and Dayle Kotturi resigned. As a result of Crabtree's secondment, a reorganization occurred in which Durand became CADC Group Leader and Stetson became Computing Group Leader for the year that began 1996 July 1. Vince Sullivan transferred to Victoria from the Ottawa location of HIA.

Temporary appointments during the year were held by Diana Chaytor, Steve Cockayne, Fahreen Dossa (Women in Engineering and Science, WES, student), Eric Eisenhuth, Greg Fox, Dr. John Glaspey, Meghan Gray (WES), Tim Hardy, Chad Hogan, Marc Leblanc, Wei Lin, Ben Lorincz, Aneela Nayani, Glen Rutledge, Dave Stevens, Caroline Swerdlyk (WES), and Carol Wong.

Alan Batten, Tim Davidge, Bev Oke and Young-Jong Sohn continued as guest workers at the Observatory for the full year. Extended periods of research studies and other interactions were taken at the DAO by Jeremy Allington-Smith (Durham), David Balam (U. Victoria), Stefi Baum (STScI), Anne Cowley (Arizona State U.), Angela Esposito (U. Padova), Carme Gallart (Carnegie), Arnold Heiser (Vanderbilt U.), Tom Ingerson (CTIO), Pierre LeSaffre (ENS de Lyon), Chris O'Dea (STScI), Daya Rawson (Mt. Stromlo Obs.), Kaiping Tian (Shanghai Obs.), Phil Williams (ROE), and Manuela Zoccali (U. Padova). Scientists making short working visits included S. Adelman (The Citadel), Miguel Albrecht (ESO), Olivier Boulad (CEA, Saclay), Ray Carlberg (U. Toronto), René Doyon (U. de Montréal), Kim Gillies (IGPO), Brent Goodrich (IGPO), Peter Hastings (Royal Obs.

Edinburgh), Robert Kennicutt (U. Arizona), Imelda Kirby (U. Arizona), Ana Larson, (U. Victoria, U. Washington), Lori Lubin (Carnegie), Yannick Mellier (IAP-Paris), A.G.D. Philip (Union College), Benoit Pirrene (ECF), Mark Postman (STScI), Carlton Pryor (Rutger's U.), William Rambolt (CFHT), Francois Rigaut (CFHT), Jene-Rene Roy (U. de Laval), Chris Shelton (Mt. Wilson Obs.), T. Smecker-Hane (UCI), Eric Steinbring (U. Victoria), D. Tody (NOAO), Jay Trauisano (STScI), Laurent Vigroux (CEA, Saclay), Gordon Walker (UBC), Steve Wampler (IGPO), Martyn Wells (U. Edinburgh), M. West (St. Mary's U.), R. Weymann (Carnegie Obs.), Gregory Wirth (U. Victoria), and Stephenson Yang (U. Victoria), and a great many colleagues from universities, industry and partner organizations within the Gemini, CFHT, JCMT and FUSE development teams to discuss matters relating to those projects.

3. COSMOLOGY

Further results of the Canada-France Redshift Survey (CFRS) were published in a series of papers by Crampton, Lilly (U. Toronto), Hammer and Le Fèvre (Obs. Paris-Meudon). In paper XIV, the spectral properties of more than 400 CFRS galaxies and their changes over the redshift interval $0 \leqslant z \leqslant 1.3$ were investigated. Within the CFRS sample, the comoving fraction of galaxies with significant emission lines (W_0(OII)$>$ 15Å) increases from $\sim$13% locally to over 50% at $z > 0.5$. The fraction of luminous ($M_B < 20$) quiescent galaxies (those without [OII] 3727 Å emission) decreases with redshift from 53% at $z = 0.3$ to 23% at $z > 0.5$, with the latter fraction being similar to that of early-type galaxies at that redshift. There is considerable evidence in the data that star formation increases from $z = 0$ to $z > 0.5$ in disk galaxies. However, the absence of extremely blue colors and the presence of significant Balmer absorption suggests that the star formation is primarily taking place over long periods of time, rather than in short-duration, high-amplitude bursts. There are several indications that the average metallicity and dust opacity were lower in emission-line galaxies at high redshift than those typically seen in luminous galaxies locally. They argue that changes in metallicity and dust extinction could be contributing to the observed evolution of the line and continuum luminosity densities, the luminosity function and/or the surface brightnesses and morphologies of galaxies in the CFRS.

The Canadian Network for Observational Cosmology (CNOC) team, including Carlberg (U. Toronto), Morris, Hesser, Hutchings, Oke, and former research associates Abraham and Smecker-Hane, used the CNOC database for an analysis in which the Jeans equation of stellar hydrodynamic equilibrium was applied to the red and blue galaxy subsamples. They find statistically identical cluster mass profiles, which provides strong evidence that these clusters are effectively equilibrium systems. This constitutes an empirical demonstration that the masses in the virialized region are reliably estimated using dynamical techniques.

Simon Morris continued to work on the oberving and data reduction for the CNOC projects. Papers describing the σ_8 measurement from the CNOC-1 cluster project and more on the cluster M/L profiles are in press. Data papers describing the first observational phase (CNOC-1) continue to be submitted.

Hutchings, Morris, and Smecker-Hane (UC Irvine) completed their analysis and modelling of galaxies in the CNOC-1 cluster 1621+246, at z=0.43. Hutchings and Chaytor continued analysis of radio sources in CNOC cluster fields.

Observational progress improved on the CNOC-2 project [led by Carlberg (U. Toronto) and involving Davidge, Hesser, Hutchings, Marzke and Schade] to obtain velocities (errors $\simeq$ 70 km s^{-1}) of $\simeq 10^{-4}$ galaxies in four patches each subtending $\simeq$ 1.5° using MOS at CFHT. These data will accurately measure the rate of growth of structure in the Universe to scales of $\simeq 15\ h^{-1}$ Mpc. Marzke and Hamilton (MPI-Heidelberg), with Carlberg, Morris and Yee (U. Toronto) are obtaining deep IR imaging of the CNOC-2 fields at the Calar Alto 3.5 m telescope. The goal is to create a subsample of the CNOC-2 redshift survey which is selected in the infrared, where the effects of galaxy evolution and the evolution of mass clustering may be more easily separated.

Marzke, da Costa (ESO) and Alonso (Obs. Nacional Brasil) are continuing their program of two-color photometry of galaxies in the Southern Sky Redshift Survey. They have obtained new colors for nearly 300 galaxies, which brings the total number in the complete color sample to more than a thousand. The goal is to obtain enough colors to measure the bivariate distribution of luminosity and color in the local galaxy population.

Marzke and da Costa began an investigation of the properties of close pairs of galaxies in the Southern Sky Redshift Survey. The goal is to provide a well-defined low-redshift baseline for studying the evolution of pairs at $z \leqslant 1$. They have obtained U and B imaging of these pairs in order to facilitate direct comparisons with the close pairs in the CNOC-2 redshift survey.

Marzke and Geller (CfA), Kurtz (CfA), Wegner and Thorstensen (both Dartmouth College) have analyzed the luminosity function of galaxies in the Century Survey. The survey probes to $z \approx 0.15$ and is selected in the R band. The goal is to explore the connection between local galaxy populations and those observed at intermediate redshifts.

In collaboration with Abraham *et al.* (Cambridge U.) and Glazebrook (AAO), van den Bergh has studied the morphology of galaxies contained in the Medium Deep Survey (MDS) and in the Hubble Deep Field (HDF). The morphology of the MDS galaxies, which are typically located at z $\sim$0.5, does not differ significantly from that of nearby galaxies in the Shapley-Ames Catalog. However, the fraction of interacting galaxies is found to be slightly higher in the MDF than it is among nearby Shapley-Ames galaxies. Major differences are, however, seen between nearby galaxies and objects in the HDF, which are typically located at z$\sim$1. A large fraction of the distant HDF galaxies is found to exhibit morphological peculiarities which makes it difficult to shoehorn them into the classification types to which most nearby galaxies can be assigned. In particular 'grand design' spirals are almost absent in the HDF, which probably indicates the assembly of giant spirals from their ancestral objects had not

yet been completed. The number of merging and interacting galaxies is significantly higher in the HDF ($z\sim1$) than it is among galaxies in the MDS ($z\sim0.5$). Barred spirals appear to be rare or absent in the HDF. Furthermore the HDF contains a class of head-tail (tadpole) galaxies that do not appear to have local analogs.

Courteau recently completed with Willick (Stanford U.) and collaborators, the compilation of the Mark III Catalog of Galaxy Peculiar Velocities. This compilation of 3100 spiral galaxies, combined with 500 'Seven Samurai' ellipticals, provides the necessary data to reconstruct local velocity and density fields and make comparisons with similar reconstructions from redshift surveys like IRAS. These comparisons suggest, among others, that light traces mass on all scales and that the density parameter Ω is likely to be greater than 0.2. In spite of careful sample matching, zero-point uncertainties persist at the 3-4% level between the northern and southern hemisphere data. Full homogenization at the 2% level, the minimum required for a 3-σ bulk flow detection at 6000 km s^{-1}, can simply not be done with existing samples. To remedy this situation, Courteau and colleagues have nearly finished a new NOAO-sponsored survey to obtain Tully-Fisher distances for a complete, full-sky sample of 300 Sb-Sc galaxies between 5000 and 7000 km s^{-1} from the Local Group, for which precise and uniform photometric and spectroscopic data from KPNO and CTIO are obtained. This will be the first well-defined full-sky survey to sample this scale, free of uncertainties from matching heterogeneous datasets. As the measured (and much contested) bulk motions on these scales are of the order of 350 km s^{-1}, a detection of high statistical significance will be well within reach for the first time. Data reduction by Courteau and Sohn is in progress.

Using the Keck Telescope, Oke, Postman (STScI) and Lubin (Carnegie Obs.) are studying nine clusters of galaxies with redshifts between 0.6 and 1.1. They derived coarse absolute energy distributions from B, U, R, I colors and compared them with galaxy models to estimate ages. Spectra were also obtained to (a) measure the redshifts and identify cluster members, (b) derive the ages of the galaxies, (c) estimate the amount of star formation, and (d) determine the metallicities in the cluster galaxies. Most of the clusters in this program are also being observed with the Hubble Space Telescope, to see what these distant young galaxies actually look like compared with nearby very old galaxies. Detailed studies of two of nine clusters with redshifts of 0.84 and 0.89 are well under way. From their comparison of galaxy energy distributions with models, they infer that the galaxies have ages of 0.1 to about 2 Gyr. Comparisons of their spectra with the models also yield similar ages with the same overall range of ages. The derived ages are measured from the time when the first burst of star formation occurred and not necessarily from when the universe began or galaxies first formed. There is a strong correlation of emission-line strengths with the ages of the galaxies derived from the colors and spectra. Very young galaxies with ages of 0.1-0.5 Gyr always have very strong forbidden emission lines of ionized oxygen. For the older galaxies the emission strengths decrease until at ages of 2 Gyr oxygen emission is either absent or very weak. This implies that there was very active star formation at young ages which rapidly decreased with time until it virtually disappeared after 2 Gyr. The HST images show in detail where the star formation inferred from the spectral emission lines occurs.

Since joining the Observatory as a member of the CADC group, Schade continues his research involving a comprehensive study of the evolution of galaxies to $z=1$ based on the Canada-France Redshift and the Canadian Network for Observational Cosmology surveys. HST and CFHT imaging (both CCD and Adaptive Optics Bonnette) form the basis for these studies, which involve collaborators at the U. Toronto, Cambridge, and Meudon. Schade is Principal Investigator on an HST project to study the evolution of cluster galaxies, and is Co-I on several others, including studies of field galaxies and nearby active galactic nuclei. Several papers were published based largely on archival HST data.

Stetson maintained his participation in the *Hubble Space Telescope* Key Project on the Extragalactic Distance Scale. He devoted most of his attention to questions concerning the absolute photometric zero-point of WFPC2 and the derivation of precise aperture corrections in the crowded galaxy images.

Van den Bergh has compiled data on all SNe Ia that have occured in galaxies for which Cepheid distance determinations are available. From these data he concludes that SNe Ia exhibit a range of about 20 times in luminosity. This suggests that great care must be exercised in attempts to use SNe Ia for the calibration of the extragalactic distance scale.

4. QUASARS

Hutchings, Neff (GSFC) and Davidge have analyzed CFHT Redeye data of January 1996 to show that the low redshift quasars in their sample all appear to have companions with similar positions in the two-color diagram. Radio-loud quasars appear to be found in richer fields than radio-quiet ones. The results also indicate the stellar populations of the host galaxies and bright features within them. Among higher redshift quasars, they find evidence in support of galaxy clustering around two quasars, one at $z = 2$, and another at $z = 2.4$.

During the commisioning of PUEO, the CFHT Adaptive Optics Bonnette, Crampton, Hutchings, Morris, Schade and Steinbring (U. Victoria) were able to resolve irregular structure in some high redshift quasars, and to detail the structure in some low redshift quasars at both optical and near-infrared wavelengths. These results are currently being analyzed. Hutchings, Chaytor and Gower (U. Victoria) prepared high resolution VLA radio maps of quasar fields for publication. Hutchings continues to work with many colleagues at STScI, GSFC and JPL, as well as Timothy (U. New Brunswick), on HST observations of quasars.

5. GALAXIES

Using ground-based optical and infrared images, Courteau has shown that the formation process for spiral galaxies probably took place over a relatively long and continuous time interval and did not occur in a rapid sequence, as suggested by many collapse models. This postulated model of

secular evolution provides a mechanism to build-up central regions in late-type spirals, whereas mergers or accretion of small satellites could explain the brighter, kinematically distinct bulges of Sa and S0 galaxies. Still, kinematical information and abundances are crucial to pin down firmly formation scenarios of the bulge and disk in extragalactic spirals. Recent studies have relied on optical and IR imaging surveys to model their dust content and stellar populations. Without spectral information, however, the effects of dust, age and metallicity are degenerate. Courteau and collaborators are acquiring the relevant data on optical major-axis absorption line-strengths, emission fluxes, and BVRHK colors using CFHT and JCMT and constructing dust scattering models to enable the determination of the age and composition of extragalactic bulges. With these they will confront models of secular evolution versus the classical view that the spheroids of disk galaxies resemble ellipticals.

Davidge, Courteau, and Crampton plan to use the PUEO at CFHT to obtain deep, high spatial-resolution J, H, K, and 2.3 microns CO absorption images of the central regions of a sample of nearby galaxies. These data will be used to investigate the structure, stellar content, and chemical evolution of the inner regions of these systems. Specific emphasis will be placed on strengthening the link, recently highlighted in the optical domain by HST, between central properties and global characteristics such as shape, luminosity, and rotation.

