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This report covers the period from 1998 April 01 through 1999 March 31, while the publications are for the calendar year 1998.

## 1. HIGHLIGHTS

The CNOC2 consortium reached the end of the data collection phase in May 1998. The data are now fully reduced yielding 6000 galaxies with redshifts between 0.2 and 0.6 in four patches on the sky.

A new analysis as part of the CFRS/LDSS collaboration finds that only  $\sim 5\%$  of the stellar mass in large field ellipticals may have formed since  $z = 1$ . The lack of evidence for a decline in the space density of large ellipticals with look-back time argues that major mergers are not actively forming many large ellipticals for redshifts less than 1.

A redshift survey and surface photometry of some 35 nearby low-surface-brightness galaxies (LSBGs) revealed that LSBGs make a negligible contribution to the overall integrated luminosity, H I mass, and total mass contained in galaxies. The lack of a surface brightness residual in the luminosity-line-width (Tully-Fisher) relation for spiral galaxies was shown to be incompatible with maximal disk mass models.

From the Local Group radial velocity dispersion of  $61 \pm 8 \text{ km s}^{-1}$ , a total Local Group mass of  $(2.3 \pm 0.6) \times 10^{12}$  solar masses, a mass-to-light ratio of  $44 \pm 12$  (in solar units), and a zero-velocity radius of  $1.2 \pm 0.2 \text{ Mpc}$  have been determined. Contrary to a widely held perception, the Local Group is rather isolated from other nearby groups.

An HST study of three of the oldest clusters in the Large Magellanic Cloud, NGC 1466, NGC 2257 and Hodge 11, finds them to be as old as Milky Way clusters with comparable metallicities; as well, the three LMC clusters are themselves the same age to within 1 Gyr. Both the similar ages to Galactic globulars and the age spread within the LMC clusters appear to be consistent with hierarchical clustering models of galaxy formation.

Extensive DAO observations of the Hg II line at 3984 Å for the binary HgMn star  $\alpha$  And reveals the first definitive variability seen among the HgMn stars. Its existence indicates spatial and/or isotopic variability and is related to atmospheric hydrodynamics.

Nearly 1600 astrometric positions of minor bodies in the Solar System were determined using Plaskett Telescope images by two teams.

The Gemini Data Handling System and Enclosure Control System software packages were delivered and accepted, and the natural guide star adaptive optics system, Altair, passed its critical design review. Construction of the focal-plane assembly for the northern Gemini multiobject spectrograph advanced well.

The FUSE Fine Error Sensor flight cameras were delivered and await launch; they were built by ComDev (Cambridge, ON), with guidance from HIA and the Canadian Space Agency.

Crampton was awarded the 1998 Helen Sawyer Hogg Public Lectureship by CASCA and the RASC.

IAU Symposium 190, New Views of the Magellanic Clouds, attracted some 190 participants from 21 countries, and honored Sidney van den Bergh in the year of his retirement from the Observatory. He nearly completed his second book, on the Local Group of Galaxies, during the year.

The 1.8-m Plaskett Telescope celebrated its 80th anniversary by participating in an international co-ordinated campaign to detect solar-like oscillations in stars.

## 2. STAFF & VISITORS

New appointments to staff during the report year included Gordon Hnylycia, Dean Josephson, and Robert Walker. Joleff Fitzsimmons and Angellic Ebberts both joined the Instrument Group after spending time with the DRAO Group. David Bohlender's term position was converted to a continuing one in the Canadian Astronomy Data Centre (CADC). Stephanie Côté transferred from an RA position to a continuing position in the Canadian Gemini Office.

Temporary assignments during the year were held by Serena Ableson, Caroline Aubin (Women in Engineering and Science, WES), Brad Cavanaugh, Pat Dowler, David Delisle, Alexandra Drew, Brian Dunn, Louise Edwards, Eric Eisenhuth, Robert Gaunt, Tyson Hare, Shannon Kolind (WES), Michael Letawsky, John Ouellette, Shelley Pinder (WES), Todd Polinsky, Chad Quinn, Eric Steinbring, Blaine Szalai.

Chris Aikman, Alan Batten, Frank Grundahl (Arhus, Denmark), Robert McClure, Bev Oke, Sidney van den Bergh and Frank Younger continued as guest workers at the Observatory for the full year. Tim Bond and Gurjeet Singh left HIA during the year.

Extended periods of research studies and other interactions were taken at the DAO by Dr. Saul Adelman (The Citadel), David Balam (U. Victoria), Mike Balogh (U. Victoria), David Barlow (U. Victoria), Steven Beard (UK Astronomy Technology Centre, ATC), Mark Brodwin (U. Victoria), Scott Chapman (UBC), Anne Cowley (Arizona State U.), Colin Dickson (U. Durham), Rene Doyon (U. Montréal), Ian Greig (Career Development Institute, CDI), Robert Greimel (U. Victoria), Elizabeth Griffen (Oxford U.), Robert Grigor (CDI), David Hanes (Queen's U.), Rosalyn Hanes (CASCA), Gretchen Harris (U. Waterloo), Grant Hill (McDonald Observatory), Douglas Howard (CDI), Mike Hudson (U. Victoria), Keith Lyttle (CDI), Angella MacEwen (CDI), Duncan Mackay (ATC), Darshan Montgomery (CDI), Jack Penfold (Mt Newton College), Kathy Perrett (Queen's U.), Anna Piersimoni (U. Trieste), Chris Pritchett (U. Victoria), Terry Purkins (ATC), Galy Raviv (Rafeal Armament Devel-

opment Authority, Israel), Mike Raviv (Department of Defense, Israel), Nicholas Ross (U. Durham), Colin Scarfe (U. Victoria), Tammy Smecker-Hane (U. California at Irvine), Eric Steinbring (U. Victoria), Faro Sullivan (Career Edge Internship), Caroline Swerdlyk (U. Victoria), Gordon Walker (UBC), Stephenson Yang (U. Victoria), Randy Zingle (U. Victoria).

Visitors to the Canadian Astronomy Data Center included Steve Wampler, (IGPO), Keith Shortridge (AAO), Alberto Micol (ST-ECF), Miguel Albrecht (ESO), Kentaro Aoki (NAOJ), Naoki Yasuda (NAOJ), and Jean-Francois Gonzalez (Lyon).

During the Saturday evening open houses, Sandy Barta, Chuck Filtner, Orion Irvine, David Lee, Norman Lewis, David Luttmann, Ed Maxfield, Rick McCrea, Frank Ogonoski, Keith Rawcliffe, Eric Schandall, and Peter Schlatter formed a core group of volunteers from the Victoria Centre of the Royal Astronomical Society of Canada, who brought their telescopes to DAO and shared their knowledge and enthusiasm with members of the public. Their efforts were well supported by Commissionaires D. Stobbert and J. McNair, with occasional assistance from B. Alcool and U. Arthur, while Saddlemyer provided technical support on most Saturday evenings.

Ed Jakeman, who worked as the 1.8-m Telescope night assistant from 1946-1983, passed away. Ed was a gentle, unassuming man who provided superb, conscientious service that made friends for him and the Observatory throughout the world.

### 3. SCIENTIFIC RESEARCH

#### 3.1 Cosmology

The Canada-France Redshift Survey (CFRS) team (Crampton, Schade, Lilly (U. Toronto), Hammer (Obs. de Paris-Meudon) and Le Fevre (LAS, Marseille)) continued their collaboration with the LDSS team headed by Ellis (IOA) to analyse HST images of a sample of 341 galaxies up to  $z = 1$ .

Crampton, Lilly and LeFevre also completed a deep UVBI imaging survey with the UK8K camera of four fields mostly centered on the CFRS fields in preparation for follow-up surveys of high redshift galaxies with the VLT and Gemini. U. Victoria student Swerdlyk is playing a major role in the data reduction.

Crampton summarized the results of observations of very high redshift objects with the CFHT Adaptive Optics Bonnette (AOB) in presentations at the CFHT User's Meeting in Quebec, at the Xth Rencontres de Blois "The Birth of Galaxies" and at U. of Arizona.

Morris co-authored a number of papers exploiting data from the first Canadian Network of Observational Cosmology project (CNOC1) primarily aimed at studying the mass density of the universe, using observations of rich clusters of galaxies. Balogh (U. Victoria) and Morris submitted a paper analysing the effects of infall into the cluster on a galaxy's star formation, concluding that large bursts of star formation are not produced.

The CNOC2 project (led by Ray Carlberg (U. Toronto), and including Morris) reached the end of the data collection phase in May 1998. The data are now fully reduced yielding 6000 galaxies with redshifts between 0.2 and 0.6 in four patches on the sky. A full analysis by Carlberg (U. of Toronto) of correlation amplitude evolution from the four patches on the sky is in progress. Morris is using these data to calculate the evolution in the star formation density (solar masses per cubic megaparsec) as a function of redshift.

