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This report covers the period from July 1, 1994 to June 30, 1995 (with a little spill-over at each end). It chronicles the main events of our academic year, and describes recent research projects completed and in progress by members of our Department. The work discussed is mainly in the fields of variable stars, surface mapping of A and B stars, stellar winds in B and Be stars, activity in cool stars, and theoretical cosmology.

1. INTRODUCTION

The faculty members of the Department of Astronomy during the 1994-95 year were Professors H. M. P. Couchman, D. F. Gray, J. D. Landstreet (Chairman), J. M. Marlborough, R. Mitalas, J. M. Moorhead, A. Wehlau, and W. H. Wehlau (Emeritus). Marlborough was on sabbatical leave during the year, but stayed on campus for most of the year, and worked on preparation for the ISO space mission, to be launched in late 1995. Gray started a sabbatical leave in July 1995, and will also stay mainly in London. Departmental staff included secretaries G. Laine-Bailey (Head Secretary) and A. Brooks, electronics technician M. Debruyne, research assistants D. Holmgren and R. Slawson (who recently obtained his Ph. D. at Western), software engineer H. Leparskas, and draftsman M. Rasche. Graduate students in residence during at least part of the year were C. Blake, E. Neagu, E. Tittley, and G. Wade.

It was a great shock to the Department when Professor W. H. Wehlau, who founded the Department of Astronomy here in 1966, and remained Head until his retirement in 1991, died unexpectedly while attending the meeting on "Astronomical Applications of Stellar Pulsations" in South Africa with his wife. A memorial service here several weeks after his death was attended by well over a hundred people from the University, the community, and from other universities, as well as by a number of his former students. IAU Symposium 176, "Stellar Surface Structure," held in Vienna in October 1995, was dedicated to Prof. Wehlau's memory, and was attended by Profs A. Wehlau and D. F. Gray and by G. Wade from UWO.

Two Department of Astronomy members who have left for positions elsewhere are Dr. D. Holmgren, now at the Ondrejov Observatory in the Czech Republic, and Dr. R. Slawson, now at the Centre for Imaging Sciences of the Rochester Institute of Technology.

Several visitors spent time at the Department during the year. Dr R. Waters of the University of Amsterdam visited Marlborough for about week. Dr I. Romanyuk of the Special Astrophysical Observatory (the six-meter telescope) in Russia started a five-month collaborative visit with Landstreet in May.

E. Neagu spent the summer working for the GONG project at Kitt Peak National Observatory in Tucson, Arizona; G. Wade spent two months working at the European

Southern Observatory with G. Mathys (ESO).

In November of 1993, the primary mirror of the University's 1.2-m telescope at Elginfield Observatory was sent off to R. Goff, of Astronomically Xenogenic Enterprises, in Tucson, Arizona, to be reground and polished. This was required to remove the surface deterioration apparently caused by the chemicals used to clean the mirror for realuminizing during 25 years of service. The mirror was returned in September of 1994 with its surface fully restored and with a significantly improved figure. This work was funded by the Natural Sciences and Engineering Research Council of Canada.

In the spring of 1994, a grant was received from UWO's Academic Development Fund for the purchase of a spectroscopic (4000×200 pixels) CCD detector from Dr. G. A. H. Walker (University of British Columbia), an IR Labs dewar, and control and readout electronics furnished by Dr. R. Leach (San Diego State University). This CCD is presently being installed on the Boller & Chivens low-dispersion Cassegrain spectrograph of the 1.2-m telescope. Preliminary tests have been very encouraging.

At the same time, work has been in progress on the construction of a two-channel, fibre-fed polarization modulator for use with our Cassegrain spectrograph, and eventually with other spectrographs. This instrument is intended to be used to obtain medium and high-resolution spectra in all four Stokes parameters of such objects as hot emission-line stars and magnetic Ap stars. The project has been funded by an equipment grant from the Natural Sciences and Engineering Research Council of Canada, and by contributions of research funds from a consortium of interested astronomers including Profs. P. Bastien and A. Moffatt (Université de Montréal), J. Rice (Brandon University), and W. H. Wehlau and Landstreet (Western). The design work is being done by M. Debruyne, and parts are mostly being fabricated in UWO's shops. Dr. N. Piskunov (JILA) has contributed much control software. This instrument is now ready for tests on the sky.