Courteau released a compilation of 300 long-slit Hα rotation curves. He has shown that late-type galaxies define a fundamental two-parameter sequence and that the best measure of maximum velocity for Tully- Fisher analyses is found at the optical radius of the galaxy where luminous and dark matter contribute equally. These data will be used in a subsequent paper with Rix (Steward Obs.) to constrain the shape of halo profiles and to examine the fundamental physical parameters which govern the rotation of galaxies. Maximum mass models by Courteau and Broeils (Stockholm) for these galaxies also serve to constrain the structure of dark matter halos. They have shown that the disk mass-to-light ratio correlates weakly with total luminosity, but more strongly with the mass of the stellar disk. This finding contradicts the hypothesis of a universal halo for galaxies and clusters of galaxies.

Courteau, Sohn, and Faber (Lick Obs.) are carrying out the first careful intercomparison of galaxy rotation curves derived from [OII], Hβ, [OIII], Hα, and H I (21-cm) data. For this study, they developed a new technique to compare convolved rotation linewidths in high-redshift galaxies with resolved rotation curves from nearby ones. Several biases, such as the matching of rotation profiles in blue and red light, and at radio and CO emission wavelengths, are investigated. Their calibration should allow the study of galaxy dynamics and stellar populations in distant spiral galaxies, and provide a means to study the change in the mass spectrum of spiral galaxies as a function of time.

Over the past three years, Courteau and Holtzman (New Mexico State U.) have collected BVRH imaging for a uniform collection of 300 Sb-Sc spiral galaxies with a full range of inclinations. They are using these data to study extinction effects, dust content, and radiation transfer in spiral galaxies, as well as the variation of morphological and structural parameters of these galaxies in different wavelength regimes.

Marzke and Hudson (U. Victoria) carried out a program of deep UBVRI imaging of nearby groups and poor clusters to study the faint end of the galaxy luminosity function; in this project, they became the first outside users of the new Big Throughput Camera on the 4-m at CTIO.

Hutchings, with Crampton and Kaiser (Johns Hopkins U.), used MOS and later OSIS at CFHT to obtain spectra of galaxies in the fields of high redshift quasars. Most of the galaxies are found to be foreground objects, and work is in progress to examine the fainter galaxies.

Morris, Hutchings, Gray (WES) and Weymann (Carnegie Obs.) analyzed HST/GHRS high resolution ultraviolet spectra of NGC 4151, showing there are several high velocity outflows from this active galactic nucleus. The complex outflowing material showed very little change over the four year monitoring period, which sets limits on its location and density.

Penfold (Mt. Royal College) and Morris continue a collaborative study with the 1.8-m telescope to monitor the variability of a sample of bright active galactic nuclei.

Sohn and Davidge have investigated the luminous stellar contents of the nearby galaxies NGC 628, NGC 672, NGC 925, and NGC 1637 using *VRI* CCD images with subarcsecond spatial resolution from HRCam at CFHT. Two-color diagrams indicate that the majority of stars in these galaxies closely follow the Galactic supergiant sequence with spectral types between A and K. Theoretical evolutionary models and isochrones, which include effects of mass loss and overshooting from convective cores, have been fit appropriately to the color-magnitude diagrams of supergiant stars in those galaxies. The majority of supergiants in their fields have progenitor masses 10 - 60 $M_{\odot}$ and appear to be younger than $\sim$40 Myrs. The exponents of luminosity functions of NGC 628 and NGC 672 are in good agreement with what is seen in other galaxies. The exponents of *V* luminosity functions in NGC 925 and NGC 1637 are, however, shallower than those in other unbarred spiral galaxies, suggesting that the bar may affect star formation in these system. Based on the brightness of red supergiants, they derive distance moduli for these galaxies. Their success suggests that photometric studies of supergiant stars are important in a cosmological context, as they can be used to determine distances to Virgo and beyond.

Hutchings and Davidge have used deep J and K images obtained with the CFHT to investigate the star-forming histories of faint objects in the field of the z = 0.4 cluster CL0939+4713. They find that the spectral-energy distributions of these objects are consistent with the previous suggestion of Dressler *et al.* that they are high redshift objects.

Côté, Oke and Secker (Washington State U.) have used the Keck-I telescope to obtain spectra for an unbiased sample of $\simeq$ 100 candidate dwarf elliptical galaxies in the core of the Coma cluster. Ages, abundances and radial velocities derived from these spectra are being used to assess the role played by environment in the evolution of these low-luminosity galaxies.

Harris (U. Waterloo), Côté, Hesser and Worthey (Michi-

gan) have used the Argus multi-object spectrograph on the CTIO 4-m telescope to obtain spectra for globular clusters surrounding NGC 5128, the nearest giant elliptical galaxy. Age- and abundance-sensitive line indices measured from these spectra are being used to identify young and/or super-metal-rich globular clusters.

Van den Bergh has studied the distribution of all supernovae for which accurate spectral classifications are available. He finds that the radial density distribution of SNe Ibc and SNe II (which are thought to have massive progenitors) is well decribed by an exponential with exponent $-4.5R_{sn}/R_{25}$. SNe Ia appear to exhibit a slightly steeper radial surface density distribution. SNe Ibc may be slightly more concentrated towards the nuclei than are SNe II.

Côté, Marzke and West (Saint Mary's U.) have shown that the bimodal metallicity distribution functions observed for the globular cluster systems surrounding numerous supergiant elliptical galaxies can be decomposed into populations of metal-rich *intrinsic* clusters, and metal-poor systems of clusters which have been *inherited* through the merging and tidal-stripping of other cluster galaxies. This is in agreement with their 1995 model of intergalactic globular clusters. With Pritchet (U. Victoria), they have obtained deep CFHT imaging of the cluster Abell 1185 to search for intergalactic globular clusters near its X-ray center, which is conveniently displaced from the nearest bright galaxy.

6. LOCAL GROUP GALAXIES

Pritchet (U. Victoria) and van den Bergh have used CCD observations of resolved stars in the outer region of M31 to study the radial surface brightness gradient . Stars are found to have a surface density that drops as r^{-5}, which is much steeper than the r^{-3} dropoff observed for the globular clusters in M31.

Spectra and images were obtained of the local group galaxy NGC 6822 by Hutchings and Bianchi (Johns Hopkins U.). These are being used in continuing investigation of massive star evolution in different galaxy environments. The HST images are being analyzed for stellar populations, clusters, and nebulae in NGC 6822, M31, and M33.

Hutchings, Crampton, Cowley and Schmidtke (Arizona State U.) observed X-ray sources in the direction of the LMC and SMC detected in their ROSAT observations. Photometry and spectra were obtained at CTIO. The binary parameters of four supersoft sources in the Clouds have been derived and discussed. The observations also yielded several background active galactic nuclei and foreground, low-mass, hot stars.

Hesser, with his many colleagues in the HST program on star clusters in the outer halo, reviewed the formation of the Milky Way at the 7th Asian-Pacific Regional IAU meeting (Pusan). It appears likely that the Galaxy formed by a mixture of rapid dissipative collapse and mergers, but the relative contributions remain controversial. In particular, evidence from a careful comparison between the color-magnitude diagrams of two clusters with the same metallicity, NGC 2419 and M92, suggest that initial star and star cluster formation occurred simultaneously over a volume that presently extends to twice the distance of the Magellanic Clouds.

Van den Bergh wrote a review paper on the Formation of the Galaxy. He concludes that the inner region of the Galaxy was probably formed by the collapse of a single protogalaxy, but that mergers with, and capture of, ancestral fragments made significant contributions to the population of the outer Galactic halo.

In collaboration with Mendez (ESO), van den Bergh has started a program to study the proper motions of stars in the central bulge of the Galaxy.

Côté, Welch (McMaster U.) and Stetson have finished the photometric portion of their phase-space survey of the inner Galaxy, and have obtained radial velocities for $\approx$ 1400 stars (about a third of their sample). The remaining spectroscopic observations are scheduled to be carried out in the summer of 1997 using the WIYN telescope. Once completed, the survey will place limits on the role played by mergers in the formation of the Galactic halo and bulge.

7. GLOBULAR CLUSTERS

Van den Bergh finds that the luminosities of globular clusters, correlate with their half-light radii. This suggests that great caution should be exercised when using the luminosity distribution of globular clusters to obtain galaxy distances. In the outer Galactic halo, clusters with red horizontal branches are, on average, about ten times fainter than those with blue horizontal branches. The reason for this large difference is not yet understood.

Harris (McMaster U.) obtained Plaskett telescope images in V and I bands through service observing of the remote, sparse globular cluster Palomar 1. Recent evidence from other such clusters shows that many or most such objects are systematically younger by a few Gigayears than the bulk of the 'normal', luminous globular clusters. Do these objects represent simply a late stage of halo formation involving smaller, leftover gas clouds? Or are they due to infall and accretion of various dwarf galaxies (a recent example of which may be the Sagittarius dwarf with its small retinue of globular clusters)? Palomar 1 is possibly in this class, but no good age information for it exists.

Côté, Zoccali (U. Padova), Oke and Hartwick (U. Victoria) have carried out a search for dwarf carbon stars in the globular cluster M71 using deep narrow-band images obtained with the CFHT. Spectra for 14 of the most promising candidates have been obtained with the Keck II telescope. In collaboration with Allard and Alexander (Wichita State U.), these spectra are being used to measure the carbon-to-oxygen ratios of these low-mass stars.

Côté, Hanes (Queens U.), McLaughlin (McMaster U.), Bridges (RGO), Hesser and Harris (U. Waterloo) reported the serendipitous discovery of a CH star in the globular cluster M14. This means there are now three globular clusters which are known to contain 'classical' CH stars. It is likely that the M14 CH star is a spectroscopic binary with a white dwarf secondary. The low-concentration environments of M14, ω Cen and of the dSph galaxies where CH stars have been found may allow the long timescales necessary for the shrinking of compact binaries into coalescence.

Côté, Hill, Gulliver (Brandon U.) and Adelman (The Citadel) have obtained spectra for more than 100 horizontal

branch stars in the second-parameter pair of globular clusters M3 and M13 using the MOS spectrograph on the CFHT. These data are being used to test the possibility that mass loss and/or helium abundance are responsible for the disparate horizontal-branch morphologies of these two clusters.

Briley (U. Wisconsin, Oshkosh), Smith and Lambert (U. Texas), Suntzeff (CTIO), Bell (U. Maryland) and Hesser demonstrated from CTIO spectra of 20 stars below the turnoff in the metal-rich globular cluster 47 Tucanae that Na I features differ star-to-star. The Na range correlates with previously discovered CN band-strength differences. Either the gas out of which 47 Tuc formed was chemically inhomogeneous, or some mechanism for altering the surface element abundances of stars operates while they are still on the main sequence.

CFHT observations with an imaging Fabry-Perot on the Subarcsecond Imaging Spectrograph by Gebhardt (U. Michigan), Pryor and Williams (Rutgers U.), Hesser and Stetson led to radial velocity determination for 1534 stars in M15, including 144 stars within $10''$ of the center and 12 stars within $2''$ of the center. The velocity dispersion profile remains flat at 11 km s^{-1} from 0.4 arcmin to $0.02'$. Under the assumption of LTE, a number of 1.0 $M_{\odot}$ objects are estimated to lie in the central few parsecs. Rotation is detected, and behaves differently within the central $10''$ than throughout the entire sample. An increase in rotation amplitude, which needs confirmation, may be the result of a central mass concentration.

Richer (U. British Columbia) and colleagues, including Hesser and Stetson, completed their analysis of white dwarfs in cycle 4 HST observations of M4. They identify a sample of some 260 white dwarfs, from which they argue that their color-magnitude diagram, mean mass (0.51 ± 0.03 $M_{\odot}$) and luminosity function confirm basic tenets of stellar evolution and current white dwarf cooling theories. The sequence is still strong at the limits of their observations where the most ancient white dwarfs are $\sim$9 Gyr old. Analysis of the lower main sequence of the cluster is nearing completion under Fahlman's (U. British Columbia) leadership.

A catalog of results from the Las Campanas program to measure calcium infrared triplet strengths for 976 giants in 52 globular clusters has been submitted for publication by Rutledge, Hesser, Stetson, Mateo (U. Michigan), Simard (U. Victoria), Bolte (Lick Obs.), Friel (NSF) and Copin (ENS de Lyon). They combine their data with studies in the literature to provide a calcium index for 69 clusters. In a companion paper, Rutledge, Hesser and Stetson find a strong linear correlation between their calcium index and the Zinn-West metallicity scale, and a comparably strong correlation with the extensive recent work by Carreta and Gratton based upon high-dispersion spectra. The significant differences between these two scales raise important questions about our understanding of Galactic formation and chemical evolution processes. Moreover, caution, perhaps considerable, may be advisable when using the calcium triplet as a surrogate for metallicity, especially for systems where ranges in age and metallicity are likely.

Sandquist, Bolte (Lick Obs.), Stetson and Hesser presented BVI photometry for M5, a relatively nearby cluster they studied from CTIO. They determined B- and I-band luminosity functions for more than 20,000 stars, which is one of the largest samples ever constructed for such work. Extensive discussion of absolute and relative age issues highlights the difficulties caused by present uncertainities in [Fe/H] for M5, as well as for other clusters of roughly comparable metallicity.

Stetson continued his reductions of globular cluster images obtained both with the HST and with ground-based telescopes.

Philip (Union College) has been using DAO computer facilities and DAOPHOT/ALLSTAR, in consultation with Stetson, to reduce four-color and Strömvil data obtained at KPNO, CTIO and the VATT. CCD frames of several globular clusters have been analyzed with special attention to the horizontal branch (HB). With ALLSTAR, stars even in the core of a cluster can be measured, provided they are sufficiently brighter than the background. The HB stars have been found to occur in several natural groups: evolving to the blue, evolving to the red, stars (possibly binaries) much more luminous than the HB, and, recently, in M92, a group of stars about half a magnitude below the HB. Additional measures are underway at the VATT using the Strömvil system.

8. OPEN CLUSTERS

Stetson began a major program of scanning archival photographic plates of a number of clusters and nearby galaxies, to provide photometry over a wider field than is easily accessible to CCDs, and to provide early epochs for proper motion studies. Tian (Shanghai Obs.) scanned some Shanghai photographic plates of open clusters of NGC 1750 and NGC 2347 on the DAO PDS-based scanning engine as part of of this collaborative effort to derive proper motions plates and photmetry for those clusters.