Courteau and Strauss (Princeton) are leading a team of five to redefine the cosmological dipole at 6000 km/s with a new homogeneous data sample with full sky coverage. Data reduction is complete and first results will be announced at the "Cosmic Flows 1999" workshop that Courteau is organizing in Victoria for 1999 July 13-17. This international workshop will gather  $\sim 100$  active cosmologists to study cosmic velocity fields as probe to the large-scale structure of the universe.

Hutchings and Edwards (U. Victoria) are using CNOC1 data for stellar populations studies of several clusters not previously analysed. These also have VLA maps and have several radio galaxies in the field.

Using the Keck Telescope, Oke, Postman (STScI) and Lubin (Observatories of the Carnegie Institution of Washington and California Institute of Technology) have been carrying out a program to study nine clusters of galaxies with redshifts between 0.6 and 1.1 using multi-color photometry, infra-red photometry, and spectroscopy. The central region of each cluster has been imaged with the HST to carry out morphological studies. Detailed studies of two of the nine clusters, with redshifts of 0.84 and 0.89 respectively, were published. Since then analysis of the data for two additional clusters at redshifts of 0.76 and 0.92 have almost been completed. The cluster at a redshift of 0.92 is particularly interesting because it is very close to the cluster at redshift 0.89 which has already been analysed; they may form a physical pair. The results are consistent with what was found for the previous two clusters but with somewhat more information now available. Defining an active galaxy as one in which there is active star formation and the equivalent width of the [O II] emission line, which is caused by this activity, is greater than  $15 \text{ \AA}$ , they find that 65% of field galaxies in the redshift range 0.45 to 0.85 are active while 79% are active for redshifts above 0.85. Within their clusters the fraction of active galaxies is only 45%. It is clear that the amount of star formation in a galaxy depends on whether it is in a crowded cluster environment and how far back in time we are seeing it. A model in which the star formation rate on average drops exponentially after the galaxy formed with a characteristic time of 200 million years is appropriate. This is confirmed by the strength of the [O II] emission lines and also the characteristics of the continuous spectra which are produced by the stars in the galaxies. If the investigators assume that the brightest galaxies in clusters are inherently the same, which appears to be the case for nearby clusters, then they find that in their high redshift clusters, which are being seen as they were nearly 7 billion years ago, the brightest galaxies are about a factor 2.5 brighter than they now are. This agrees with the predictions of the models. The galaxies in the  $z=0.9$

clusters have a very wide range of color and do not produce the red ridge-line seen in clusters with redshifts of 0.5 or less. If, however, the galaxies in their  $z=0.9$  clusters are allowed to evolve to correspond to clusters as observed at a redshift of 0.50, then it is found that the red ridge-line appears and looks like observed clusters at redshifts of 0.5.

Schade, as part of the CFRS/LDSS collaboration, finds the field elliptical galaxy population from redshift 0.2 to 1.0 shows evolution in luminosity which is consistent with the expectation of passive evolution of an old stellar population. On the other hand, 30% of these ellipticals display [O II] emission indicating that some residual star formation is taking place. They estimate that  $\sim 5\%$  of the stellar mass in large ellipticals may have formed since  $z = 1$ . There is no evidence for a decline in the space density of large ellipticals with look-back time. This argues that major mergers are not actively forming many large ellipticals since  $z = 1$ .

### 3.2 Galaxies

Côté, with WES student Kolind, finalized the redshift survey and surface photometry of about 35 nearby low-surface-brightness galaxies (LSBGs). The objects were selected as the lowest surface brightness galaxies in the APM catalogue (with  $\mu \geq 24$  mag arcsec<sup>-2</sup> down to a magnitude limit of  $b_j \leq 17$ ). A luminosity function was constructed, and H I line widths were used to construct a total mass function. Results show that LSBGs make a negligible contribution to the overall integrated luminosity, H I mass, and total mass contained in galaxies.

Côté has started investigating the kinematics of nearby spiral galaxies at very large radius using Ly- $\alpha$  absorption lines in the spectra of background quasars. So far half a dozen QSO spectra were obtained with HST's STIS. Ly- $\alpha$  lines were successfully detected for all galaxy-QSO pairs with impact parameters  $< 165$  kpc, with Ly- $\alpha$  velocities agreeing to within  $< 100$  km s<sup>-1</sup> of those for target galaxies.

Courteau continues his research on the structure of nearby spiral galaxies for application to galaxy evolution studies. He and Rix (Steward/MPA) demonstrated that the lack of a surface brightness residual in the luminosity-line-width (Tully-Fisher) relation for spiral galaxies is incompatible with maximal disk mass models. They used models of adiabatic infall of luminous matter into dark matter halos to show that the dark matter contributes significantly to the galaxy potential of late-type spirals, even at their centre. This establishes a continuous transition with lower surface brightness galaxies where similar trends are observed.

Courteau is working with de Jong (Steward) and Veilleux (Maryland) on a new project to constrain the shape of dark matter halos at the center of galaxies, where accurate optical rotation curves and infrared images are essential.

In another collaboration with Sohn (Yonsei/HIA) and Faber (UCSC/Lick), Courteau has looked at the calibration of blue line widths of H $\beta$ , [O III], [O II] for use in studies of disk evolution with look-back time.

Hutchings and Davidge are analysing STIS images and spectra of the central galaxy in Abell 2390. The UV spectrum shows outflows in the galaxy which also is considered to have a cooling inflow. Hutchings and Schade have ob-

tained AOB imaging in near IR and I-band wavelengths of regions in CNOC1 clusters. Together with HST imaging from STIS and WFPC2, and narrow band CFHT images by Balogh (U. Victoria), the data are being used for detailed morphology studies. A preliminary result is that there are several cluster galaxies with significant tidal disruptions not previously recognised.

### 3.3 QSOs and Active Galaxies

Two successful runs on CFHT with AOB in January and March by Hutchings, Morris and Crampton yielded a sample of some 10 high- $z$  QSOs with resolved structure in the near IR. The structure indicates that most if not all are undergoing major tidal events and are also within a dense and compact group of companion galaxies. The galaxies are small and appear to have very young stellar populations. The relation between galaxy formation, merging and QSO activity over cosmic time is still unclear but tantalising. Continued observations are scheduled for the visible regions, to sample the stellar populations and dust in the rest UV. Further work is planned with emission line imaging. PSF modelling and subtraction is being performed on the data by Steinbring (U. Victoria). Sample selection from catalogues is underway by Durand and Morris.

Hutchings is PI on an HST cycle 6 program to image high redshift QSOs with WFPC2. The delayed program has now started and work has begun on detailed modelling of the PSF based on observations designed for that purpose. Collaborators are Hanisch (STScI), Neff (GSFC), and Redding (JPL). Hutchings, with Kinney and Schmitt (both STScI), has VLA maps and CFHT narrow band images of an unbiased sample of Seyfert galaxies to study nuclear orientation statistics.

Hutchings has led a STIS team program to obtain STIS long-slit data of nuclear jets discovered in 3C galaxies by HST imaging. There are two types of jet: an extended emission-line outflow region and true synchrotron jets. The sample has about equal numbers of each. The synchrotron jets appear to break up when they encounter the edge of a central cavity around the galaxy nucleus. The emission-line jets show bidirectional outflows similar to those in Seyfert galaxies. The group has been awarded cycle 8 HST observing time to continue this program.

Hutchings also led a STIS team program to investigate the bright Seyfert NGC 4151. Two kinematics papers have been completed on the complex of outflowing clouds around the nucleus, which indicate more than one mechanism is involved. Further long-slit data are being analysed to measure the flows in weaker lines, with planned work including high dispersion UV spectroscopy of the nucleus and high dispersion spectra of selected nuclear regions. The group has been awarded cycle 8 HST time to pursue the kinematic work on other Seyfert galaxies.

Hutchings has analysed STIS images and spectra of a high redshift QSO which shows extended emission line gas and a compact group of peculiar companions. The sites of high redshift QSO activity appear to be associated with the early stages of galaxy formation. Further STIS QSO spectra and imaging are scheduled for 1999.

Morris continues a monitoring campaign on Seyfert galaxies with Penfold (Mt. Royal College) using the DAO 1.8-m telescope.