Zoccali (U. Padova) carried out observations with the 1.8-m telescope to obtain Strömgren photometry and radial velocities for two open clusters, NGC 6866 and NGC 7142. She also reduced CTIO observations of the open cluster NGC 2287, in collaboration with Stetson and Harris (U. Waterloo).

McClure has continued radial-velocity observations of giant and subgiant stars in the old open cluster NGC 188, using the radial-velocity spectrometer at the coudé focus of the 1.2-m telescope. These velocities cover a time period approaching two decades. The binary frequency appears to be similar (20-25%) to other open star clusters, and a few binary orbits can be computed. The velocity dispersion in the cluster is very low, and obviously affected by long period binaries, but the data hopefully can be used to set limits on the mass of the cluster.

McClure has obtained CCD frames in B, V, and R colors of the old open cluster NGC 188 using the imaging focus of the Plaskett 1.8-m telescope. Color-magnitude diagrams are being constructed to compare with theoretical isochrones in collaboration with VandenBerg (U. of Victoria).

Wallerstein (U. Washington) continued to assemble spectra of the cool supergiants in the young double cluster, h and χ Persei. The data will be analyzed to derive the abundances

of elements and isotopes that are sensitive to nuclear reactions in the stellar interior followed by mixing to the stellar surface. The critical species are Li, ^{12}C, ^{13}C, N, O, Na and Al. Observations for Li, O, Na, Al and other metals are complete for six stars and are being extended to a number of others. The carbon isotope observations are being carried out largely by Smith and Lambert (U. Texas); the analysis will be carried out in cooperation with Smith, Lambert and Gonzalez (U. Washington).

9. BINARY STARS

McClure found that in a sample of 22 early R-type carbon stars observed at the 1.2-m telescope over the last 16 years, none has variable radial velocities that indicate binary motion. It is known that the R stars do not have the same abundance patterns, e.g. enhanced s process elements, as found in other stars where deep mixing occurred while on the asypmtotic giant branch. He concludes that R-type carbon stars were probably binaries with separations too small for evolution up the giant and asymptotic giant branches. Possibly the coalescence of these systems caused mixing of helium core flash material to the surface of the resulting star.

In the spring of 1995, Leahy (U. Calgary) initiated spectroscopic monitoring with the 1.8-m telescope of a set of six X-ray binaries with early-type companions, to obtain radial velocities. These will be used to search for orbital periods, expected to be in the range of 20-100 days, when enough data for each binary have been obtained. The observing is done primarily by the service observing offered to Canadian university professors.

Heiser (Vanderbilt U.) continued analysis of his photometry of V578 Mon, the eclipsing binary in NGC 2244. Data obtained at both the Dyer Observatory and at the KPNO from 1962 through 1981 have been combined with observations made with the Vanderbilt 41-cm automated photometric telescope in 1994 and 1995 to refine the primary period to 2.4084655 days. The timing of the secondary minimum varies in phase from about 0.45 to 0.55, with an indicated period of approximately 32 years.

Scarfe (U. Victoria) has continued to obtain radial velocity observations of binary and multiple stars with the 1.2-m telescope, chiefly with the radial velocity spectrometer (RVS), although photographic observations are still obtained for a small number of objects for which more accurate data over a long period are required. He also continues to obtain observations of IAU standard velocity stars, again mainly with the RVS. Several new spectroscopic binaries among the stars in the Bright Star Catalogue Extension have been identified and are being followed to determine orbital parameters. An analysis of the visual-spectroscopic triple system HD 202908 has been completed. The radial velocities of all three stars in the system have been followed for the past twenty years, covering periastron in the long-period orbit. The DAO data have been pooled with velocities from McDonald and Kitt Peak (Fekel), CORAVEL (Duquennoy) and Crimea (Tokovinin) and with visual and speckle observations, the latter primarily from CHARA (McAlister, Hartkopf and Mason). The analysis, performed in Victoria by Barlow, yields accurate masses and luminosities for all three stars. Scarfe has also measured a series of photographic spectra of the primary component of the multiple system μ Orionis, which cover more than a full cycle of the long-period orbit. Another collaborative analysis is planned for that system.

Elizabeth Griffin (Oxford U.) used the 1.2-m telescope to make phase-critical observations of certain composite-spectrum binaries, and to seek out DAO's extensive collection of historical spectrograms of one of the most famous of them, 31 Cyg. Nearly 500 photographic spectrograms of 31 Cyg (mostly relating to the chromospheric eclipses of 1951 and 1962) are being scanned and analyzed by her.

Grant Hill continues a long running program studying WR+O binaries using high S/N, moderate resolution spectra obtained with the 1.8-m telescope. This project, started in 1986 with Underhill (U. British Columbia), has allowed the determination of improved orbits for a number of systems. Phase coverage for some of the longer period systems is nearing completion. Besides obtaining improved orbits, Hill and Underhill are using this data set to study wind-wind collision effects.

Kijewski (U. Calgary) obtained 1.8-m telescope observations of the radial velocity of RT Lacertae for use in a new light and velocity curve solution of this binary system for his MSc thesis.

Shadbolt (U. Calgary) obtained deep CCD images of the cluster NGC 6791 with the 1.8-m telescope. Her multi-passband observations of the variable stars of this old galactic cluster yield light curves being analyzed for her MSc thesis.

In 1994, Harmanec (Ondřejov Obs.) organized and coordinated an international observing campaign of the well known peculiar binary β Lyræ involving the optical spectrointerferometer at Observatoire de la Côte d'Azur (France), as well as DAO telescopes and others. An excellent series of spectra secured here by Walker, Jiang (both U. British Columbia) and Yang (U. Victoria) combined with interferometric, spectral and photometric data from other sites led to the discovery of bipolar jets in the system. These are centered on the point of apparent impact of the gas stream between the components onto the dense part of the accretion disk around the more massive component. This published result generated considerable interest, and was reported as one of several significant achievements in the annual report of the Academy of Sciences of the Czech Republic for 1996.

10. STELLAR PULSATIONS

Holmgren and Harmanec (both Ondřejov Obs.), in collaboration with Yang (U. Victoria), used the 1.8- and 1.2-m telescopes to pursue an observational study of a number of early-type binary star systems. This project, known as SEFONO (SEarch for FOrced Nonradial Oscillations), is unique in its quest for line profile variability (LPV) which could be induced by mutual tidal forcing. Since current theories of nonradial pulsation are incomplete, it is felt worthwhile to explore the possibility that orbital forcing may be a cause of nonradial pulsation evidenced by LPV. So far, their search for LPV in early-type binary systems has been highly successful, with the DAO instruments playing often the crucial role, but always supported by Reticon data obtained at

Ondřejov. They have identified line profile variability in the systems V436 Persei, AR Cassiopeiae, and ρ Aurigae. Line profile variability was discovered in AR Cas during the July/August observing run. In the case of ρ Aur, a possible line profile variation period of about 2.8 days has been identified. Variations on this timescale could not have been determined from a single facility: the longitude difference between Ondřejov and Victoria has removed the aliasing effects which would otherwise be present in such data. Advantage of the long-interval data sets has been taken also in their studies of the binary system ι Orionis and the Be star δ Scorpii. The work on SEFONO has been reported in November 1996 both at the Tatranská Lomnica, Slovakia meeting on 'Physical Processes in Interacting Binary Systems', and at the meeting of Czech variable-star observers held in Brno.

Milone and Wilson (both U. Calgary) continued analysis of high amplitude δ Scuti stars using RV and some IR data from DAO. The data and image analyses of DY Peg have now been completed with a preliminary Baade-Wesselink radius of 2.31 ± 0.13 solar radii.

11. STELLAR SPECTRA

Since joining HIA, Bohlender has begun several programs on the 1.2-m and 1.8-m telescopes. Spectroscopic studies of long period (>6 days) Ap stars are well matched to his access to the 1.2-m telescope. In collaboration with Grant Hill, he is using the high quantum efficiency, thin CCD's to conduct a high S/N, high resolution study of several interesting long-period Ap stars.

In support of a similar CFHT program by Bohlender and Gonzalez (Lyon), Bohlender and Grant Hill are also obtaining phase-resolved spectra of C, N, and O lines in bright Ap stars with the 1.2-m telescope. Gonzalez has conducted a theoretical investigation of the radiative accelerations on these important elements in A-type stars. The goal of the DAO study is to compare observed abundances and abundance geometries of CNO to those predicted by Gonzalez theory. Non-variable Am, HgMn, and λ Boo stars are being included, as time permits.

Bohlender is collaborating with Walker and Matthews (UBC) and Yang (UVic) in a search for intrinsic variability in 51 Peg and other solar-type stars which show evidence for companion planets. Data are being obtained on the 1.2-m telescope to support CFHT runs. This project developed as a result of Gray's (UWO) recent discovery that 51 Peg shows line bisector variations with the same period as the radial velocity variations published earlier. This suggests that the radial velocity variations are likely not a result of reflex motion caused by an orbiting low-mass companion, but instead arise from intrinsic variability of the star itself.

Bohlender, Adelman (Citadel), Bolton (DDO), and Grant Hill have completed spectroscopic, polarimetric, and photometric investigations of the helium-strong star, δ Ori C, and the helium-weak stars, HD 35502 and 36 Lyn. Three papers in preparation describe the Hα emission variability seen in these peculiar stars.

Grant Hill with Marchenko, Moffat, Eversberg, Morel (all U. de Montréal), Tovmassian (IdA, Mexico), Antokhin (SSAI, Moscow), and Seggewiss (Bonn) completed a program of simultaneous photometry and spectroscopy of WN8 stars with a number of telescopes around the world, including the DAO 1.8-m telescope. Among the 'late-type' WN stars these stars consistently reveal the highest degree of intrinsic variability among all WR stars, whether in photometry, polarimetry, or spectroscopy. Are we seeing low-mass orbiting companions, pulsations or rotation of the WR star, blob ejection, or some combination of these? Until now, spectroscopy has not been extensive enough to say. The data obtained seem to indicate that the stellar core of these stars plays a leading role in structural variations within the wind.

Grant Hill is using the 1.2-m telescope and coudé spectrograph to obtain spectra of rapidly rotating A-type stars to investigate how high in $v \sin i$ one can perform reliable abundance analyses. Diffusion theory predicts that meridional circulation should prevent abundance anomalies from becoming established for a rotational velocity of about 100 km s^{-1}. This facet of the theory remains untested because of the difficulty in determining abundances from broad-lined stellar spectra.

Adelman (The Citadel) continued his studies of sharp-lined normal and peculiar main-sequence B, A, and F stars based primarily on 2.4 Å mm^{-1} observations obtained with the 1.2-m telescope. With Ryabchikova (Russian Academy of Sciences), and colleagues, he continued investigations of binary stars with HgMn primaries and participated in an analysis of the magnetic CP star γ Equulei. The binary star studies show how the abundances of the components change as a function of effective temperature. The magnetic studies show the importance of being able to include magnetic effects when deriving the abundances. With Caliksa (Istanbul U.), he investigated the abundances of three moderately sharp-lined early A stars which are marginally metal rich. Together with Bolcal and Kocer (Istanbul U.), they studied the sharp-lined F2 V star σ Boo which they found to be marginally metal-poor and improved previous analyses of two Am and of two F stars. Spectra of B, A, and F stars which belong to the Ursa Major Cluster, as well as possible Ursa Major Stream stars, were taken to derive radial and rotational velocities. These data will be used in connection with Hipparcos satellite measurements to determine cluster membership and physical properties for the stars.

Using the 1.2-m telescope and the UBC long detector, Larson (U. Washington) and Greimel (U. Victoria) obtained high quality spectra ($S/N \geqslant 600$) of the infrared Ca II triplet region of a magnitude-limited sample of over 100 G-K-M giants. These spectra will be compared to synthetic spectra to derive the effective temperatures, surface gravities, metallicity, and elemental abundances of the giants. When combined with improved parallaxes from Hipparchos data and angular diameters derived from the infrared-flux method, the surface gravity values should give more accurate mass determinations for a large number of stars whose masses are notoriously difficult to derive. This study follows the completion by Larson of her Ph.D. thesis from similar DAO-based data.

Gulliver (Brandon U.), Graham Hill and Adelman (The Citadel) have restructured their joint program to reflect two aims: to determine astrophysical *gf* values, and to study stars in clusters and associations. Grant Hill, Younger, Hubeny

(NASA-GSFC) have joined these efforts, with the additional participation of Perry (formerly LSU), Cowley (U. Michigan), and Fuhr (NIST). The oscillator strengths are being improved from high signal-to-noise CCD and Reticon spectra at 2.4 Å mm^{-1} of late B to middle F type stars. Fine analysis of the photographic region spectrograms of three primary sharp-lined stars (observed with S/N $\geqslant$500), o Peg, γ Gem, and Procyon, is well underway, which will be followed by a more detailed spectrum synthesis study. Although non-LTE effects are expected to be small, they will be taken into consideration. Systematic oscillator-strength problems will be corrected and then checked using a larger number of stars with S/N$\geqslant$ 200 spectra. This work should lead to a reduction in the systematic errors in the abundance analyses. This is especially important for the analyses of those stars whose lines are broadened by rotation.

12. ASTEROIDS & COMETS

Aikman, Dossa (NRC-WES) and Balam (U. Victoria) reported a total of 1260 astrometric positions of minor planets and comets from 1.8-m telescope observations to the Minor Planet Center during 1996. During the first three months of 1997, observations by Balam and Aikman resulted in the issuance of 14 *Minor Planet Electronic Circulars* (of the 47 Circulars containing astrometric positions issued during this interval) by the Minor Planet Center of the IAU. This program is conducted jointly with the Climenhaga Observatory of the University of Victoria.

Among the recently-discovered, potentially dangerous objects observed with the Plaskett Telescope are 1996 JA1, 1997 AE12, 1996 BQ, and 1997 BR, with estimated sizes of 300 m, 800 m, 1.0 km and 1.4 km, respectively. 1996 JA1 was monitored just prior to its passage at 0.003 AU from Earth on May 19, 1996, the closest approach yet recorded for an object of this size. At another extreme of distance, 1997 AE12 was observed at a distance of 1.57 AU from Earth while at V$\sim$21.4. This observation followed its initial discovery by the Spacewatch team at Kitt Peak, whose observations suggested the object was Earth-approaching by its peculiar motion in elliptical co-ordinates. The DAO observations allowed the first orbital solution for the object, which was found capable of approaching the Earth to within 0.037 AU in its present orbit. Unfortunately, further follow-up observations of this particular object have been lacking. 1997 BQ (discovered at Kiso) and 1997 BR (discovered at the Beijing Observatory) have been objects of ongoing close scrutiny in this program, as these objects can approach the Earth to within 0.035 and 0.014 AU, respectively.

Balam automated the software required to permit almost-real-time reduction of multiple exposures with the Plaskett Telescope of objects to V$\sim$22, whose orbital motion limits individual frame exposure times to a couple of minutes or less, which is generally the case for all asteroids that are Earth approaching. Images are dynamically shifted and stacked to reduce sky noise, allowing the detection of faint moving objects as point sources, while producing trailed images of the reference stars. However, the positions of the astrometric standard stars are easily measured as point sources from the first frame of the series since the shift is known for all subsequent frames. This method holds great potential for the recognition of faint Earth-approachers near aphelion, when they are most likely to be detected by the current search techniques employed at other observatories, as was the case for 1997 AE12. Use of these reduction scripts simultaneously solves the problems of object motion and background sky brightness, and allows useful astrometric observations to be taken over almost any phase of the lunation cycle.

Balam has implemented the use of the newly-issued USNO-SA1.0 astrometric catalogue, which may be considered to be the optimal catalogue for astrometric reductions with CCD field sizes typical of intermediate-aperture telescopes (like our 1.8-m). The advantage of this catalogue is its high star density (averaging 30 stars per CCD frame), spatially uniform distribution, and suitable magnitude range.

13. DAO TELESCOPES

The 1.2-m McKellar telescope was used for astronomical observations for 1325 hours on 209 nights during the reporting period. This compares with an average of of 1390 hours on 210 nights over the past 12 years since digital detectors largely supplanted photographic plates at the foci of the spectrographs. The subscription factor was 133% averaged over the fiscal year, and 156% for the two quarters with highest probability for clear skies. This year, CCD detectors were used on 72% of the useable nights, the Radial Velocity Scanner on 22%, photographic plates on 4%, and an infrared array detector on 2%. Of the 355 nights originally scheduled on the telescope, 25% were assigned to projects lead by staff members, with the remainder going to other Canadian (42%), American (20%) and overseas (13%) scientists as principal investigators; 30 scientists, including 6 students, were involved with the 23 visitor projects. Three thesis projects and one project co-ordinated with space observations were supported.

The 1.8-m Plaskett telescope was used for astronomical observations for 910 hours on 157 nights. These values are 22% and 20% below the average values for the past dozen years in reflection of unusually cloudy winter weather which affected the photometric programs that now dominate useage of the telescope. The subscription factor was 101% averaged over the fiscal year, and 114% for the two quarters with the highest probability for clear skies. The telescope was used in imaging mode 62% of the nights, exclusively with a CCD detector except for two nights when an infrared array was employed. The remaining 38% of nights employed a CCD detector at the Cassegrain spectrograph focus. Of the 361 nights originally assigned on the telescope, 63% went to non-staff Canadians and 10% to overseas scientists as principal investigators, and the remaining 27% to staff astronomers. Thirty-six scientists, including 14 students, were involved with the 22 visitor projects. Five thesis projects and one project co-ordinated with space observations were supported.

Morris and Saddlemyer coordinated the acquisition of new ‘bare CCD’ guide cameras for the DAO 1.8- and 1.2-m telescopes. Saddlemyer and Wong designed and implemented the control system for their use in acquisition and

guiding on both telescopes. The cameras are installed and functioning very well. Saddlemyer and Wong also implemented an interface for writing data from the telescopes to CD-ROM for archival purposes, obviating the need to make tape copies for the telescope archive.

At the close of the report year, delivery was accepted of a new flat secondary mirror for the modified Newtonian focus of the 1.8-m telescope. The new mirror has a polished nickel surface with a protected aluminum reflective surface. This will result in improved image quality and reduced scattered light compared with the present diamond-turned aluminum mirror in use since 1991. The protecting surface is a hard coating of silicon dioxide and can be cleaned *in situ*. This project has been overseen by Saddlemyer.

He also monitored the contract to obtain a set of 1.2-m coudé mirrors multi-layer dielectric coated for high reflectance ($\geqslant$99%) from 5000 Å to 9000 Å, to improve the throughput to the telescope focus. With these hard coatings, the mirrors can be cleaned *in situ* for optimal perfomance.

A number of detector changes have occurred or are imminent. The SITe-1 CCD failed, and Saddlemyer and Leckie replaced it by a geometrically identical but cosmetically superior chip named SITe-3. Saddlemyer oversaw the purchase of an engineering grade 4K $\times$ 2K CCD. This device is a thinned, backside-illuminated chip with a good region of 4096 $\times$ 900 pixels which is sufficent for the focus of the 1.2-m coudé spectrographs where it will be employed. Grant Hill has characterized and calibrated an experimental 4096 $\times$ 200 thinned CCD detector built by Walker and Johnson (U. British Columbia). This detector has subsequently been used for observations with both the DAO 1.2-m and the CFHT 3.6-m telescopes, but will not be officially commissioned here.

Gulliver (Brandon U.) has expended considerable effort in learning about the characteristics of the SITe-2 CCD, which replaced the Reticon as a prime detector at the 1.2-m coudé focus. His study has resulted in a new estimate of $\sim$3.5% for the scattered light of the 96-inch camera, although the exact value is variable in a systematic manner along the dispersion. In the high S/N regime in which stellar astronomers are now operating, removing such systematic effects are important for high quality analyses. Software is being developed by Hill and Gulliver to optimize the reduction of CCD spectroscopic observations.

McClure is the DAO contact person for the construction of a near infrared camera by the Université de Montréal group led by Daniel Nadeau. This camera is a clone of the MONICA infrared camera used at the Mont Mégantic and the CFH Telescopes, and will operate at the modified Newtonian focus of the 1.8-m telescope.

The shutter of the 1.2-m telescope dome suffered a major failure. Szeto and Bond worked with a Victoria firm, United Engineering, to implement a repair that should provide more reliable operation in future.

14. COMPUTER SYSTEM & LIBRARY

A complete rewiring of the voice and data communications network throughout the various buildings on the Observatory site was completed in May 1996. Over 30 km of new cable were installed. This has enhanced the reliability and flexibility of our computer network, while providing a communications infrastructure whose capacity will hopefully suffice for the next 20 years.

The HIA administration and JCMT groups from Ottawa were integrated into the newly upgraded and expanded Victoria network. DRAO was linked to Victoria using the BC-Tel Ubiquity (ATM) network with a fractional T1 link. This replaced their Internet and NRC WAN link formerly through Saskatoon at 56 kbps. The Victoria NRC WAN link remains at a problematic 56 kbps. The Computer Group now provides partial support to DRAO, and several trips were made to Penticton during the report year.

To support a unified HIA email system and a transported (from Ottawa) hia.nrc.ca Internet Domain, a dedicated Domain Name System and email server were established in Victoria and changes to fully implement a switch to the format, Firstname.Lastname@hia.nrc.ca, for all of HIA were nearly complete at fiscal-year end.

Various upgrades and installations were done. Notably, for the CADC, a second 500 CD jukebox and a Sun Ultra 2 (for its Gemini DHS contract) were installed, while, for the DAO, memory and disks on all compute-servers and a faster CPU in one compute-server were installed. A tape server separate from the main NFS Unix server to host some user tape drives significantly improved the reliability of the main NFS server. A second 10/100 Mbps ethernet switch was installed, as were 100 Mbps ethernet interfaces on several Unix servers. This brings 100 Mbps network connections to most server-class Unix machines, as well as more expandability and upgradeability for the future. Several of the most critical servers were protected by installing uninterruptible power supplies, the need for which was dramatically demonstrated by significant power problems during the Christmas shutdown and other winter storms.

A major reorganization and expansion of the library occurred with the transfer of the library materials from the HIA collection in Ottawa to Victoria. A new web-based library catalogue software system was implemented by Nayani. It is called ‘libsearch’, and replaces the old ‘libcat’ system.

15. CANADIAN ASTRONOMY DATA CENTRE

The CADC software system is now entirely based on the World Wide Web (WWW). Through Durand’s efforts numerous tools have been designed and implemented for the community. On average, there are about 3000 requests a day. More than 30,000 different computer hosts were served last year. The average WWW traffic (not counting astronomical images) is 40 Mbytes per day. For the past year, more than 10 Gbytes of data were transfered through the WWW, while a total of 90 Gbytes of astronomical data were retrieved. More than half a million results were retrieved from CADC databases. Data retrieval grew nearly a factor two over that of the previous fiscal year. The Royal Greenwich Observatory now uses the CADC WWW system for its La Palma archive, while the Royal Observatory Edinburgh uses CADC tools for the United Kingdom InfraRed Telescope archive.

HST Archive Activities: A financial arrangement with the Canadian Space Agency continues to enable CADC to ac-

quire the HST data, and to support partially the distribution to clients.

During the report year, all CADC staff actively supported the new HST archive tools. Since April, 1996, the CADC has offered its ''recalibration on the fly'' for the HST archive. This innovation allows users to retrieve data that are recalibrated with the latest generation of software and calibration files. The system was cloned for the ST-ECF (HST European Coordinating Facility, Garching). STScI is considering offering it to its users. In order to make ''recalibration on the fly'' possible, the CADC migrated all raw HST data to CD-ROMs which allow the entire archive to be on line around the clock from a juke box. So far, about 50 CDs for post-COSTAR data and 20 CDs for pre-COSTAR data have been produced. Because this effort relies on having the latest IRAF/STSDAS software, CADC maintains those packages for HIA.

Late in the fiscal year, Schade and Durand began the design and implementation of pipelines for processing data from the new instruments (STIS and NICMOS) installed during the February, 1997 servicing mission. Two STScI software engineers visited CADC to study the CD pipeline software developed here. CADC also continues to generate the preview images used by the ST-ECF and the STScI database browsers that allow users to get a compressed version of the original science images in order to judge data quality, thereby making the retrieval process more efficient.

CFHT Archive Activities: The following instruments are supported for the CFHT archive: Gecko, MOCAM, FOCAM, HRCAM, MOS, MOSFP, REDEYE, SIS, and SISFP. An elementary reduction pipeline was put in place for direct imaging instruments and some previews were generated. Some scripts were written with the help of John Glaspey to reduce automatically the coudé f/4 data. Bohlender is now primarily responsible for CADC's efforts on the CFHT archives.

CFHT no longer provides data to CADC on optical disks, so that a more labor-intensive effort is now required to read their exabyte tapes onto optical disks. A CD-ROM production pipeline is nearing completion for the CFHT archive. A major effort by Gaudet, Stevens and Durand was necessary to correct faulty RUNID parameters in the FITS headers; retrieval of datasets based on RUNID will soon be possible.

JCMT Archive Activities: Gaudet and Cockayne implemented the JCMT catalogue, which will be updated every six months. It includes all data for the past 10 years. The spectra themselves are being put on CDs and should soon be available for public browsing. The CADC archive system is also being used at the JCMT headquarters in Hilo for internal use.

European Southern Observatory Activities: ESO contracted the CADC group to develop a prototype for the data storage system for the Very Large Telescope. The successful design by Gaudet and Dunn was released in February, and a final release is due in June, 1997.

Second Generation Digitized Sky Survey (DSS): At STScI request, CADC duplicates for six partners the CDs containing images from the second version of the Digitized Sky Survey produced by STScI. The project, led by Durand and Fisher, will require some five years to complete and $>$3600 CDs will be written. CADC retains a copy for use by its clients. To date, some 150 original CDs have been duplicated.

SKYCAT Software: Durand is a member of the development team for SKYCAT at ESO. SKYCAT implements a new common URL interface between data providers (CADC, ESO, ECF and CDS) and allows image display and catalogue overlays.

Processed Datasets: Since joining CADC, Schade has focussed on integrating processed datasets (as opposed to raw datasets) into the CADC environment in order to offer a more highly refined product that will make the archival investigation process much more efficient. This involves developing automatic procedures to pre-process and combine data, as well as web-based tools to evaluate data quickly and to analyze them. He is also working to offer reduced and analyzed survey data to CADC users.

16. CFHT INSTRUMENTATION

PUEO, the CFHT Adaptive Optics Bonnette, was delivered to CFHT in early 1996 and was installed on the telescope in March of that year. In commissioning tests, it delivered diffraction-limited images almost immediately, and has performed almost flawlessly ever since. Crampton, as co-Principal Investigator, assisted in the on-telescope commissioning tests from April to September 1996.

Crampton and Roberts participated in the successful commissioning of the OSIS spectrograph at CFHT in May, 1996. OSIS is an upgrade of the MOS/SIS instrument, with optics designed by Morbey, and provides fast-guided multi-slit capability in the non-thermal near infrared, as well as in the visible wavelength region.

Morbey made a number of optical designs for a prime focus corrector (with and without an atmospheric dispersion compensator) for the proposed CFHT Megacam project. Crampton, Roberts and Szeto particpated in the conceptual design and cost estimate studies of Megacam.

Morbey made a number of large (up to 12-m) telescope designs for a study on replacing the 3.6-m mirror of CFHT.

17. GEMINI - GEMINI MULTI-OBJECT OPTICS SPECTOGRAPH (GMOS)

Crampton and Murowinski, continued as co-project scientist and manager, respectively, of the Gemini Multi-object Spectrograph (GMOS). The GMOS design went through a very successful Preliminary Design Review at the DAO in March, 1996 and an equally successful Critical Design Review (CDR) at ROE in February, 1997. The latter was attended by T. Bond, B. Leckie, R. Murowinski, S. Roberts and K. Szeto from the DAO GMOS team.

Leckie continued his work on the Gemini Multi-Object Spectrograph (GMOS) control system. He headed the control system design team and produced the schematics for the computer control system and the fore-optic mechanisms. He performed laboratory evaluations of a number of the components that will be used in the GMOS control system. In conjuction with his colleagues at the Royal Observatory in Edinburgh, Leckie wrote the Electronics and Control section of the GMOS CDR document.

Szeto coordinated mechanical engineering design work between DAO and our UK partners, ROE and Durham, performed FEA structural analysis on components where flexure is critical in the focal plane area; designed an efficient focal-plane support structure that meets stringent mass, space envelope and flexure specification; performed heat transfer and thermal stress analyses to determine the survivability of optical elements when subjected to a sudden temperature change, i.e. transports from the cold telescope floor to the warm instrument preparation room; performed cost and schedule estimates for design, fabrication, installation and testing; and prepared documentation for, and participated in, the CDR.

Roberts designed the handling system for the GMOS slit mask and integral field unit, on Instrument Wavefront Sensor and a concept for a fibre feed to the Gemini High Resolution Optical Spectrograph (HROS) from GMOS.