Schade, Boyle (AAT), and Letawsky have completed a study of the properties of X-ray selected AGN and their host galaxies at low redshift. From a sample of 77 galaxies at  $z < 0.15$  with HST snapshot images combined with ground-based imaging it is found that the distribution of galaxy types is biased toward early-type galaxies (54% are in E/S0 galaxies) compared to the general field galaxy population (where  $\sim 20\%$  are type E/S0). The luminosity distribution of the host galaxies is not significantly different from a control sample drawn from a survey sample within the same redshift range.

### 3.4 Local Group Galaxies

Courteau and van den Bergh have redetermined the solar motion within the Local Group. They find a velocity of  $306 \pm 18 \text{ km s}^{-1}$  directed towards  $l = 99 \pm 5$  degrees, and  $b = -4 \pm 4$  degrees. From the Local Group radial velocity dispersion of  $61 \pm 8 \text{ km s}^{-1}$ , they find a total Local Group mass of  $(2.3 \pm 0.6) \times 10^{12}$  solar masses, and a mass-to-light ratio of  $44 \pm 12$  (in solar units). The Local Group is found to have a zero-velocity radius of  $1.2 \pm 0.2$  Mpc. The number-density of galaxies is 30 times higher within 1.0 Mpc of the center of the Local group than it is in the shell with radius 1.0 - 1.5 Mpc. This shows that the Local Group is, contrary to a widely held perception, rather isolated from other nearby groups.

Hesser summarized IAU Symposium 192 on The Stellar Content of the Local Group. This was the first IAU Symposium held in Africa, at Cape Town. Dramatic progress reported for photometric measurements holds out the promise of unravelling the surprisingly complex star formation histories of local group galaxies, but only once spectroscopic information becomes available to break the age-metallicity degeneracy of red giant stars.

As part of the STIS team nuclear dynamics group, Hutchings has nuclear spectra of the local group galaxy M33. The data should reveal the composition and velocities of this very low luminosity galaxy core.

Hutchings and Cavanagh (U. Victoria) used WFPC2 images from the spectroscopy programs of Hutchings and Bianchi (JHU), to examine the stellar population of the halo of local group galaxy NGC 6822. There is a sparse young population in the faint extended halo seen on one side of the galaxy, suggesting that the current star-formation may have been triggered by a tidal event

Smecker-Hane (UCI), Stetson and Hesser reported on their new, deep photometry of the Fornax dwarf spheroidal (d Sph) galaxy at IAU Symposium 192, as well as on the spatial distribution of the remarkably young population ( $10^8$  years), which is much more flattened than, and its major axis is offset by  $\sim 30$  degrees from, the galaxy as a whole. The wide spread in giant branch color must reflect a spread in metallicity of at least 1.5 dex.

Smecker-Hane (UCI), Stetson and Hesser obtained infrared calcium triplet spectra of some 100 red giant stars in the

Carina dSph galaxy using the CTIO 4-m Telescope and its multi-fibre spectrograph. The data are now under analysis with Mandushev (UCI).

During the report year van den Bergh almost completed his monograph *The Galaxies of the Local Group*, which reviews present knowledge about the evolution and stellar content of Local Group galaxies. The history and dynamical evolution of the Local Group are also discussed.

Van den Bergh used data on the internal velocity dispersions in, and the velocity difference between, NGC 147 and NGC 185 to show that these two spheroidal galaxies form a stable bound pair. He has also found that the dwarf spheroidal galaxies fainter than  $M_V = -12$  must have a relatively low specific globular cluster frequency. Furthermore he has discussed the possibility that the recently discovered Sagittarius dwarf galaxy is a Searle-Zinn fragment that started its life in the outer Galactic halo. Van den Bergh has found that dwarf spheroidal galaxies in the Local Group are much more strongly concentrated in the Andromeda and Milky Way subgroups of the Local Group than are the dwarf irregular galaxies.

Van den Bergh finds that the Antlia-Sextans clustering constitutes the nearest external group of galaxies. It is located at a distance of only 1.7 Mpc from the centroid of the Local Group, and has a population of about 1/5 that of the Local Group. This clustering lies well-beyond the zero-velocity surface of the Local Group which has a radius of 1.2 Mpc.

### 3.5 Novae and Supernovae

A paper on the expansion of the supernova remnant RCW 86 that was being drafted by van den Bergh in collaboration with Westerlund and Kamper cannot be completed because of Kamper's death. A joint investigation into the proper motions of nebular fragments in the supernova remnant Cassiopeia A was delayed for the same reason. This project will, however, be continued and expanded in collaboration with Fesen (Dartmouth), using recent epoch data obtained with the Hubble Space Telescope.

### 3.6 Globular and Open Clusters

Gim, VandenBerg (both of U. Victoria), Hesser, and Stetson published two papers based on DAO 1.2-m and 1.8-m telescope observations for the rich, intermediate-age open cluster NGC 7789. The first of these papers, written with co-author McClure, presented 597 radial velocity observations from the 1.2-m telescope for 112 stars, and determined that the cluster radial velocity is  $-54.9 \pm 0.12 \text{ km s}^{-1}$  and the dispersion is  $0.86 \text{ km s}^{-1}$ . Some 32% of radial-velocity members are possible velocity variable stars; these seem to be concentrated toward the center of the cluster and, when combined with published data for other open clusters, strongly support the conclusion that mass segregation is being detected. The second paper presented a well-defined V-I color-magnitude diagram from Plaskett Telescope observations for some 15,000 stars in the field of the cluster. The morphology of the upper main sequence indicates that significant convective-core overshooting is taking place. Con-

sidering the morphology both of the main-sequence turnoff and of the giant branch, theoretical models seem to require that sometime within the past few hundred million years, the ignition of helium burning in NGC 7789 has switched from a quiescent to an explosive *flash* phenomenon, and the length of the cluster's red giant branch has been steadily increasing with the passage of time since then. The authors infer a distance modulus  $(m - M)_V \leq 12.2$ , a reddening  $0.35 \leq E(V - I) \leq 0.38$ , and an age of at least 1.6 Gyr.

Grundahl, Andersen (Nordic Optical Telescope), Stetson and Vandenberg (U. Victoria) are carrying out a large program of *uvby* photometry of open and globular clusters with the aim of providing improved age estimates. Initial program results were published for the globular cluster M13. It is approximately 12 billion years old. Based on main-sequence fitting to field sub-dwarfs of metallicity similar to M13, the apparent *V* band distance modulus is 14.44. With Catelan, Landsman (NASA/GSFC), Stetson and Anderson, Grundahl led an investigation of the apparently overluminous horizontal branch stars first found in M13. They found that apparently all clusters with blue horizontal-branch stars hotter than 11500K appear to show a jump in the Strömrgren luminosity at this temperature. The likely explanation is that radiative levitation of metals from the stellar interior to the surface causes a significant drop in the hydrogen opacity just shortward of the Balmer jump, thus giving rise to enhanced *u* flux (compared to models).

Grundahl, Vandenberg, Bell (U. Maryland) and Andersen are further investigating the age of the globular clusters M13 and M92 using their data base of *uvby* photometry and updated evolution models and atmospheres in order to determine improved values for the cluster ages using the Strömrgren  $c_1$  index. This method is independent of cluster distance, and depends only slightly on the amount of interstellar reddening towards the clusters. Their preliminary value for the age of M92 is 15 billion years.

A search for candidate globular clusters in the inner regions of the nearby giant elliptical galaxy NGC 5128 using *V*, *I* imagery from the Hubble Space Telescope has been completed by Holland (Aarhus University), P. Côté (California Institute of Technology) and Hesser. They measured physical parameters for 21 candidates and found no evidence for them to differ systematically from Milky Way clusters in terms of their core or tidal radii, or concentration, but they are systematically more elliptical. Roughly half of the candidates have colors similar to those of old Milky Way globulars, while the other half can be either old, unreddened clusters similar to those of the Milky Way or young, reddened clusters formed during the recent merger event.

Johnson, Bolte (both Lick Observatory), Stetson, Hesser and Somerville (Racah Institute) completed an HST study of three of the oldest clusters in the Large Magellanic Cloud, NGC 1466, NGC 2257 and Hodge 11. Their photometry extends some three magnitudes below the turnoff from the main sequence. The three clusters are found to be as old as Milky Way clusters with comparable metallicities; as well, the three LMC clusters are themselves the same age to within 1 Gyr. Both the similar ages to Galactic globulars and the age spread within the LMC clusters appear to be consistent

with hierarchical clustering models of galaxy formation. These results were presented at IAU Symposia 190 and 192.

Pryor (Rutgers U.), Gebhardt (Lick Observatory), O'Connell, Williams (both Rutgers), and Hesser obtained CFHT images through a Fabry-Perot etalon mounted behind the Adaptive Optics Bonnette in their continued quest to measure an accurate velocity dispersion for the core of the globular cluster M15. Images were obtained with cores exhibiting FWHM  $\sim 0.1$  arcsec during part of the run.