Morbey undertook the optical design, tolerance specification, and scattered light and ghost calculations for the GMOS optics. Redesigns were necessary due both to alterations in the scientific requirements, and decisions by glass manufacturers to discontinue various glass types. He and Tim Bond specified the new glasses for the GMOS optics. Bond also worked on the design of the atmospheric dispersion corrector, optical barrels, and the mounting of the optical elements in GMOS.

Saddlemyer contributed software design and documentation towards the GMOS.

Fletcher analyzed the effects on image quality due to initial alignment errors, dynamic alignment changes during observing and temperature changes, all with a view to setting tolerances for GMOS.

18. GEMINI - GEMINI ADAPTIVE OPTICS SYSTEM (GAOS)

Simon Morris was appointed Project Scientist for the Gemini Adaptive Optics System (GAOS), for which Herriot is Project Manager. The GAOS Operational Concepts Document and Functional and Performance Requirements Document were prepared by Morris and Herriot, and have passed a recent review. GAOS is scheduled for a Preliminary Design Review in October 1997.

Szeto participated in project planning, costing and scheduling of the mechanical design work; assisted in the structural design and layout for the new optical design; and assisted in the structural design and layout for the electronic enclosure.

Roberts acted as lead mechanical engineer on the design.

Saddlemyer began work on the preliminary design of the Adaptive Optics reconstructor system.

Fletcher analyzed the effects on image quality at the science focus of GAOS due to initial alignment errors and dynamic alignment changes during observing with a view to setting tolerances.

19. GEMINI - DATA HANDLING SYSTEM

The CADC is developing Gemini's Data Handling System (DHS). This object-oriented software runs primarily on UNIX and is responsible for accepting data from instruments and creating files, for elementary processing of the data, for providing visualization tools, and for saving data in a form suitable for archiving.

Project staffing in April 1996 included Gaudet as Work Package Manager, Crabtree as Work Package Scientist and N. Hill and Kotturi as software engineers. In May, Durand replaced Crabtree, in November Kotturi resigned, and in March Dunn joined the project. While the DHS is more than 50% done, the schedule has slipped because of Kotturi's departure.

Work on the Bulk Data Transfer prototype, begun in January 1996, was completed in June, when the software was released to the International Gemini Project Office for porting to the VxWorks operating System. Efforts on the DHS Preliminary Design began in June 1996 and were completed with the successful Preliminary Design Review held in Victoria on September 17. Finally, work on the DHS Core Track design and development began in September and is scheduled to finish in April, 1997. This track includes most of the general purpose libraries, the DHS library that all instrument software will use, the Command Server and the Status Server.

20. GEMINI - OTHER

Leckie has continued as the Canadian Project Manager for the Gemini Wavefront Sensor (WFS) Work Package. The Workscope for this project was signed in October 1996 after many months of negotiations. He presented the WFS CCD camera design to the critical design review panel (Sept. 1996). Subsequent to the CDR, he has supervised the testing of the small format CCD's that will be used in the WFS camera.

Roberts designed the packaging for the Gemini wavefront sensor CCD.

Fletcher designed the fore-optics on the pick-off arm that patrols the field of view at the telescope focus for the Gemini On-Instrument Wave-Front Sensor. The light is fed to a WFS with a Shack-Hartmann array and CCD. The effects of alignment errors and tolerances was included in the study.

21. INSTRUMENTATION - OTHER

Jennings and Bond aluminized a set of large, thin mirrors from the University of Regina Physics Dept., which were then shipped to Japan for use in an international project.

Morbey reviewed in detail the proposals submitted by two contractors for phases C and D of the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite project. Close communication was maintained with John Hopkins U., Goddard Space Flight Center, the Canadian Space Agency, and COM DEV (the prime contractor) with regard to many design aspects of FUSE. He specified the FUSE Fine Error Sensor calibration procedure and tolerances, and advised on the baffling system for the telescope.

Morbey designed a null lens for a proposed 3.6-m liquid mirror telescope.

Szeto coordinated activities among the mechanical engineers, designers and the machine shop; participated in evaluation and implementation of CAD hardware and software in order to streamline the work in the design office including:

PC, inkjet plotter, Mechanical Desktop and FEA software; participated in the planning and testing of the Instrument Group DateBase (IGDB) software; familiarized and trained engineers to use the Algor FEA software; assisted a new engineer and a new designer in their adjustment and integration into the design office; and acted as the general technical support person on AutoCAD, mechanical structure and FEA software.

Szeto participated in the technical discussion on the mooring concept and the reflector mechanism for the Large Adaptive Reflector (LAR) for radio astronomy.

Szeto also participated in the DEIMOS mechanical design review at Lick Observatory; at the Optical Telescopes of Today and Tomorrow conference at Landskrona/Hven; presented a paper on fabrication of narrow-slit masks for the Gemini Multi-Object Spectrograph and provided technical guidance to a group of UVic Mechanical Engineering students who were studying a novel actuation mechanism to perform linear and rotation motions which may be applicable to telescope secondary mirrors for tip/tilt and focus correction.

22. OUTREACH ACTIVITIES

Starry Messenger Communications (Don Moffatt and Fraser Chambers) were again contracted to perform many of these activities. During the year they conducted 100 tours for school groups (attendance: 2800), 25 tours for other groups (attendance: 500), and were responsible for the 25 Saturday night open houses between 1 April and 31 October (attendance: 5000). In addition, special programs were mounted during the report year for public viewing of Comet Hyakutake (attendance: 1000) and Comet Hale-Bopp (attendance: 200). The grounds and display gallery remained open to the public during office hours and summer weekends, and attracted a large number of additional visitors. During the Saturday evening open houses, Sandy Barta, Rick McCrea, Keith Rawcliffe, and Peter Schlatter formed a core group of volunteers from the Victoria Center of the Royal Astronomical Society of Canada who brought their telescopes to DAO and shared their knowledge and enthusiasm with members of the public. As in previous years, Younger volunteered many Saturday evenings to operate the 0.4-m telescope for public viewing.

HIA hosted Starry Messenger's WWW educational service, ScienceWeb (http://scienceweb.hia.nrc.ca), during the year. ScienceWeb developed a successful feature, the Hairy Star Party, for the two bright comets. They re-oriented their service during the year to provide a great deal of material to assist teachers with science themes in the news, and teachers responded by having their classes submit observations to ScienceWeb. Moreover, the Hairy Star Party is featured in Science Probe, the new grade 7 text for British Columbia. Other popular features they developed focus on daily science news, science in popular movies and television programs and a new section of geology and paleontology. Some five million visits or 'hits' were recorded during the year. CADC staff provided some technical advice.

Aikman maintained and expanded the DAO and HIA WWW pages during the year; these pages are meant primarily for HIA users and can be reached at http://hia.nrc.ca. Starry Messenger Communications implemented, under contract, some HIA pages designed for the general public.

The Ministry of Education, Province of British Columbia, is striving to expand work experience opportunities for secondary school students. Aikman, Hesser, Grant Hill, and Stetson supported 'day shadow students', while McClure and Saddlemyer hosted Pearson College science students. Côté and and Hesser continued their participation in the 'Scientists in the Schools' program, and visited many schools under its auspices. Hesser presented an invited paper on the latter program at a special session on education at the seventh Asian-Pacific Regional meeting of the IAU in Pusan, Korea. He also gave Shapley Lectures at Okanagan University College campuses in Salmon Arm and Kelowna.

23. MISCELLANY

The new HIA Advisory Committee conducted a site visit of the Optical Astronomy program at DAO on 16-17 December, and reported their findings. The committee was chaired by David Turner (St. Mary's U.), and has as members Claude Carignan (U. de Montreal), Leroy Cogger (U. Calgary), Eduardo Hardy (U. de Laval), Harvey Richer (U. British Columbia), and Christine Wilson (McMaster U.).

Aikman serves as an associate member of the Meteorite and Impacts Advisory Committee the Canadian Space Agency.

Batten has continued to work for the IAU as Chairman of the Working Group for the Worldwide Development of Astronomy. In April he visited El Salvador and Honduras, taking part in the Second Central American Course on Astronomy and Astrophysics in San Salvador and visiting the newly equipped Central American Observatory in Tegucigalpa. In September, he took part in the Sixth UN/ESA Workshop on Basic Space Science in Bonn, Germany and in October he spent a week in Morocco, mainly at the Université Hassan II in Casablanca, where he gave a lecture and spoke to an undergraduate class.

Crampton continues to serve on the CTIO Time Allocation committee. He attended the conference ''HST and the High Redshift Universe'' in Cambridge, July 1996.

Dunn visited the ST-ECF to install the first release of the storage server developed at CADC for the VLT.

Durand was invited to participate in discussions in Tucson for the Gemini Science Operations Working Group, at RGO about the La Palma archive, and at Garching on three occassions for next generation archive facilities, the HST SM-2 mission and for Gemini/ESO coordination meetings. He also supported the 1996 Astronomical Data Analysis and Software Systems meeting (ADASS 96).

Gaudet attended two Gemini principal systems meetings, participated with N. Hill and Kotturi in interface definition meetings between the observatory control and DHS systems, and participated in the core instrument system beta review, all at the International Gemini Project Office. In addition, he attended the ESO-VLT/Gemini coordination meeting at ROE, installed at ST-ECF the first release of the storage server developed at CADC for the VLT, and supported the ADASS96 meeting.

Glaspey participated in the conceptual design review for the Gemini high-resolution optical spectrograph.

Hesser continued his service on the CFHT Board of Directors, as an Adjunct Professor in the Department of Physics and Astronomy, U. of Victoria, on the Board of Editors of the Publications of the Astronomical Society of the Pacific, and on the Council of the Royal Astronomical Society of Canada Victoria Center. He served on an NSF review panel for the NOAO, as part of which he chaired a site visit to CTIO and served on the site visit for nighttime astronomy in Tucson. He also served on an AURA directorial review committee. He continues to co-supervise M. Gim, an MSc student at U. Victoria.

Grant Hill gave a series of lectures at the Lester B. Pearson College of the Pacific on astronomical spectroscopy; he also co-supervises the senior thesis of one of their students.

Hutchings worked with the HST STIS team in preparing the instrument for launch, and designing verification and early science observations. These are proceeding at the time of writing. Hutchings worked on a concept study for a UV imaging satellite for the Canadian Space Agency (CSA), an HST instrument proposal, and three NASA UV imaging proposals or studies. Hutchings served on the XTE NASA proposal review panel. Hutchings, Morbey, Murowinski, and Hardy worked with CSA and their contractors on the Fine Error Sensor for the FUSE mission. Hutchings participated in FUSE science planning as a Canadian science team member. Grant Hill has worked with Hutchings on some of the STIS and FUSE tasks. Hutchings served on the CFHT Scientific Advisory Committee (SAC) and Canadian Time Allocation Committee (CTAC), and is chair of CTAC for 1997. Hutchings is organising a workshop on Megacam imaging science for the three CFHT communities. Hutchings has continued as library advisor, where a major task has been the transfer of the astronomy collection from Ottawa. Hutchings attended the ESO workshop on QSO host galaxies in Tenerife, and presented two papers, which will appear in the proceedings.

Marzke gave invited talks at Rome (Vatican Workshop), Heidelberg (Ringberg Workshop), as well as colloquia at Santa Cruz, U. Western Ontario, U. Toronto and U. British Columbia.

McClure continued as the chairman of the DAO Time Assignment Committee. He reviewed the role of binary stars in the carbon star phenomenon at IAU Symposium 177 held in Antalya Turkey in May of 1996.

Morris is chair of the Canadian Astronomical Society Optical and IR advisory Committee, and a member of the Joint Subcommittee for Space Astronomy. He is also a member of the Canadian Gemini Science Steering Committee, and served on the Cycle 7 HST TAC (AGN1 Panel). He is advising Mike Balogh, a U. Victoria PhD student, and taught part of a cosmology course at U. Victoria during spring 1997 with Courteau and van den Bergh.

Oke continues as Editor for instrumentation for the Publications of the Astronomical Society of the Pacific; during the past year he handled 50 instrumentation papers. He also is a member of the Selection Committee for the Henry Norris Russell Lectureship, and a member of the Institute Visiting Committee for the Space Telescope Science Institute.

Roberts particpated in a review of the DIEMOS spectrograph at Lick Observatory in May 1996. He also took part in the CFHT Megacam technical meetings in March 1997. He supervised students in the U. Victoria mechanical engineering design course (CFHT tip/tilt concept), and judged at their design contest.

Stetson advised Prismoid Consulting on quality assurance standards for the digital scanning of aerial reconnaissance photographs for the purpose of producing resource maps of British Columbia. During the year he has supervised or partially supervised UVic students M. Gim, R. Zingle, and R. Greimel, and worked with visitors M. Zoccali (U. di Padova), P. Lesaffre (E. N. S. de Lyon), and K. Tian (Shanghai Observatory). Stetson has become an affiliate member of the MACHO project, where he consults with team members on details of photometric analysis. Stetson's 'FIND' routine from DAOPHOT was applied by researchers at the STScI, Johns Hopkins U. and Georgetown U. Radiology Laboratory to the early detection of microcalcifications that may lead to breast cancer.

Van den Bergh participated in a debate on the extragalactic distance scale that was held to commemorate the 76th anniversery of the great Curtis-Shapley debate in the Smithsonian Institution in Washington D.C. He also received an honorary DSc degree from St. Mary's University in Halifax N.S., and was elected a Fellow of the American Association for the Advancement of Science.

24. HIA STAFF PUBLICATIONS

Papers listed in this section and the section following are those bearing a 1996 cover date; a few papers inadvertently omitted from previous reports are also included.

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This report covers the period from 1 April 1996 through 31 March 1997, while the publications are for the calendar year 1996.

1. PERSONNEL

The professional continuing staff of the Observatory comprises T.L. Landecker (Director), C.R. Purton (Deputy Director), L.A. Higgs, G.J. Hovey, J.D. Lacey, K.F. Tapping, A.G. Willis and W. Wyslouzil. D.R. Karpa, who had been filling Hovey's position while the latter was on study leave at the University of British Columbia, left the Observatory in April 1996. M. Davies joined the engineering group in July 1996 for one year. Four Research Associates are contributing to the Galactic Plane Survey - A. D. Gray, S. M. Dougherty (U. Calgary), B. J. Wallace, and L. B. G. Knee. The last two joined DRAO during the summer of 1996. J.A. Galt and R.S. Roger are continuing as a Guest Workers. M. Neuman (Okanagan University College) arrived at DRAO in September 1996, for a one-year sabbatical.

P.E. Dewdney, based at DRAO, is the Coordinator of Future Radio Telescope Initiatives for the Herzberg Institute of Astrophysics, and the activities of this program are reported elsewhere.

B.R. Carlson continues to work on the Space VLBI correlator project (supported by the Canadian Space Agency), along with W.T. Petrachenko (Natural Resources Canada, Ottawa) who has been seconded to the project. D.D. Wellborn completed his work with this project in October 1996, and T.A. Burgess left the project at the end of January, 1997.

D.A. Lyder (Ph.D candidate, U. Victoria) is completing his thesis research at the Observatory.

A.R. Taylor (U. Calgary) has made several visits to the Observatory over the year in connection with the Galactic Plane Survey.

2. INVOLVEMENT IN THE SCIENTIFIC COMMUNITY

S.M. Dougherty is a member of the Radio Astronomy Committee of the Canadian Astronomical Society (CASCA). L.A. Higgs, who served on the Board of Directors of CASCA as Past-President (1994-96), is also a member of its Radio Astronomy Committee and chaired (1993-96) a CASCA committee which allocated travel grants to scientists from the Former Soviet Union. He is also a member of the Canadian Time Allocation Group for the James Clerk Maxwell Telescope. C.R. Purton is also a member of the Board of Directors of CASCA. R.S. Roger is the Canadian 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), and is acting as Secretary of the Canadian National Committee of 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. He is also a member of the Canadian Science Team for the ODIN satellite-borne sub-millimetre telescope, a joint project of Sweden, Canada and France. A.D. Gray chaired the Scientific and Local Organizing Committees for the 1996 Naramata Summer School on the Interstellar Medium. 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. A.G. Willis serves on the Scientific and Technical Advisory Group for AIPS++.

Two staff members are Adjunct Professors at the University of Alberta: T.L. Landecker and A.G. Willis, while P.E. Dewdney is an Adjunct Professor at the University of Calgary and C.R. Purton is an Adjunct Professor at the University of Victoria. T.L. Landecker has been a member of the Board of Governors of Okanagan University College, and assumed the chairmanship of the Board in 1996. L.A. Higgs is a member of the B.C. Science Council (Okanagan).

3. TELESCOPES

DRAO is operated by the Herzberg Institute of Astrophysics (HIA) as a National Facility for Canadian radio astronomy. Two radio telescopes, the Synthesis Telescope and the 26-m Telescope, are available to outside 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.

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° and 8° at 1420 and 408 MHz) and good angular resolution (1.0 and 3.5 arcmin at 1420 and 408 MHz) which make 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.

In the summer of 1996, summer student Nathalie Robitaille (U.Laval), working with Gray and Landecker, produced holographic maps of the Synthesis Telescope antennas, following up on the earlier work of Kevin Douglas (1995 U.B.C summer student) and Brenda Lowe (U. Victoria winter co-op student). Robitaille demonstrated that Douglas's measurements were repeatable (yielding surface errors no greater than 3 cm) and that errors in antenna focus estimated by Lowe are potentially correctable. Anne Thorsley (U. Alberta M.Sc. student) will do further work on holography in the summer of 1997, with the aim of using this information to improve image fidelity.

Gray has been working with Knee, Landecker and Purton on the pointing of Synthesis Telescope antennas. Measurements were made in the summer of 1996 and were reduced over the winter. The preliminary assessment is that at present the pointing of the array as a whole is quite good, with rms errors of only 2.5 arcmin in hour angle and 3.4 arcmin in declination, both small compared to the 2-degree antenna beams. There is room for improvement, however, with individual antennas having rms errors of up to 7 arcmin. Removal of these errors will be required in order to aceive a target rms error of 1 arcmin. Knee is currently working on a physical pointing model to replace the current empirical look-up table of pointing offsets. This will hopefully improve pointing performance at declinations between those where pointing observations exist.

The bulk of the observing time on the telescope is devoted to the Galactic Plane Survey; 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 chris.purton@hia.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%. 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 director@drao.nrc.ca).

6. COMPUTER SYSTEMS

The computing power at the Observatory has been recently upgraded with the acquisition of two 200-MHz dual-processor Sun Ultra clones. These machines were purchased in order to speed up the processing of Galactic Plane Survey data. The remaining computer systems consist of a number of IBM RS/6000 workstations (two model 320Hs, two model 520s, two model 550s and one 58H), an SGI Indigo 2, and two VAX/VMS minicomputers which control the Synthesis Telescope. All the computers at the Observatory are connected by a local area network, which also supports numerous X-terminals and PCs.

Hovey, Willis, A.P. Hoffmann (computer-systems manager) and Davies have developed new UNIX-based control and data-acquisition software for the 26-m Telescope. This software runs on one of the IBM 520s. Real-time displays have been developed for inspection of the data collected by the 26-m Telescope. This new data-collection system interfaces with a new 512-channel spectrometer system, and has required the development of new post-observation software by Willis and Higgs for averaging and calibrating the H I data. Higgs is developing software which will take calibrated spectra and produce low-spatial-frequency data to be combined with H I observations collected by the Synthesis Telescope, as part of the Galactic Plane Survey.

The spectral-line data cubes generated by the Galactic Plane Survey contain a wealth of information but this is sometimes very difficult to visualize. G. Higginson (U. Victoria co-op student), working with Willis, developed programs, based on *tcl/tk*, that allow an astronomer to visually examine a data cube through interactive rotation or zooming of the data.

7. AIPS++

HIA 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 is doing beta testing of the initial release of this package.

8. IMAGE PROCESSING

Wallace has been investigating the best way to subtract the 21-cm continuum contribution from observed H I-line data. Traditionally at DRAO, one uses an average continuum image formed from two 7.5-MHz bands straddling the H I band but Wallace has found that noticeable residual bandwidth-smearing defects exist when this is subtracted from the line data. He has found that a better method is to create a quasi-continuum image by summing empty channels at the velocity ends of the H I data cube itself.

Together with Willis, Wallace has successfully extended the application of the **modcal** algorithm so that artefacts created by bright confusing sources, such as Cygnus A, that lie outside the direct field of view can be successfully subtracted from line data.

9. INSTRUMENTATION

The requirements of the Galactic Plane Survey stimulated a number of improvements in the instrumentation of the Synthesis Telescope and the 26-m Telescope which have been more or less completed in 1996. These have been carried out mainly by the engineering and computing team of Davies, Hovey, Willis and Wyslouzil. Recent efforts have been directed towards software reliability in the Synthesis Telescope control system, in particular related to difficulties in the

position-control system in cold weather and problems arising from noisy encoder readings. Hovey and R. Casorso (DRAO technologist) have solved these problems.

During the period of this report, a new 512-channel autocorrelation spectrometer, similar to the spectral correlators for the Synthesis Telescope, has been brought into operation on the 26-m Telescope. The H I receiver has been modified to maximize dynamic range and linearity, new calibration arrangements have been installed, and the antenna aperture efficiency remeasured. The software and operating arrangements for the telescope and the new spectrometer are being modified to be compatible with the scheduling and data-handling arrangements used for the Synthesis Telescope.

A proposal to build a multi-beam spectral-line system at DRAO for the James Clerk Maxwell Telescope (JCMT) was accepted by the JCMT Board in November, 1996. The project will be a cooperative one between HIA and the Royal Observatory in Edinburgh. The spectrometer will ultimately support receiver systems with up to 16 beams on the sky in an ''imaging'' matrix, each producing a 2000-channel spectrum of nearly 2-GHz bandwidth. Used in scanning modes, this machine will enable observers to make high-resolution spectral-line images of large areas of sky. A parallel project at Cambridge University will provide an 8-element array at 345 GHz. The correlator will use components already developed by NRAO and others for the Green Bank Telescope. Hovey and Casorso have begun to evaluate these components for the higher bandwidth of the JCMT correlator.

10. THE GALACTIC PLANE SURVEY

Taylor (U. Calgary) is leading a consortium of 33 scientists from Canada and other countries who are carrying out a program of panoramic imaging of the northern Galactic plane in the radio continuum, infrared and H I and CO emission, using the DRAO Synthesis Telescope and other instruments. Observations at DRAO began in March 1995, with the intent of completely mapping, in a five-year period, a strip 8.5° wide in Galactic latitude along the plane from $l = 75°$ to $l = 147°$. This requires the observation of some 190 individual fields (each 2° in diameter at 1420 MHz). Images of these fields are being assembled into larger mosaic images, 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 Center, 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.

As of mid-March 1997, 36% of the Synthesis Telescope observations have been completed in 39% of the allocated observing period. During this same period, 15 fields outside the region of the Galactic Plane Survey have been observed for other users of DRAO.

The 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 peter.dewdney@hia.nrc.ca).

11. SPACE VLBI

Canadian participation in the VSOP and RadioAstron Space VLBI missions is continuing, funded mainly by the Canadian Space Agency. Dewdney is the Canadian principal investigator. The VSOP satellite, now called *HALCA*, was successfully launched from Japan in February, 1997, by the Institute of Space and Astronautical Science (ISAS). It has opened up to its intended 8-m diameter, and has begun to observe radio sources. Single-antenna tests at 1.6 GHz (18 cm), 5 GHz (6 cm) and 22 GHz (1.3 cm) have begun. The in-orbit check-out period – a progressive series of single-antenna and Space VLBI tests – will end in June, 1997. After that, routine observations will be phased in.

Canadian participation is a collaboration between HIA/DRAO, the Institute for Space and Terrestrial Science (ISTS), and the Dept. of Physics and Astronomy at the University of Calgary. Progress in Canada has been rapid over the past year with two new people now working on the program. The Canadian Space VLBI correlator, located at DRAO, has now been qualified for the mission. Test observations to qualify Ground Radio Telescopes (GRTs), equipped with S2 recording systems developed at ISTS, are currently being carried out. A delay of a few months is expected before the S2 recorders will be installed in all the NASA/DSN tracking stations, but tracking stations in Japan and Green Bank (NRAO) are expected to be available for the In-Orbit Checkout (IOC) phase of testing (April to June, 1997). During May to August, observations for the General Observing Time and the VSOP Survey will be phased in. A total of 56 observations are scheduled for the S2 system from April to August, 1997. Scheduling, image processing, and processing of Survey observations is being done at the University of Calgary. Further information can be found on the DRAO Web page (http://www.drao.nrc.ca) under the ''Space VLBI'' heading.

12. 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 H I images. Tapping is leading this program, assisted by Higgs and Knee. A detailed investigation of the sidelobe characteristics of the antenna will be carried out, after which a wide area of the Galactic plane will be sampled at an interval of about 0.3 beamwidths. The H I spectral data will then be corrected for sidelobe contributions before being incorporated into the Galactic Plane Survey images.

The 26-m Telescope has been less active than usual during 1996 and early 1997 while software modifications in

preparation for the Galactic Plane Survey observations have been carried out. Before that, it has been used for a wide variety of OH and H I investigations, and observations of methanol masers. In the course of Lyder's thesis research, he and Galt have discovered a new methanol maser source in Perseus. Galt has observed Comet Hale-Bopp in the OH line on a semi-regular basis since February, 1997.

13. POLARIZATION OF GALACTIC EMISSION

Analysis of the 1420-MHz polarization data from the DRAO Galactic Plane Survey Pilot Project (see Normandeau *et al.*, 1997, ApJS, 108, 279) has shown several new, interesting phenomena arising from Faraday-rotation effects on the diffuse Galactic synchrotron emission. A general mottled polarization spanning the full 8-degree by 6-degree field has been attributed to a magneto-ionic screen contrained to lie in the Perseus arm, probably coincident with the W3/W4/W5/HB3 complex. The W3/W4/W5 H II regions have been shown to have a large impact on the polarization, leading to depolarized zones on lines-of-sight passing through these objects – and in the case of W3 and W4 extending out into the halo surrounding these sources. This work has shown the value of high-resolution, wide-scale polarimetry in studies of the interstellar medium (ISM). Furthermore, comparison with work at 325 MHz indicates that different frequencies must probe different media, emphasizing the usefulness of multi-frequency studies in probing a range of ISM conditions. This work has been submitted for publication.

14. STAR-FORMATION REGIONS

Knee and Sandell (JAC, Hawaii) have observed the high-velocity molecular outflows from young stars in the NGC 1333 low-mass star-forming region. Their high-angular-resolution mapping in the CO (J=3−2) line with the JCMT provides the most detailed overview yet available of the outflows in the region. Several new outflows are identified, including a new highly collimated flow from the Class 0 protostellar object SSV 13b. This outflow is probably responsible for the excitation of the Herbig-Haro object HH 12. Other new Class 0 objects were found to drive highly collimated CO jets. Most of the deeply embedded pre-stellar objects driving outflows are wide doubles and are probably proto-binary systems.

Knee and collaborators from the University of Helsinki have made a multi-transition molecular-line study of the R Coronae Australis (R CrA) star-formation region using SEST (Swedish-ESO Submillimetre Telescope). They find evidence for rotational motion in the dense circumstellar ridge around the young object IRS 7, which they interpret in terms of an accretion disk. Certain kinematic features in the dense gas distribution can be interpreted in terms of a mass-transfer or accretion flow from one dense star-forming core to another.

Knee has mapped the CO (1−0) emission from the R CrA region using SEST. These new high-sensitivity and high-angular-resolution observations of the high-velocity outflowing gas reveal a very different situation to that assumed previously. Strong evidence is found for large wind-blown gas bubbles driven from within the cloud core and emanating probably from IRS 7. The Herbig-Haro objects are aligned with the bipolar structure, and provide further evidence that all of the mass-loss phenomena in the R CrA region can be accounted for by only one pre-stellar source.

Knee and Prusti (ISO) have detected a weak and clumpy distribution of CO (1−0) gas in the vicinity of the candidate pre-main-sequence (PMS) star HD 104237 and its common-proper-motion companion Epsilon Cha. Distance, velocity, and IRAS information allow the possibility that this tenuous dispersing molecular gas is the remnant birthplace of these stars, and lending support to the PMS identification of HD 104237. If so, the HD 104237 - ϵ Cha system may be a rare example of isolated intermediate-mass star formation.

Lyder has continued his thesis research, entitled ''Star Formation in Camelopardelis: Cam OB1,'' under the supervision of Purton and Gower (U. Victoria). A comparison of CO (J=1−0) emission with optically identified stars has established the distance to this star-forming region to be about 975 pc. Two distinct different stellar groups have been identified, one of older and more massive stars, and one of younger, less massive stars. They may be the result of a sequence of star formation related to dynamical interaction of two CO complexes.