Shetrone and Bolte (both of Lick Observatory) and Stetson derived chemical abundances for four giant stars in the Draco dwarf spheroidal galaxy from Keck HIRES spectra. They found an unmistakable difference in  $[\text{Fe}/\text{H}]$  among the four stars analyzed, with the range  $-3.0 < [\text{Fe}/\text{H}] < -1.5$ . The abundance ratios are found to be consistent with a Population II sample, although the  $[\text{Ca}/\text{Fe}]$  ratio may be more nearly solar and the  $[\text{Ba}/\text{Fe}]$  ratio exhibits a steeper slope with  $[\text{Fe}/\text{H}]$  than has been found in the Galactic globular clusters or in the Galactic halo field stars. A hint of a deep-mixing pattern is found in one star (D473), suggesting that Draco giants may be more similar to globular cluster giants than they are to the field Population II giants.

J. Skuljan (Canterbury University) observed a number of northern stars for his PhD project on moving groups of late-type stars in March-April 1998, using the DAO 1.2-m coude spectrograph and the radial velocity scanner (RVS). The project is supervised by Hearnshaw and Cottrell. Results from the observations, together with those collected in June-July 1997, were presented at the IAU Colloquium 170, "Precise Stellar Radial Velocities." A typical internal precision of about  $100 \text{ ms}^{-1}$  has been achieved, which is a factor of two or three better than the usually adopted value for the RVS.

Tian, Zhao, Shao (all of Shanghai Astronomical Observatory) and Stetson measured proper motions for 540 stars in the field of the open clusters NGC 1750 and NGC 1758 in the Taurus dark cloud region, from 20 plates spanning a total time interval of 68 years measured with the HIA PDS microdensitometer. A powerful new method of analysis revealed 332 probable members of NGC 1750 and 23 probable members of NGC 1758. The core radii of the two clusters are found to be very different: 17.2 and 2.25 arcminutes, respectively. It is concluded that the proposed open cluster NGC 1746 is probably not real.

Van den Bergh has studied the relations between the structural parameters for globular cluster systems. Strong correlations were found between parent galaxy luminosity and both the slope of the radial density profile for clusters and their color (metallicity) distribution. He concludes that these systems must have had a complex evolutionary history. It is also found that the variations in the rates with which clusters form in different galaxies show much larger ranges than do the rates with which stars form in these galaxies. In particular it appears that the rate of cluster formation in the LMC increased much faster  $\sim 4$  Gyr ago than did the rate of star formation. It has been found that "young" globular clusters with ages more than 3 Gyr less than those of the majority of globulars are all located at more than 15 kpc from the Galactic center. The data may indicate that the

mean luminosities of outer halo clusters decreases with time and becomes similar to that of open clusters at late epochs.

### 3.7 Binary Stars

Adelman (The Citadel) and Gulliver (Brandon University) continued their studies of high dispersion spectrograms of B and A type stars. Adelman has been collaborating with Ryabchikova (Astronomical Council, Moscow) on studies of binary HgMn stars. Their work on  $\kappa$  Cnc revealed the presence of weak lines of the secondary star. They have also been studying the binary HgMn star  $\alpha$  And. As the DAO spectrogram which included the Hg II line at 3984Å, a line which exhibits isotropic structure, showed a peculiar line profile, Adelman and Gulliver obtained additional spectrograms. These showed that the line profile was variable and an extensive set of observations were obtained in the summer and fall of 1998 revealing variability of two different kinds. This is the first definitive observed variability seen among the HgMn stars. Its existence indicates spatial and/or isotopic variability and is related to atmospheric hydrodynamics. New insights into the physics of stellar atmospheres may result from following up this discovery.

Bohlender, in collaboration with Paunzen (Vienna), obtained spectra of several potential spectroscopic binaries among the peculiar  $\lambda$  Boo stars with the 1.2-m telescope. These data have the potential of providing relatively accurate masses and, hence, evolutionary states for these stars.

R.E.M. Griffin used the 1.2-m coudé spectrograph extensively during the third quarter of 1998 for two programs: (a) to monitor a transient, phase-dependent emission line which appears in certain composite-spectrum binaries, and (b) to obtain full coverage of spectra of  $\zeta$  Aur during its egress from chromospheric eclipse. Program (a) has been continued via occasional service observing during the fall and winter. Program (b) was favored by an uninterrupted run of 20 nights; preliminary indications confirm that the chromospheric K line became double at considerable physical distance from the limb of the supergiant primary, but that the quantitative details may vary from one eclipse to another.

Scarfe (U. Victoria) continued 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. Orbits for two such systems with periods near 100 days were discussed in a paper presented at the 1998 annual meeting of the Canadian Astronomical Society in Quebec.

Scarfe presented an invited review paper, entitled "Radial Velocities of Visual and Interferometric Binaries," at IAU Colloquium 170 in June 1998, based on DAO observations over the past 35 years.

### 3.8 Stellar Spectra and Radial Velocities

Bohlender is continuing several programs on the 1.2-m and 1.8-m telescopes. These include spectroscopic studies of long period ( $> 6$  days) Ap stars, a continuing investigation of the helium line profiles of the so-called "sn" stars, and investigations of the helium abundance geometries of the helium-peculiar stars.

In support of a similar CFHT program being conducted by Bohlender and Gonzalez (Lyon), Bohlender is 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 but observations in these spectral regions are rather sparse. The goal of the study is to compare observed abundances and abundance geometries of CNO to those predicted by Gonzalez's theory. Non-variable Am, Hg Mn, and  $\lambda$  Boo stars are also being included in this program.

Bohlender, Gonzalez (ESO), and Matthews (U. British Columbia) completed a paper on the incidence of nonradial pulsation (NRP) in the peculiar  $\lambda$  Boo stars. Spectra obtained at the CFHT and at the DAO show that more than 50% of these stars are undergoing high-order NRP. Bohlender also headed an intensive multisite campaign on one particularly bright, large amplitude pulsator, 29 Cyg. A detailed study of the frequency spectrum of the pulsation for this and other members of the class will provide a direct measurement of the evolutionary state of these stars. Current theoretical speculation concerned with the origin of the  $\lambda$  Boo phenomena suggests that all members of the class should all be on, or close to, the ZAMS. Using the same data, Bohlender and Gonzalez are also searching for evidence of circumstellar material around the stars.

Bohlender collaborated with Walker, Matthews (both U. British Columbia) and Yang (U. Victoria) 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 and data from a five night run at the CFHT are being reduced and analysed. This project was initiated as a result of Gray's suggestion 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 perhaps not a result of reflex motion caused by an orbiting low-mass companion, but instead arise from intrinsic variability of the star itself. Gray and others have not been able to confirm these results, but the CFHT data are of considerably higher quality so should enable a definitive conclusion to be made.

Bohlender collaborated with Walker, Yang, and Puxley (Gemini) to obtain UKIRT CGS4 spectra of the companion of GL229A. These data are being used to search for radial-velocity variations of GL229B which might arise from sub-Jupiter-mass objects orbiting in the habitable zone of this brown dwarf candidate.

Bohlender and Dworetzky (UCL) are continuing investigations of the mercury and platinum isotope abundances of the peculiar HgMn stars. This work involves careful modelling of high-S/N, high-resolution spectra obtained with CFHT's Gecko spectrograph. The first published results from

this work have shown that the usual hypothesis - that a fractionation process is responsible for the isotope peculiarities - apparently fails.

Bohlender continues a few long-term programs of H  $\alpha$  spectroscopy on the 1.8-m telescope. These include a search for optical evidence of magnetospheres in the helium-peculiar stars, and a search for emission variability in the Ae-shell stars. Efforts by Bohlender to obtain high S/N, high-resolution FTS spectra of the He I 10830 line in late-A and early-F dwarfs in order to search for the convective envelope boundary in main sequence stars were thwarted because of the gearbox failure of the CFHT telescope drive.

Bohlender and Leone (Catania Astrophysical Obs.) used two JCMT shifts and SCUBA to obtain 850 micron photometry of a few magnetic peculiar B stars. The detection - or nondetection - of mm-wave radiation from these objects will conclusively show if the source of their observed nonthermal radio emission arises from cyclotron radiation from nonrelativistic electrons escaping along the open magnetic field lines of the stars or from gyrosynchrotron radiation produced by relativistic electrons trapped in their magnetospheres.

Wallerstein (U. Washington) used several nights on the 1.2-m telescope on the following projects: the determination of the ratio of Zr/Ti in S stars, an exploration of the diffuse interstellar band at 8626 Å in stars with a wide range of reddening, a very preliminary exploration of the possibility of determining abundances in dM stars, and the determination of the metallicity and lithium abundance of stars reported to have planetary companions.