Wallace, Routledge (U. Alberta) and Fich (U. Waterloo) are engaged in investigating an unusual H I feature found in Galactic Plane Survey data. It is double-lobed, has associated infrared emission, and has a velocity structure reminiscient of a bipolar molecular outflow. Observations of ^{12}CO in the region, made with the CfA 1.2-m telescope, show no evidence for molecular material associated with the feature. Further observations are being made to uncover the nature of this strange object.

15. PHOTODISSOCIATION REGIONS

Blouin (U.B.C. M.Sc. student) and McCutcheon (U.B.C.) with Dewdney, Roger, Purton and colleagues in the Netherlands have mapped the continuum and H I-line emission associated with the nebula Sharpless 185 which comprises two comet-shaped clouds, IC 59 and IC 63, illuminated by the star γ 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 γ Cas complex.

16. H II REGIONS

The nearby (750 pc) H II region IC 1396, which contains a number of dense cometary globules, was observed as part of the Galactic Plane Survey. Moriarty-Schieven, 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.

17. WOLF-RAYET STARS AND THEIR ENVIRONS

Dougherty has been involved in the study of non-thermal radio emission from Wolf-Rayet systems in collaboration with Williams (Royal Observatory Edinburgh) and van der Hucht (SRON Utrecht) Using the MERLIN array, the star WR 147 is resolved into two components; one is thermal in nature and is coincident with the WR star, and the other is non-thermal, and is closely associated with an IR point source. The IR source is identified as a B0 main-sequence star. They hypothesise that the non-thermal emission arises from Fermi acceleration of electrons in a region of shocked gas where the two stellar winds collide. This hot plasma also accounts for the X-rays from this system.

New high-frequency VLA observations confirm that WR 146 is a radio-double source, and like WR 147, has both a thermal and a non-thermal component. This system is also thought to be a colliding-wind binary. Of the four Wolf-Rayet stars that exhibit non-thermal emission, three are now identified with colliding-wind systems.

Arnal (Instituto Argentino de Radioastronomia) and Roger have analyzed Synthesis Telescope observations of the surroundings of the Wolf-Rayet star WR 3 (HD 9974). They find evidence of an ovoidal minimum in the H I distribution that may have been created by the joint action of the progenitor to HD 9974 and the WR star itself. A geometrical model fitted to these observations may explain some of the features seen in other interstellar bubbles related to WR stars.

18. RADIO SOURCES NEAR THE GALACTIC CENTRE

Studies of the polarization of G357.1-00.2 by Gray suggest that the rotation measure towards this object may be 4500 rad/m^2. Aside from extragalactic objects (such as Cygnus A), rotation measures of this magnitude have only been found in filamentary structures closer to the Galactic Center, such as G359.1-00.2 (''The Snake''; see Gray *et al.*, 1995, ApJ, 448, 164), a new study of which Gray is currently undertaking with M. Goss (NRAO-VLA). The high rotation measure on G357.1-00.2, which has a tangled filamentary structure, may indicate that it is a related phenomenon, or that it is embedded in a similar medium. Gray has also had contact with Cornelia Lang (UCLA graduate student), who is working with Goss and M. Morris (UCLA) on high rotation measures in the Galactic Center, with a view to expanding research in this field.

19. SUPERNOVA REMNANTS

Wallace, Landecker and Taylor (U. Calgary) have studied the candidate filled-center supernova remnant (FC SNR) G63.7+1.1 and its environment using WSRT continuum data, DRAO H I data, and FCRAO CO data. Both the morphology of the SNR and the distribution of the ISM around it suggest that there is an interaction occuring at the edges of the remnant. This result would appear to contradict the widely held belief that FC SNRs lie in low-density regions of the ISM. The results of this research are being prepared for publication.

Similarly, Wallace, Landecker, Taylor and Kalberla (U. Bonn) have used the DRAO Synthesis Telescope and the Effelsberg 100-m radio telescope to study the ISM around the Crab Nebula. The Effelsberg data, which cover a $4° \times 4°$ area, indicate that the Crab 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. These results are also being prepared for publication.

Wallace and Gaensler (U. Sydney) are engaged in mapping the unusual SNR G292.0+1.8 at several radio frequencies. This SNR is distinguished by its FC radio morphology combined with its thermal X-ray spectrum, prompting speculation that this object is a shell-type SNR evolving in an unusual environment. The highest resolution observations of this object ever made have been obtained and show little indication of limb-brightening. Information at a further two frequencies is to be obtained to investigate the polarization and spectral-index structure of this unusual remnant.

Roger and Leahy (U. Calgary) have been investigating the interaction of the bright supernova remnant IC 443 with the surrounding ISM through Synthesis Telescope observations of the continuum radio emission at 408 MHz and 1420 MHz. At 1420 MHz the strongest fractional polarization is confined to the less bright areas of emission, indicating a high degree of depolarization in volumes of high emissivity. The radio emission lends scant support for the existence of a second older remnant to the south-east of IC 443, suggested by the X-ray observations with ROSAT.

Leahy (U. Calgary) and Roger are studying the variations of the spectral index within emitting features of the Cygnus Loop SNR, using Synthesis Telescope observations at 408 and 1420 MHz together with published Effelsberg observations at 2695 MHz. Pronounced spectral curvature is evident, particularly in emission from the bright north-east rim. Studies of the polarization characteristics at 1420 MHz have been prepared for publication.

Pineault (U. Laval), Landecker, Swerdlyk (U. Guelph) and Reich (MPIfR, Bonn) have made new observations of the supernova remnant CTA 1 with the DRAO Synthesis Telescope, with higher sensitivity than earlier observations. A low-level extension to the north-west, suspected from the earlier observations, is confirmed. The extension is probably the result of breakout of the blast wave into a low-density region of the interstellar medium. The spectral index in the breakout region is higher than in the bright shell. This conclusion is supported by flux-density measurements at low frequencies, including a flux density at 22 MHz obtained from DRAO archives. The spectral-index pattern is similar to that seen in other breakout remnants. The spectral-index variation is interpreted as the result of a lower Mach number for the shock in the breakout region.

Landecker and Higgs, in collaboration with Zhang and Zheng (Beijing Astron. Obs) have obtained a flux density at 232 MHz for the supernova remnant G76.9+1.0. Combining this flux density with existing data at other frequencies indicates that the SNR has a spectral index of about 0.6 above 1 GHz with a possible break at about 1 GHz to a flatter spectral index below that frequency.

Zhang and Zheng (BAO), together with Landecker and Higgs, have made a new map of the very bright supernova remnant G78.2+2.1 at 232 MHz using the Miyun Radio

Synthesis Telescope. By combining these data with images at 408, 1420, 2695, and 4850 MHz, they have been able to demonstrate that there are significant variations of spectral index across the remnant; comparison of all pairs of data produce a similar result. Regions of higher spectral index (steeper spectra) appear around the periphery of the remnant and in its central area. There is no clear correlation of spectral index with intensity across the SNR. Contamination from background or foreground emission may contribute to the spectral-index variation, but it is likely that physical conditions differ from place to place within the SNR, with local effects on particle acceleration which then appear in the radio spectrum.

20. 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(Na I)/N(H I) of $\sim 2 \times 10^{-8}$ for the cloudlets.

21. EXTRAGALACTIC ASTRONOMY

Together with Mack and Klein (U. Bonn) and O'Dea of the STScI, Willis is continuing to investigate the properties of large radio galaxies. This work involves the intercomparison of high-resolution, low-frequency images obtained with the Westerbork Synthesis Radio Telescope with corresponding images obtained at higher radio frequencies with the Bonn 100-m telescope.

Willis has begun to examine images collected by the Galactic Plane Survey for large-angular-diameter extragalactic radio sources that may be hidden behind the Galactic plane.

Carignan (U. Montreal) and Purton have completed the analysis of H I observations of the dwarf irregular galaxy DDO 154, in which data from the DRAO Synthesis Telescope and the 26-m Telescope have been combined with data from the VLA in its D-configuration. This has enabled the derivation of the rotation curve of the galaxy beyond the turnover point.

22. THE 2800-MHZ SOLAR FLUX MONITORING PROGRAM

The last year has seen continuing efforts to increase the quality and availability of the 10.7-cm flux measurements made by the National Research Council. These data now form a consistent, continuous database extending from 1947 to the present. The objectivity, availability and continuity of the data, and the fortuitous choice in 1946 of an observing wavelength of 10.7 cm, close to the peak of the spectrum of the slowly-varying (S) component, have led to the worldwide use of the 10.7-cm flux as a primary index of solar activity. Known as the Penticton 10.7-cm solar flux, or just the 10.7-cm flux, the data are used as an index in their own right or as a proxy for quantities more difficult to measure. The program was moved to DRAO in 1990, and is now fully integrated into the routine operation of the Observatory. The 10.7-cm flux is used both for solar research and in areas of human activity which are affected by solar activity. Current applications include studies of the ozone layer and global warming. The 10.7-cm flux has played a pivotal role in at least 250 papers published over the last five years.

The measurements are made using two completely independent flux monitors, with automatic data distribution by fax and e-mail. During 1996-97, efforts have continued to increase the level of automation in the acquisition and dissemination of data. The most important steps have been to make an up-to-date database of present and past measurements available on the World-Wide Web (see http://www.drao.nrc.ca), and the integration of the routine daily support of the program into the operation of the Observatory.

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This report covers the activities of the JCMT Group for the period from 1996 April 1 to 1997 March 31. The publications list covers the calendar year 1996.

The James Clerk Maxwell Telescope (JCMT) Group of the Herzberg Institute of Astrophysics (HIA) supports the JCMT by posting several staff members to the Joint Astronomy Center (JAC) in Hilo, Hawaii to help operate and maintain the telescope, by providing services, advice, and liaison to Canadian university astronomers, by building advanced receiver systems, and by serving on pertinent committees. Canada has a 25% share in the telescope, while the UK has 55% and the Netherlands has 20%. The three partner countries have access to 90% of the net observing time, according to their share in the telescope, and the University of Hawaii has a 10% share. The international community also obtains observing time each semester.

1. PERSONNEL

Astronomers and Engineers include L.W. Avery (JAC), M.B. Bell (until October 1996), S. M. X. Claude (NSERC Fellow, since December 1996), C.T. Cunningham, P.A. Feldman, R.H. Hayward (until July 1996), J.M. MacLeod (Group Leader), H.E. Matthews (JAC), R.O. Redman, J.D. Wade (until December 1996), and Keith Yeung (since February 1997). Technologists include S. Brooke (JAC, until August 1996), A. Mirza and E. Taada (until March 1996). Guest workers include M.B. Bell (from October 1996), J.R. Fletcher, T.H. Legg, J.P. Towle and J.D. Wade (from January 1997).

J. Arlett (Queens U.) worked with Avery as a student in the NRC's Women in Engineering and Science program. M. Pollanen (Carleton U.) worked as a summer student with Matthews.

In addition, three staff at the Joint Astronomy Center are supported by financial contributions from the National Research Council of Canada.

During this period the JCMT Group was transferred from Ottawa to Victoria as part of the move to consolidate the entire HIA in one location. So as not to interfere more than necessary with the completion of receiver RxB3 (as discussed below) some of the group moved as early as June 1996 while others remained in Ottawa until their duties permitted them to travel. The last member of the group arrived in Victoria in January 1997. As a result of the move, several former group members retired or chose to pursue other career options. To replace their expertise we have hired Yeung as an electrical engineer and have advertised for a receiver engineer. Claude joined the group in December 1996 and is working with Cunningham on the development of low-noise SIS mixers.

The push to deliver RxB3 to the JCMT and the move to Victoria have occupied most of the time and effort of the JCMT Group during the last year. We look forward to a more settled and balanced life and to enhanced astronomical contacts in our new quarters at the Dominion Astrophysical Observatory in Victoria.

2. SCIENTIFIC ACTIVITIES

2.1 Solar System

Beginning in February 1996 and continuing into June 1996, Matthews coordinated JCMT observations of Comet Hyakutake which made a surprise visit to the inner solar system in March 1996. Although Hyakutake was a fairly small comet, the closeness (about 0.1 A.U.) of its passage by the Earth resulted in some spectacular results, including the first detection of HNC in a comet (Irvine *et al.* 1996), and the first submillimeter spectrum and continuum map of a comet (Jewitt, Matthews; Astron. J., in press for March 1997). The HNC result has significance for the constitution of the early solar system, and the continuum observations demonstrate the presence of mm-size particles in the cometary coma. Mathews is working in collaboration with groups from UH Manoa, JAC, and Meudon to analyze the numerous observations of the submillimeter lines of HCN, CO, CS, H_2CO, and CH_3OH which were obtained.

Matthews, in collaboration with Jewitt, Meier and Owen (IfA), and Irvine and Senay (FCRAO), have continued an extensive program of observations with the JCMT of the bright long-period comet Hale-Bopp. Following the first detection of CO in September 1995 using the JCMT, HCN was found in May 1996. CO is the first major volatile to be released from comets as they approach the Sun while still beyond the orbit of Jupiter, and is responsible for the development of the early coma. Subsequently, H_2O outgassing becomes dominant within the orbit of Mars. HCN is a trace constituent, but gives bright lines because of its high dipole moment. Throughout 1996 Matthews and colleagues carried out a program primarily to determine the outgassing rates of CO and HCN as a function of heliocentric distance. First results showed a rapid increase on CO outgassing (Jewitt, Senay and Matthews 1996), which appears to have been one of a series of outbursts in response to early warming by the Sun. As Hale-Bopp approached perihelion on 1997 April 1, the HCN 4-3 line exceeded 20 K in antenna temperature so that isotopic lines could also be measured. Matthews and partners have shown that the isotopic ratios $^{13}C/^{12}C$ and $^{15}N/^{14}N$, and $^{34}S/^{32}S$ (from CS lines) have closely terrestrial values. A second major goal is the determination of the behavior of the ratio of HNC to HCN. The cometary material is considered to be a representative sample of the proto-solar nebula so that the ratio should indicate the temperature of the nebula where the cometary ices condensed. The present efforts are directed toward understanding whether subsequent processing by solar radiation can modify this ratio. Observations of the continuum emission at 344 GHz show that the

dust output from Hale-Bopp continues to increase, with an estimated output 40 times that of C/Halley in 1986. Almost all observations of Hale-Bopp since the beginning of 1997, including the continuum measurements, have been carried out with the new 345-GHz dual-channel SIS receiver RxB3 built by the JCMT Group in the HIA.

2.2 Interstellar and Circumstellar Matter

Avery and Arlett developed multi-parameter statistical equilibrium codes for modeling observations of SO, CO and CS lines from interstellar molecular clouds. These codes were used to estimate physical properties of a number of bipolar outflow regions including L1157, V380 Ori and NGC 2024.

Avery and MacLeod continued their observational program of spectral line emission from young bipolar outflow regions. Multi-line observations of methanol in a number of outflows will be used for excitation studies of these regions. In addition, high resolution CO 3-2 line maps of L1157, V380 Ori, L281 and NGC 2024 show the presence of shock-like structures that correlate well with H_2 emission, and twisted, helical strands of molecular emission.

Feldman and Matthews are continuing their JCMT study of highly excited water in circumstellar envelopes and star-forming regions, building on previous astronomical and spectroscopic collaborations with Amano (Ibaraki U., Japan) and Scappini (CNR, Bologna). They expect to use the new 345-GHz receiver RxB3 to refine earlier detections in VY CMa of two quasi-maser transitions of H_2O and to extend the observations to other evolved stars and possibly to several star-forming regions. This work has the potential to yield important constaints on the physical conditions inside circumstellar and interstellar masers.

Pollanen and Feldman produced a set of practical tables and figures useful in scaling IRAS flux densities of cosmic dust emission to submillimeter and millimeter wavelengths, as functions of the dust emissivity spectral index β and the dust temperature T. This should be useful in planning SCUBA observations with the JCMT. They also derived several useful analytic formulae for ''blue-body'' thermal dust spectra that are analogous to the Wien displacement laws for Planckian black-body spectra. This work has been submitted for publication in Ap&SS.

Kneller (U. Alberta), working with Feldman, MacLeod and Redman, has been compiling a catalogue of molecular outflows as complete as possible to the end of 1995. One purpose of the compilation is to assist on-going research on outflow properties by Group members currently using the JCMT. An early result of this effort was finding evidence for what may be a very extended ''fossil'' outflow, which they have begun to map at the JCMT in ^{12}CO 2-1.

Duley (U. Waterloo), Feldman and Towle used the JCMT to search for interstellar TiO toward a number of likely warm sources in star-forming regions. No firm detections were made, but several possible candidates affected by severe line confusion were identified for future SSB observations with RxB3. Upper limits for interstellar TiO that are substantially better than those currently in the literature were established, and these can be interpreted to mean that titanium depletion is very high in dense molecular clouds.

Feldman and Matthews used the JCMT to search for radio-recombination-line (RRL) masers at H30α toward a number of giant extragalactic H II regions (GEHRs) in M101 and M31. The goal was to find extragalactic RRL masers that are similar to, but more powerful than, the one recently reported in η Car. No detections were made, but it is hoped that this search can be extended in future to many more GEHRs at H26α with the much more sensitive RxB3.

Towle, Feldman and Watson of the Steacie Institute of Molecular Science (SIMS, NRC) produced a catalogue of accurate H, He, C and S radio-recombination-line frequencies from 100 GHz to 10 μm. This should help facilitate observation and study of high-frequency RRL masers in astronomical sources. This catalogue is unique in providing explicit Dirac-equation treatment of hydrogenic fine structure, which has been ignored by radio astronomers in the past because its effects only become important at frequencies in the submillimeter band and above.

Bell has prepared a paper describing a new data reduction technique that removes strong contiuum-related baseline structure from single-dish spectra without fitting polynomials or sinusoids. Using this technique flat baselines can be obtained over the entire instantaneous bandwidth provided by the receiver, even when the source continuum is strong and the linewidths are reasonably wide. The paper will appear in PASP, May, 1997.

Bell and Feldman, in collaboration with Travers, McCarthy, Gottlieb and Thaddeus of the Center for Astrophysics at Harvard University, used the NRAO 140-foot telescope at Green Bank to detect near 13 GHz two consecutive transitions of the long, linear cyanopolyyne molecule $HC_{11}N$ (HCCCCCCCCCCCN). The column density of this molecule in the cold, dark dust cloud TMC-1 was found to be a few times 10^{11} cm^{-2}. Its observation in space has confirmed that detectable quantities of molecules with nearly twice the molecular weight of glycine can form under conditions markedly different from those on Earth. This work has been accepted for publication in ApJL.

Bell, working with Seaquist, Carlstrom and Bryant, used the JCMT and the Owens Valley Radio Observatory to investigate the millimeter recombination line radiation from the starburst galaxy M82. Comparisons between spectra at H41α and at H29α and H27α show that while most of this emission in M82 is consistent with spontaneous emission, some regions may emit at H27α predominantly by maser amplification. This is especially the case at the tangent point of the molecular ring on the west side of the nucleus where large velocity deviations are seen at H41α.

2.3 Laboratory Spectroscopy with Astrophysical Applications

Towle, in collaboration with Körsgen, Mürtz, Lipus and Urban (Inst. Angewandte Physik, Bonn) and Brown (Oxford), detected the iron dihydride (FeH_2) radical in the gas phase by measuring infrared transitions in the fundamental band of its antisymmetric stretching vibration ν_3. They established that the molecule is linear in its ground state and

that this state is $^5\Delta_{(g)}$. FeH and other transition-metal monohydrides are known to be present in the atmospheres of cool stars and our Sun. It is hoped that the laboratory detection of FeH_2 will lead to better understanding of the role of transition-metal dihydrides in cool stellar atmospheres.

Towle has reanalyzed a number of millimeter- wavelength rotational transitions of the ground electronic state ($^3\Pi$) of the SiC radical, originally observed by C. Gottlieb at the Harvard-Smithsonian Center for Astrophysics. Previously, separate sets of spectroscopic constants were published for each of the two isotopomers $Si^{12}C$ and $Si^{13}C$. It has proved possible to fit both isotopomers with one set of parameters in a generalized Hamiltonian using isotopic scaling and the corrections derived by J. Watson (SIMS, NRC) for the breakdown of the Born-Oppenheimer approximation. This work will be submitted to the J. Mol. Spectroscopy.

Previously, Feldman and Matthews in collaboration with McDade (York U.), Amano (Ibaraki U., Japan), and Singleton (ICPET, NRC) used the JCMT to detect the $J=4-3$ line of $O_2(^1\Delta_g)$ in the Earth's atmosphere. Recently, Amano and his student have made direct laboratory measurements at IMS (Okazaki) and Ibaraki U. (Mito) of the pressure-broadening coefficient of $O_2(^1\Delta_g)$ in an O_2 discharge and plans to extend the measurements to an N_2 and O_2 mixture. This will permit them to calculate the vertical density profile of this important atmospheric species from telescopically-measured line shapes.

3. INSTRUMENTATION DEVELOPMENT

3.1 RxB3 Completion and Commissioning

The JCMT Group completed and commissioned a new 345 GHz receiver called RxB3 for the JCMT in Hawaii. This two-channel, low noise SIS receiver is fully automatic and provides a substantial improvement in observing speed over the former instrument.

RxB3 was assembled by Hayward, Cunningham, Wade and Mirza in the receiver lab in Ottawa and began its initial characterization during the summer of 1996. At the same time Hayward and Redman completed the development of the real-time control software for the embedded OS-9/G-64 microcomputer used in RxB3. Redman finished the initial development of the I-tasks (Instrument tasks) which provide the software interface between RxB3 and the JCMT telescope control system and was able to demonstrate the automated tuning of the receiver under computer control by late September.

Following shipment in October and reassembly at the JCMT in mid-November, RxB3 began commissioning on the telescope in early December by a team consisting of Avery, Cunningham, Dent (JAC), Fuka, Hayward (on loan from his new position at the Heinrich Hertz Submillimeter Observatory in Tucson, Arizona), Mirza, Redman, I. Smith (JAC) and Wade. They achieved first light on December 5th 1996. Although not formally released for general use until February 1997, the improvement in the performance of RxB3 over its predecessor was so great that all programs in this frequency band have used RxB3 since late December. Redman is continuing to work with the JAC staff to complete the documentation and final integration of the I-tasks over the next few months.

The equipment from the receiver laboratory in Ottawa was shipped to Victoria where staff have set up a new laboratory which became operational in March 1997.

3.2 Upgrade Program

In an attempt to maintain the best possible instrumentation on the JCMT the Group is engaged in a receiver upgrade program. Cunningham and Claude are currently developing new SIS mixers for the 230 and 345 GHz bands. If these mixers show promise they will replace the devices currently in use. Cunningham is also involved in developing a mixer for 800 GHz in collaboration with a group at the Rutherford Appleton Laboratory in the UK. In preparation for the linking of the JCMT to the Smithsonian array, we will be modifying JCMT receivers by altering the intermediate frequency (IF) to 5 GHz to match that of the array. This will maximize the overall array sensitivity.

Cunningham, Mirza, Redman and Yeung have begun work to convert the old 345 GHz receiver which RxB3 has replaced into an improved 230 GHz receiver to be known as RxA3i. In the first phase the mixer will be replaced with a state-of-the-art tunerless 230 GHz mixer built by the NRC machine shop in Ottawa. These devices should greatly improve the ease of operation of the receiver while providing a somewhat better noise temperature than the current 230 GHz receiver. The dewar will also be modified to allow the receiver to fit into a new position within the Cassegrain cabin of the telescope. The first phase should be completed and the receiver re-commissioned by the autumn of 1997. In the second phase of the project, the frequency multiplier in the local oscillator will be replaced by a tunerless multiplier, the IF will be increased from 1.5 to 4 GHz, and the control microcomputer may be replaced with one following the current JCMT standard. The second phase should be completed by late 1998.

Work on a 345 GHz heterodyne, focal-plane array was continued by Legg, Bell and Fletcher in collaboration with J.F. Vaneldik, D. Routledge, and K. Kornelsen at the University of Alberta. A new type of antenna was developed which, for the first time, made constructive use of reflections from the edges of the quartz substrate and superstrate. The result is an antenna that launches the same desired waveguide mode in both E and H planes. A large scale model of the antenna was extensively tested and found to operate satisfactorily over a bandwidth of about 2 to 1, i.e. over a range that could in principle cover both A and B bands at the JCMT.

3.3 Future of Canadian Radio Astronomy

T. H. Legg continued to work on the design of a new type of radio telescope as part of the Canadian contribution to the international ''Square Kilometer Array'' project. The aim is to make very large telescopes more affordable. The proposed Canadian design has a primary reflector that is ground-supported, almost flat, and slightly adjustable in shape. For

wavelengths from decimetres to millimetres the receivers would be supported by some form of aircraft, possibly a tethered balloon. At very long wavelengths it appears to be less expensive to station the receivers on the ground and mount a large secondary reflector made from fabric on the aircraft.

The Canadian radio astronomical community also has expressed an interest in the proposal to link the JCMT and the Sub-Millimeter Array (SMA), being constructed on Mauna Kea by the Smithsonian Astrophysical Observatory, to make a larger and significantly more powerful interferometric telescope. A major difficulty facing any such telescope is correction of the phase offset induced at each antenna by water vapour in small cloudlets along the line of sight. Feldman and Redman have begun a study of ways to measure the column density of water vapour with high relative precision. It is intended that this project will involve collaboration with university partners and would be a suitable thesis topic for a graduate student.

4. JCMT SUPPORT

4.1 Canadian Time Allocation Group (C-TAG)

The C-TAG Committee oversees the refereeing and assessment of proposals requesting time allocation for Canada's share on the JCMT. W.H. McCutcheon (UBC, Vancouver) is Chair. Feldman had been a member of the C-TAG since September 1992 and was replaced by MacLeod in January 1997. Feldman was also Chair of the JCMT International Time Assignment Committee until December 1996. Other members of C-TAG are M. Fich (since January 1997) (U.Waterloo), L.A. Higgs (HIA), and D. Puche (Montréal). J.P. Vallée (HIA) serves as Technical Secretary of the C-TAG.

4.2 Canadian Service Observing (CANSERV)

Canadian JCMT support scientists (Avery and Matthews) and other experienced astronomers from the Group in Victoria carry out short observing programmes on the JCMT for Canadian astronomers so that they do not have to travel to the telescope to acquire small amounts of data (generally four hours or less). Such observations are useful in responding rapidly to new astronomical discoveries, accommodating important short observations, monitoring variable objects, completing nearly finished projects, or providing pilot or speculative observations prior to a full application for observing time.

CANSERV has been much less active than normal during this period because so much of the time on the JCMT was allocated for the commissioning of SCUBA and RxB3. We expect a return to normal activity levels in Semesters 97A and 97B. CANSERV observations were performed for the following projects during the period April 1, 1996 to March 31, 1997:

• Low-excitation SO or High-excitation HCN in CRL2688? (Matthews, JAC)

• Formaldehyde in Hot Cores and Shocked Clumps (Mitchell, Hasegawa, St.Mary's; Matthews, JAC)

• HCO^+ $J=4-3$ in M82 (Seaquist, U. Toronto; Bell)

• Excitation Conditions in Molecular Gas in Elliptical Galaxies (Wilson, McMaster)

• Hydrogen Recombination Lines in Arp 220 at Mm Wavelengths (Bell; Seaquist, U.Toronto)

• Confirmation of HCO^+ (4-3) profiles in M82 (Seaquist, U.Toronto; Bell; Frayer, U.Toronto)

• The Temperature of Molecular Gas in NGC 6822 (Wilson and Petitpas, McMaster)

4.3 Staff Seconded to the JAC

Avery and Matthews continued their postings to the JAC as a Canadian staff members. As JCMT Support Scientists they provide assistance to visiting Canadian astronomers. In addition, they completed data acquisition for two Canadian students whose PhD theses are based upon JCMT data but who had lost significant amounts of observing time to bad weather.

Avery is responsible for maintenance of the database of spectral-line standards at the JCMT. In the past year this database has been converted to the UNIX-based system that is now operating at the JCMT, and all of the spectral-line standards are now accessible from within the standard data reduction package, SPECX. Working with Matthews, he has provided access to the spectral-line database via the WWW.

Avery also is a member of the Canadian Science Team for the ODIN submillimeter space mission, scheduled for launch in 1998.

Matthews provides regular updates to the ''Guide for Prospective Users of the JCMT,'' which is distributed in hardcopy format, electronically through a file server, and on the World Wide Web (WWW). Similarly, he maintains the ''Astronomer's Reference Manual,'' a comprehensive collection of documents on how to use the JCMT, portions of which he has now made available via the WWW. Matthews took on the task of leading the upgrade of the JCMT control room, a project which is now almost complete.

5. PUBLISHED PAPERS BY STAFF MEMBERS (CALENDAR YEAR 1996)

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