Adelman has also studied Am and A stars in part in collaboration with astronomers in Turkey. Work on several additional Am and F stars is in progress. Coworkers with Adelman on his DAO-related research include graduate students B. Albayrak, University of Ankara, Turkey, and T. Cay and H. Gokmen Tektanali, Istanbul University, Turkey, as well as colleagues H. Caliskan and D. Kocer, Istanbul University, Turkey, and T. A. Ryabchikova, Astronomical Council, Russian Academy of Sciences. B. Albayrak visited Adelman in Charleston from October 1997 through September 1998 during which time he completed most of his analysis of Deneb based on DAO plate material. A spectral atlas is in preparation.

### 3.9 Interstellar Medium

Keenan, Smoker and Lehner (Queen's U., Belfast) have reduced spectra of 16 stars observed in the line of sight towards the high velocity cloud (HVC) in the direction of the M15 globular cluster. These data were taken using the Cassegrain spectrograph of the Plaskett with a velocity resolution of  $\sim 38 \text{ km s}^{-1}$ . The aim of the observations was to search for interstellar Ca H & K absorption at the cloud velocity in the spectra of stars selected to be as early-type as possible. However, no such absorption was detected. This means that either 1) the HVC is located behind all of the target stars, or 2) the gas density and/or metallicity of the HVC is too low to enable absorption to be detected.

Walker (UBC), Krelowski (Nicolaus Copernicus U.), and Bohlender used the high-resolution Gecko spectrograph at CFHT to obtain extremely high signal-to-noise ( $\sim 1000$ )

spectra of several reddened early-type stars to investigate the profile shapes of various diffuse interstellar bands (DIB). Resolved, triple structure seen in some of these features are very similar to gas-phase electronic transitions of carbon chain cations such as NCCCCN<sup>+</sup>, although none coincides exactly with any spectra yet measured in the lab. It is hoped that these and future Gecko spectra will finely securely establish a molecular origin for many of the DIBs.

### 3.10 X-ray sources

Hutchings, Crampton, with Cowley and Schmidtke (ASU), have completed papers on several supersoft binary systems in the Magellanic Clouds. The implied stellar masses and sizes are not in accordance with standard theory of the origin of these systems, and their evolutionary history is not yet clear. They have observing time to continue this work on galactic objects. They have also completed identification of X-ray sources from their ROSAT imaging programs.

### 3.11 Hot Stars

Bianchi (JHU) and Hutchings have continued their work on spectra of hot supergiants in local group galaxies with HST. They have combined the UV spectra with CFHT and Calar Alto spectra at visible wavelengths. They have been [4] awarded cycle 8 HST time to continue this program.

Hutchings is leading the FUSE team program on hot stars. The program contains 70 stars in the Magellanic Clouds and will also utilise FUSE spectra of a similar number of Galactic stars from the ISM program. Preparatory work has included collecting HST and IUE data from program stars and ground-based spectroscopy from ESO. Hutchings is co-supervising Anne Pellerin (Laval) who will do a thesis on these data.

### 3.12 Asteroids & Comets

Aikman continued his program of astrometric observations of near-Earth asteroids with the Plaskett 1.8-m telescope. During the year 710 astrometric positions of more than 130 different objects were reported to the IAU Minor Planet Center. About 75% of the observed objects are in the Aten-Apollo-Amor classes of planet-crossing asteroids, but priority is always given to recently discovered confirmation objects that are just suspected of being in those classes. About 25% of the observed objects fall into the tighter subclass of objects considered by the Minor Planet Center to be potentially hazardous. Highlights of the year included making the confirming observations of 1998 QS<sub>52</sub> on August 27, 28 and 29 following its discovery by the LINEAR group on 1998 August 25. QS<sub>52</sub> is a  $\sim 6 \text{ km}$  asteroid which can approach within three lunar distances of Earth. It had been thought that our inventory of Earth-approaching objects was almost 100% complete down to this size range, which is approaching the class of the event thought to have caused the extinction of the dinosaur. Also of interest was the discovery that two of the objects (J98S01 and J98V24S), which were announced as asteroids, were found to be cometary during the process of Victoria observations.

Balam (U. Victoria), with the assistance of Greimel and Banh (U. Victoria students) reported 858 astrometric positions of 155 newly-discovered asteroids and comets in the course of a program of systematic confirmation and follow-up of unusual Solar System objects done in collaboration with the Central Bureau for Astronomical Telegrams, the Minor Planet Center, the Spacewatch program (U. Arizona) and the Catalina Sky Survey (U. Arizona). During 1998, observations by Balam, *et al.* resulted in the issuance of nine *International Astronomical Union Circulars* (confirmation of five new comets and three extragalactic supernovae) and 51 *Minor Planet Electronic Circulars*. Four Aten objects, 44 Apollo-class asteroids, 40 Amors, 24 Mars-approaching objects, six Hungarias, 35 main-belt asteroids, a Jupiter Trojan and a Centaur-class object were confirmed and tracked during the year. Twenty-five newly-discovered potentially-hazardous asteroids (15% of the total known population) are included in the sample. Banh discovered asteroid 1998 AC<sub>5</sub> in the course of astrometric follow-up of the program objects. Two periodic and 11 newly-discovered comets were observed in 1998. In addition, images of Comet Zhu-Balam (1997 L1), discovered by Jin Zhu (Chinese Academy of Sciences) and by Balam using the 1.8-m telescope in 1997, were obtained when the comet was apparent magnitude  $V = 21.5$  and 6.11 AU from the Sun.

There was a diversity of size among the sample of potentially hazardous asteroids (PHA's) that were tracked during the year. The largest potential impactor was 1998 QS<sub>52</sub> with an estimated diameter of over 6 km. Fortunately, even though 1998 QS<sub>52</sub> can approach the Earth to within 0.008 AU (three times the distance of the Moon), there will be no close encounters from this object within the next 100 years. Other large PHA's include 1998 SS<sub>49</sub> (diameter > 2 km) and 1997 XF<sub>11</sub> (diameter ~ 1.5 km). The latter asteroid was observed both in January and on the night of the IAU press-release in March when it was apparent magnitude  $V = 21.3$  and west of the stationary point. The smallest objects of the PHA sample are 1998 MV<sub>5</sub> and 1998 KY<sub>26</sub>. The estimated size of these objects is ~ 50 meters, about the same size as the object responsible for the Tunguska event of 1908. The remaining 17 PHA's of their observed sample are in the 500 - 1000 m size range. Most of the new PHA's were discovered pre-close-encounter and at moderate (~ 0.3 AU) distances with the exception of 1998 KY<sub>26</sub> (which approached the Earth to within 0.005 AU on June 8) and 1998 UT<sub>18</sub>, which passed within 0.062 AU on Nov. 28. Future close Earth encounters among the above size range include an approach to within 0.0075 AU in 2013 by 1998 FW<sub>4</sub>, while 1998 SF<sub>36</sub> will pass within 0.014 AU of the Earth in 2004.

Requests for confirmation of new comets were received from the Central Bureau for Astronomical Telegrams and S. Nakano (Japan) and resulted in the publication of four IAU Circulars. Two new comets (C/1998 M2 and C/1998 Q1) were originally reported as asteroids by the LINEAR team and subsequently identified as comets from 1.8-m Plaskett telescope images. Greimel obtained images of Periodic Comet Harrington-Abell (52P) and, along with Balam, confirmed that this object was ten magnitudes brighter than the

predicted apparent brightness of  $V \sim 21$ . An additional object detected by LINEAR (1998 WG<sub>22</sub>) and subsequently identified (by Marsden at the MPC) as an object discovered by Vaisala (Turku, Finland) in 1939 was confirmed as a comet by request from Green (CBAT).

#### 4. DAO TELESCOPES

The 1.2-m McKellar Telescope was used for astronomical observations for 1159 hours on 192 nights during the reporting period. This compares with an average of 1385 hours on 211 nights over the last 14 years. The subscription factor was 91% averaged over the fiscal year. CCD detectors (including the infrared camera, VERONICA) were used on 78% of the usable nights, the Radial Velocity Scanner on 17%, and photographic plates on 5%. Of the 331 nights scheduled on the telescope, 22% were assigned to projects led by staff members, with the remainder going to other Canadian (47%), American (14%) and overseas (17%) scientists as principal investigators; 17 scientists including two students were involved with the 10 visitor projects. Two thesis projects, one project coordinated with space observations, and one project coordinated with a multi-site ground-based campaign were supported.

The 1.8-m Plaskett Telescope was used for astronomical observations for 1356 hours on 192 nights. These values compare with an average of 1145 hours on 194 nights over the past 14 years. The subscription factor was 121% averaged over the fiscal year. The telescope was used for optical imaging on 61% of the usable nights, infrared imaging on 4% of the nights, and with a CCD on the Cassegrain spectrograph focus the remaining 35%. Of the 364 nights originally assigned on the telescope, 74% went to non-staff Canadians, 3% to Americans, 7% to overseas scientists as principal investigators, and the remaining 16% to staff astronomers. Thirty-six scientists, including three students, were involved with the 19 visitor programs. Three thesis projects were supported, as was one program coordinated with other ground-based observations.

Businesses owned and operated by Chris Aikman, David Balam and Frank Younger offered service observing to DAO Telescope users. This service was first offered in late FY97/98 and has proven popular, as users do not have to miss classes and are charged only for hours worked by the contractors. In FY98/99 40 nights of 1.8-m Plaskett and 115 nights of 1.2-m McKellar Telescope time were scheduled for contract service observing.

Following his historic night of observing on an international campaign that could not have been envisioned by founding Director, J.S. Plaskett, Danish post-doctoral research fellow Frank Grundahl wrote: "On May 6th 1998 the Plaskett Telescope celebrated its 80th birthday by observing a  $V = 2.7$  mag star all night (and the previous five nights), trying to make the first detection of solar-like oscillations in other stars. The project is a joint venture with people from Denmark, Australia and the U.S., with simultaneous observations being carried out at the Nordic Optical Telescope on La Palma and at Lick Observatory. One could say that we are now back to basics with this telescope, by observing stars that could have been observed in 1918. However, with the

internet for coordinating observations and CCD's to detect the photons, we are (hopefully) somewhat more efficient now-a-days. I did not have any encounters with "ghost observers" from the past, but it did cloud over shortly after midnight."

Bond continued to provide much complimented support to guest observers throughout the year, and to implement a number of improvements to the operating environments of the telescopes. He worked closely with Jennings, Heppner and others to arrange repairs by United Engineering to the 1.8-m dome shutter following its failure. Drew and Saddlemyer implemented a new Graphical User Interface for the telescope control systems and a Web-based one for the data storage mechanisms. These increase the observing efficiency and the data management efficiency, respectively. Jennings, Saddlemyer, Ganton and Stajduhar recoated the 1.2-m mirror in August.

Bohlender prepared the quarterly schedules, while Hesser chaired the Time Assignment Committee, whose other members for the year were Bohlender, Grundahl, Hartwick (U. Victoria), Morris, Saddlemyer, and Walker (UBC).

Doyon (U. de Montreal), with assistance from Bond and Saddlemyer, commissioned VERONICA, the clone of the MONICA near-IR imager successfully used for many years at CFHT. Veronica has a scale of  $0.52 \text{ arcsec pixel}^{-1}$  and a field of view  $133 \times 133 \text{ arcsec}$ . Balam and other users helped to characterize the detector.

Leckie, Hardy, Saddlemyer and Stilburn implemented SITE 5, a  $1024 \times 1024$  thin, backside illuminated CCD to replace SITE 3, which failed.

## 5. CANADIAN ASTRONOMY DATA CENTRE

### 5.1 HST Archive

Funding from the Canadian Space Agency allowed the CADC to continue to provide access to HST data and novel tools for using the HST archive.

Durand, in collaboration with Micol (ST-ECF), finished the first release of the "On the Fly Recalibration" for the STIS and NICMOS instruments. After the completion of the calibration pipeline, Durand added the preview pipeline to the system allowing users to preview data from these two new HST instruments. Support for the "On the Fly Recalibration" system for the older instruments was also enhanced.

In July, Durand installed a new tool, developed in collaboration with the ST-ECF group, that allows retrieval of WFPC2 data for a series of frames associated with an object. Users receive stacked WFPC2 images that have been cosmic ray cleaned and registered. This tool continues to be improved. In addition, extensive consistency checks of HST data were performed, as was electronic retrieval of missing data.

During this fiscal year, CADC serviced more than 10,402 catalogue accesses retrieving details on 247,000 entries; processed 709 data requests; and distributed the resulting 160 Gbytes of Hubble Space Telescope data to its users, which is twice as many as last year!

### 5.2 CFHT Archive

Bohlender and Gaudet continued development and maintenance of the CFHT archive. Following fixes of data-dictionary/header problems, about two years of data were finally ingested, resulting in about a 10% increase in the number of files in the CFHT archive science catalogue.

Gaudet, in collaboration with CFHT staff, performed an experiment on electronic data delivery to CADC directly from the acquisition computer. This was done to determine if CADC could operate the CFHT archive more simply without having multiple transfers involving tape media. Gaudet also designed the CFHT data migration pipeline for automatic CDROM production which is now operational. The CFHT archive was accessed 7788 times during the past year, for a total retrieval of more than 200,000 entries.

### 5.3 JCMT Archive

Bohlender completed the biannual update of JCMT catalogue. JCMT archive access remains modest, in part because the JCMT uses a unique non-standard file storage format. Around 76,000 entries were retrieved from the catalogue during 1301 distinct queries; about 150 data requests were fulfilled.

### 5.4 IUE Final Archive

Bohlender assumed responsibility for the International Ultraviolet Explorer (IUE) final archive. The CADC will act as a National Host for the IUE Newly Extracted Spectra (INES) archive once data and software are delivered and ported.

### 5.5 CNOc Archive

Schade, Dowler, and Zingle worked to implement and populate the CNOc1 archive as a test-bed for remote querying and data-mining of basic astronomical data (images) and derived information (scientific parameters). This is basically an On-Line Analytical Processing (OLAP) system which stores the results of image processing and scientific analysis and all the information needed to reproduce the results. The archive itself is very general and capable of storing, and allowing querying on, an inhomogeneous and extensible collection of data (i.e., we can continue to add results of processes to the database, even if we have not conceived of the process or type of result yet). Currently there are approximately 400,000 scientific "facts" about 28,000 objects in the survey fields.

### 5.6 ESO ASTO Project

Dunn, Gaudet, Hill, and Jaeger worked on the Archive Storage Subsystem (ASTO), parts I and II, for the European Southern Observatory (ESO). The first ESO contract with the CADC, ASTO part I, was completed in Spring 1998. A second contract was issued in Fall, 1998, and the software was delivered at the end of March 1999. The second contract included design of enhancements, development and testing of ASTO II, and the writing of final documentation.

## 5.7 Electronic Proposal System

Durand and Bohlender developed POOPSY, the first electronic proposal system for CFHT, which will also be used for Gemini proposals. This Web based system allows users to submit LaTeX proposals, on which POOPSY then performs some consistency checks before submitting the formatted proposal to the proper agency. POOPSY was used successfully for the 99II CFHT semester. The work was partly supported by the Canadian Gemini office.

## 5.8 GEMINI Projects

Dunn, Gaudet, Hill, Jaeger, and Cockayne continued design development and testing of the Gemini Data Handling System (DHS). They completed the final documentation of DHS, and version 0.14 was accepted and released in August 1998. The Data Processing Detailed Design Review was held in January 1999, with the final version passing the acceptance test; it was released in March 1999.

In addition, efforts continued to secure agreement to proceed with a contract to implement the Gemini archive system as proposed jointly by Canada and Chile.

## 5.9 Digitized Sky Survey CD Duplication

Durand continued the duplication of the second Digitized Sky Survey (XDSS), with more than 2600 CDs having been written and distributed to the project partners so far. This includes two new copies for the GEMINI telescopes North and South. The first color of the survey is almost finished and duplication for the second color will start soon.

## 5.10 Data Mining

With a special allocation from NRC, the CADC acquired two 450 SUN SPARC servers, 130 GBytes of disks, and were able to hire a computer programmer, Pat Dowler, for one year, for the data mining project. CADC has begun developing expertise in this field because astronomy is an endeavor that will benefit greatly from the ability to extract effectively knowledge from existing, very large, distributed datasets. The data mining capabilities under development will be applicable to any archival dataset and will greatly enhance astronomer's ability to work across archive boundaries and across wavelength boundaries. These capabilities represent the next generation of archive-user interface and will change the way that science will be done. The net result will be greater scientific power in the hands of the user, maximum exploitation of existing data, and lower costs for a given scientific output.

In order to develop fully the data mining concept, a huge number of CPU cycles is required. This amount of power is not accessible by conventional means, given our limited budget, but other, more effective means are becoming available. Through a special allocation from NRC, DRAO and CADC jointly acquired a Beowulf type cluster in March. The system is a 16 CPU PC-Pentium based one running at 400 MHz under Linux.

## 5.11 Other Activities

CADC continues, with financial help from CSA, to pay for Canadian access to SIMBAD. As in the past, CADC supported IRAF and various scientific application software packages for HIA Victoria.

Gaudet remained responsible for the maintenance of critical CADC pipeline systems, e.g., preview, retrieval, recalibration, media ingestion and verification, and for operational support, e.g., CDROM writing, offline user requests, tape backups, migration of databases to new computer, etc.

Gaudet actively pursued commercialization of CADC software with several Canadian firms and with the support of NRC services in Ottawa.

During the year CADC supported HIA's participation in the High Performance Computing collaboration with U. Victoria. Since its inception the CADC has maintained vigorous collaborations with its international partners, Space Telescope Science Institute (STScI), which operates with NASA funding, and the Space Telescope European Coordinating Facilities (ST-ECF), which operates with ESA funding. These associations increase the visibility of CSA among its counterparts in other countries. Both of these facilities have drawn from CADC experience and vice versa. ST-ECF has cloned our entire system including CD-ROM storage, recalibration, and previews, while they are developing a query mechanism for the new NICMOS. STScI uses our previews and is increasingly moving toward a system like CADC, while they facilitate CADC's acquisition of HST data. Strong collaborations allow us to share scarce resources, avoid duplication of effort, keep abreast of recent developments, and yield a return of goodwill and recognition for Canada's achievements.

CADC joined the AstroBrowse consortium, whose goal is to offer its services using a common, well defined interface for sharing information between archive centers. As well, CADC also offers its services through the SKYCAT consortium. SKYCAT is a visualization tool which accesses CADC databases of catalogues and images. In collaboration with the CFHT librarian, CADC maintains on behalf of the international community the list of all astronomical meetings, which was heavily consulted by the international community during the fiscal year.

## 6. COMPUTER SYSTEMS AND LIBRARY

### 6.1 Computer Systems

Computer Group staff during the fiscal year consisted of Broom, Justice, Stetson (Group Leader), and Sullivan; Isherwood and Shew also contributed their skills for terms of a few months each. Robert Walker joined the Group early in 1999. Apart from routine maintenance and enhancement activities (which were numerous), a few major advances are worthy of particular note.

During the year the number of PC work stations deployed and functioning increased from about 60 to more than 100. In addition, between 20 and 30 machines were reconfigured and redeployed for new tasks. In sum, some 47 machines were completely configured or reconfigured, 33 new

work stations were created, and no computers were retired from service during this period.

All of the Unix computers for HIA science and engineering, some eleven in total, were upgraded from Solaris 2 to Solaris 2.6. A new Ultra system was brought on line to replace a Sparc station for scientific computing. A new Cisco router/switch provided by NRC was successfully implemented, enabling the connection of HIA Victoria to CA\*Net II. Much effort was spent in confirming that HIA Victoria computing is not particularly vulnerable to any major Year 2000 design flaws. NRC's new SAP software system, Sigma, for financial and human resource activities was largely deployed.

## 6.2 Library

Hutchings continued as advisor to the library which operates as a branch of NRC's Canada Institute of Scientific and Technical Information, CISTI. Their acquisitions budget has been greatly reduced, as a result of which the HIA library suffered the first of two 30% cuts, which affects both the DAO and DRAO sites.

Among various activities, Leblanc supervised development of a prototype database for fuel cells for the NRC Innovation Center and co-ordinated the move from an in-house software package to CISTI's Innopac circulation system. Hanna made regular visits to DRAO, and reported the extensive contents of the observatory publications collection to CISTI cataloging. During her one year internship Sullivan barcoded the monograph collection, and began a CD-ROM archive of newspaper articles dating back to DAO's founding.

## 7. INSTRUMENTATION AND SOFTWARE

### 7.1 Gemini Multi-Object Spectrograph (GMOS)

Crampton and Murowinski continued as Canadian Project Scientist and Managers, respectively. Roberts worked on the GMOS focal plane environment integration and test.

Szeto spent time on design completion, fabrication drawing production and fabrication specifications development for various GMOS fore-optic structural components. They included the Fore Optic Support Structure (FOSS), Focal Plane Support Structure (FPSS), Mask Cassette Support Structure (MCSS). Working closely with our UK partner, the Front Focal Plane Enclosure (FFPE) design was proposed, and eventually it was decided to shift the FFPE work to the UK for final design and fabrication.

Szeto also worked on the development of the flexure test jig so that the fore-optic components could be integrated, tested and characterized under different gravity vectors before delivery to the UK. The flexure test jig design incorporated a mounting plate, mimicking the Gemini telescope Instrument Support Structure (ISS), on the Unertl table in the optical shop

Szeto worked on addressing GMOS opto-mechanic issues such as optic mounting modification, mounting arrangement and alignment of lens groups on the collimator and camera barrels. Detailed finite element analysis (FEA) was conducted to determine the stress level and optimize the "fin-

ger" flexure geometry. The barrel designs were revised in order to make fabrication and optical alignment practical. The fabrication and delivery of GMOS components also required ongoing engineering support and monitoring throughout the remainder of the year until the main structure FOSS was shipped from NRC Ottawa just before Christmas. Szeto presented a poster paper at SPIE conference describing the flexure compensation system developed for GMOS.

### 7.2 Gemini Adaptive Optics System (Altair) and Related Work

Morris continued as Project Scientist and Glen Herriot continued as Project Manager, leading the Altair team to a successful Critical Design Review (CDR) in February 1999.

Herriot responded to issues raised by the Preliminary Design Review and in particular managed the design of a Laser Guide Star upgrade for Altair. He invented a novel method to estimate centroid gains in both natural and laser guide star wavefront sensors for adaptive optics, he managed a sub-contract awarded to McGill University to develop a Deformable Mirror hysteresis model, included in performance estimates for Altair. Herriot presented a poster on Altair at the ESA/OSA conference on Adaptive Optics in Germany in September 1998, and gave invited Altair talks in May at the CASCA meeting in Quebec City and at DRAO.

Véran updated the Altair error budget, revised the servo-loop analysis from PDR, and developed a new tip-tilt correction scheme that meets the initial error budget. He presented a paper on this work at the same ESO/OSA conference. He supervised and then took over work from U. Victoria PhD candidate Eric Steinbring, on a novel optimal linear extrapolation method. He also designed an Altair modal control scheme. Further, he investigated modelling hysteresis on piezo-electric material with Herriot, Steinbring and McGill University engineers. Véran interacted with optical and mechanical engineers to assess the performance of their design, and worked with Herriot on various servo schemes for Altair. Roberts produced systems-level and detailed designs for the Altair critical design review, and was the lead mechanical engineer on the project.

Szeto's major design effort for Altair was spent in finite element analysis (FEA) to determine the static and dynamic characteristics of the optical bench and its Serrurier truss support system. Engineering support was also provided to the design team in order to define the various mechanical interfaces, instrument handling and thermal analysis.

Véran pursued his investigations of the use of image processing tools to analyse adaptive optics images. His work mainly consisted of four collaborations: with Beuzit (CFHT) on accurate astrometry and photometry of binary stars, with Walker (UBC) on detection of extra-solar planets, with C. Roddier (UH) on accurate astrometry of the components of the T Tau system observed (papers presented at ESO/OSA conference), and with ONERA, France on myopic deconvolution of images. Véran also participated in the writing of US\$19 million NSF funding proposal for a Center for Adaptive Optics and visited the VLT adaptive optics group in Paris. Herriot participated in meetings of the Gemini Laser Guide Star working group.

### 7.3 Other Gemini

Wooff, as manager of the Gemini Enclosure Control System, and Rambold, completed and delivered this project. It is now in use on Gemini North.

### 7.4 CFHT Instrumentation

Crampton, as co-PI of the CFHT Megaprime project, participated in a review meeting at CFHT in March 1999. The optical design was completed by Morbey and the optical blanks have been ordered. Mechanical design and fabrication of the lenses are just beginning.

Roberts and Szeto worked on the preparation of the conceptual design review for the CFHT new wide field camera MegaPrime, including conceptual designs for the guiding system.

### 7.5 Next Generation Space Telescope (NGST)

Crampton, Morris, and Hutchings are working on three prototyping contract studies for NGST for the CSA. These are for a multi-object spectrograph (MOS), a Fourier transform spectrograph (FTS), and an optical imager. These were initiated by a meeting with CSA and NASA at HIA in November.

The FTS study is in collaboration with BOMEM (Quebec City), while the MOS study is together with engineering groups at U. Victoria and Simon Fraser U. Herriot and Roberts studied and advised on concepts for a MOS focal plane assembly. The imager project is led by Hickson (UBC) and is in collaboration with Hutchings and CAL Systems.

Hutchings served on the NGST external science review panel held by NASA in December.

### 7.6 Other Space Instrumentation

Hutchings has worked with Murowinski and Hardy and groups from CSA, JHU, and ComDev in developing the cameras for the FUSE Fine-Error Sensor, including testing the engineering model camera in the lab at HIA, in preparation for a launch in mid 1999.

Hutchings is the mission scientist for CUVIT, the Canadian Ultraviolet Imaging Telescope, which was [4] awarded a CSA contract for phase A study. The study was done with Murowinski and Morbey, with contracts and collaborative work at Bristol Aerospace, Routes Inc, MSSSL, and the NASA Spartan Lite team. CUVIT was not selected for the initial Scisat flight by CSA, but the project is continued for further development within the Scisat program. The project has a science team of astronomers across Canada. The project may also include an international partner.

## 8. MISCELLANY

Bohlender continued to serve on the CFHT Time Assignment Committee, and was co-chair of the Local Organizing Committee of IAU Symposium 190, New Views of the Magellanic Clouds, which attracted about 190 participants from 21 countries.

Bond co-chaired the HIA Safety Committee, which worked closely with staff and management to implement numerous preventative measures.

Courteau chairs both the Scientific and Local Organizing Committees of the workshop on Cosmic Flows being planned for U. Victoria in 1999 July. He continues his educational and outreach activities. For the last three years he has provided Canadian Airlines with popular scientific articles for their inflight magazine. The latest story focuses on the new Gemini twin telescope project. Courteau is also a regular guest on the Canadian Broadcasting System French language network's radio morning show "CBUF-Bonjour," and is an active member of the B.C. program "Scientists and Innovators in the Schools."

The Canadian Astronomical Society (CASCA) and the Royal Astronomical Society of Canada (RASC) [4] awarded Crampton the 1998 Helen Sawyer Hogg Public Lectureship. He spoke on "Exploring the Universe with New Eye" at the 1999 RASC Annual General Meeting held at Pearson College. He presented scientific justifications and proposed astronomical specifications for a widefield IR camera for CFHT at the fifth CFHT Users' meeting in Quebec City. Crampton and Morbey also presented designs for a very large wide field optical telescope at the same meeting. Crampton attended the conference "The Birth of Galaxies" in Blois, France in July.

Durand and McClure actively developed HIA Web pages and served on HIA's Web committee.

Durand, Jaeger and Gaudet attended ADASS98 in Illinois. Bohlender, Durand, Gaudet, and Schade attended CASCA98. Durand, Gaudet, and Schade attended TERAPIX meetings in Strasbourg to plan the pipeline processing of MegaCam images from CFHT. Durand and Bohlender attended the CFHT users meeting in Quebec City. Gaudet attended a Software Commercialisation Workshop in Aylmer, Quebec. Durand and Schade attended the Gemini Science Archive workshop.

Hesser completed his co-supervision as an adjunct professor at U. Victoria of M.Sc. student M. Gim, whose thesis on NGC 7789 was fully published. He co-chaired with David Bohlender the Local Organizing Committee of IAU Symposium 190. As a Victoria Centre Council member, he assisted the RASC with the 1998 Annual General Meeting held in Victoria. He also is serving on the LOC for the Cosmic Flows workshop being organized for 1999 July at U. Victoria, and as local contact for the 1999 meeting of the Antique Telescope Society in Victoria in 1999 October. Hesser participated in numerous meetings of the HIA Building Committee which is working with NRC and its contractors to plan safety upgrades to, and expansion of, the Victoria facilities, including plans for a new visitor centre. He continued on the Board of Directors of the CFHT, where he chaired the selection committee for the next Executive Director, coordinated agency interaction with an external review committee, co-organized an inter-agency meeting and served as Vice Chair. Hesser also continued service on the AURA Board of Directors, and attended their quarterly meetings as well as the annual meeting of the Member Representatives. He serves on AURA's committee to examine the future di-

rections of NOAO. At the invitation of the Harvard College Board of Overseers, he served on their Visiting Committee for the Department of Astronomy. He made many presentations to classrooms (under the auspices of B.C.'s Scientists and Innovators in the Schools program) and service clubs.

Hutchings chairs the CFHT Scientific Advisory Council (SAC) for 1998-9. The SAC met in Quebec City in May and Hawaii in October, and also ran the CFHT users meeting in Quebec City immediately prior to the CASCA meeting. The users meeting proceedings have been published and the SAC reports are published in the CFHT web site. Hutchings reported to the CFHT Board in December on behalf of SAC. The SAC has been discussing several new initiatives, including queue scheduling, web proposal submission, the establishment of a joint French-Canadian TAC, and the definition of major survey programs with the Megacam. These changes are being considered in view of the new role of CFHT as the VLT and Gemini telescopes are commissioned. Hutchings continues as a member of the STIS and FUSE science teams, and attended the FUSE proposal peer review in June. Hutchings will serve on the FUSE observers advisory panel for 1999. Hutchings served as student term coordinator, and leader of the HIA Victoria science committee. He was a member of HIA building committee discussing and reviewing work on building extension, renovation, and visitor centre design. He participated in several news media releases and interviews during the year, and gave some public talks. He attended IAU symposia at U. Victoria and Cape Town.

Morris continued as a member of the Canadian and the international Gemini Science Steering Committees, the Canadian NGST Science Steering Committee and as chair of CASCA's Optical and Infra-red Advisory Committee. He is also a member of the Long Range Planning Panel, charged with producing a plan for Canadian Astronomy for the period through to 2015. Morris continues to act as supervisor for Mike Balogh (U. Victoria) and Scott Chapman (U. British Columbia).

Guest worker Oke is a member of the Institute Visiting Committee for the Space Telescope Science Institute. With the support of HIA, Oke continues as Editor for Instrumentation for the Publications of the Astronomical Society of the Pacific. During 1998, he handled 43 Instrumentation papers.

Schade made tutorial presentations on CADM to students and faculty at several Ontario universities: McMaster, Queens, Toronto, York and Waterloo. He served on an HST Time Allocation Panel and on the National Extragalactic Database Advocacy Board. He also supervised a co-op student (Letawsky) and worked with several day-shadow students. He advised L.F. Barrientos on his U. of Toronto Ph.D. thesis work; Barrientos is now a faculty member at U. Catolica de Chile.

Stetson spent July and August as a guest of the Australian National University, where he worked on data analysis for the HST Key Project on the extragalactic distance scale.

Guest worker van den Bergh continued to serve on the KPNO time allocation committee for Galactic astronomy, as a member of CITA, and retired from the editorial board of *Vistas in Astronomy*. A ceremony held at IAU Symposium 190 celebrated his official retirement from the Observatory

staff at the end of March, 1998. Van den Bergh wrote an article on the importance of a paper by Johnson and Morgan (1953) to the history of observational astronomy for a volume celebrating the 100th anniversary of the *Astrophysical Journal*. He has also prepared a short paper on the early history of "dark matter."

## 9. OUTREACH PROGRAM

Starry Messenger Communications (Don Moffatt) completed the eighth consecutive year under contract to perform many of these activities. During these years, Starry Messenger's excellent programs were enthusiastically received by the public of all ages. At fiscal year end the contract passed to another firm.

During the report year Starry Messenger conducted 128 group tours, for Preschool-Kindergarten (9%), Elementary Schools (49%), Secondary Schools (19%), Post-Secondary Schools (6%), Adult Groups (10%), and Mixed Age Groups (7%). Since the minimum size for a group tour is 15, and a typical school class visit is 25 students plus 5 adults, more than 3,000 individuals are estimated to have participated. Starry Messenger was also responsible for the 30 Saturday night open houses between April 1 and October 31, where attendance was estimated to have been about 3,500. The grounds and display gallery remained open to the public during office hours and summer weekends, and attracted large numbers of additional visitors. Under a separate contract, Starry Messenger Communications delivered a comprehensive public outreach web site for HIA.

During the year staff hosted major open houses for staff families plus members of the Victoria Centre of the RASC on the occasion of the 80th anniversary of the Plaskett Telescope on 6 May, as well as for IAU Symposium 190, IAU Colloquium 170, the RASC General Assembly, and the 6th International Colloquium on Atomic Spectra and Oscillator Strengths.

Staff also hosted many "day shadow" students from area secondary schools, and Pearson College work term students.

## PUBLICATIONS

### 10.1 HIA Staff Publications (calendar year 1998)

(Note: a few publications missed in previous years are included herein.)

Aikman, G.C.L. et. al. 1998, IAU Circular, 7071

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