2. VARIABLE STARS

A. Wehlau and R. Slawson have derived magnitudes for more than 60 variables in the remote globular cluster NGC 7006 using 120 B frames and 106 V frames of the cluster taken from 1984 through 1994 by J.M.Nemec. This data have been used to improve the periods and period changes rates presented in an earlier paper which reported on one color photographic photometry for 46 of the RR Lyrae variables (AJ 103, 1583,1992). In addition, periods have been obtained for five additional RR Lyrae stars and colors have been derived for all the variables observed. Preliminary results of the study were presented at IAU Coll. 155 and a complete discussion will be submitted to the Astronomical Journal. W. H. Wehlau and A. Wehlau presented an analysis of the light variability of the Delta Scuti star 28 Aql at IAU

Coll. 155. Photoelectric observations made during four years at UWO were combined with published observations and two frequencies present in every year in which observations were made were identified. A complete discussion of the results will be submitted for publication. A paper by Bax, Wehlau and Matthews on the multiple-period Delta Scuti star FM Comae will be published soon in the Journal of the Royal Astronomical Society of Canada.

3. SURFACE MAPPING, MAGNETIC FIELDS, AND NORMAL AND PECULIAR A AND B STARS

J. B. Rice (Brandon University) and W. H. Wehlau completed and published a Doppler imaging study of the Ap star 17 Comae (A&A 291,825,1994). Distributions and abundances of iron, chromium, barium, cerium and lanthanum were presented. Observations of epsilon UMa by Rice and Wehlau have been reduced by D. Holmgren and maps of the Oxygen distribution have been completed. Mapping of other elements is in progress and a paper is in preparation.

An analysis of the limb darkening of the rAp star HR 3831 by J. M. Matthews, Gordon Walker (both University of British Columbia), W. H. Wehlau, and J. B. Rice is appearing in the Astrophysical Journal. Mapping of the surface distribution of chromium and the surface magnetic field on HR 3831 has been completed by N. Piskunov (JILA), G. Mathys (ESO) and W. H. Wehlau and a paper will be submitted to Astronomy and Astrophysics.

Landstreet has been obtaining CFHT and OHP spectra with $R = 120,000$ of some of the A and B stars (both magnetic and non-magnetic stars) which have the smallest known values of $v \sin i$, in an effort to study the intrinsic line profiles of such stars. In particular, he is trying to detect directly the excess broadening presumably produced by the microturbulence almost always deduced from abundance analyses. This effort has been complicated by the fact that most A and B stars of really low $v \sin i$ are either magnetic or members of SB2 systems.

Landstreet, S. Vauclair and N. Dolez (both Observatoire Midi-Pyrénées, Toulouse) have been studying the use of Ne and O as possible tracers of weak winds in late B stars. These elements are too abundant to be levitated significantly by radiation forces, but in the presence of a weak stellar wind ($\sim 10^{-13} M_{\odot} \text{ yr}^{-1}$) may be levitated in the stellar envelope (where the ion-ion coupling is strong) but not pulled up through the atmosphere (where the neutral-ion interaction is much weaker). An overabundance of one of these elements in a stellar atmosphere could thus be a recognizable symptom of an otherwise not easily detectable wind. A paper is in preparation.

Wade, Neagu and Landstreet have been collaborating with J.-L. Leroy (Observatoire Midi-Pyrénées, Toulouse) to study a number of cool magnetic Ap stars with unusually strong magnetic fields for which broad-band linear polarization measurements provide information about the transverse component of the global magnetic field, a characteristic of the field normally hard to constrain observationally. Analysis of results for the linear polarization variable HD 115708 has been accepted by A&A; analysis of the star HD 192678,

which shows both resolved Zeeman splitting and variable linear polarization, is almost ready to submit.

In connection with the collaboration with Leroy, Wade is modeling detailed profiles of the Fe II 6149 Å line to examine the extent to which they are consistent with a magnetic field geometry model derived from the linear and circular polarization data.

Landstreet, G. Mathys, T. Lanz (NASA-Goddard Space Flight Center), and J. Manfroid (University of Liège) continue to obtain measurements of resolved Zeeman splitting of spectral lines in a number of slowly rotating magnetic Ap stars of large fields. These data provide a valuable source of constraints on possible field structures in the stars in which splitting is detectable. At present, some 25 stars are known in which splitting is measurable; most of these stars are now being observed systematically to determine the field variation during rotation in order to make modeling possible.

4. BE STARS AND STELLAR WINDS

Marlborough and associates are continuing investigations of the structure and dynamics of the circumstellar matter around hot stars. P. Zaal (Astronomical Institute 'Anton Pannekoek', University of Amsterdam, The Netherlands), L. B. F. M. Waters (Academy Fellow, Astronomical Institute 'Anton Pannekoek', University of Amsterdam, The Netherlands) and Marlborough have predicted the IR spectrum from a low density disk around a hot star in the wavelength range 2-50 microns (AA 299, 574, 1995). Marlborough, Waters, and J.-W. Zijlstra (Kapteyn Astronomical Institute, Groningen, The Netherlands) have completed a parameter study of the strengths and shapes of several infrared recombination lines of hydrogen formed in a disc-like model of the circumstellar region around a Be star. A summary of this study is currently being prepared for publication. The results of these latter two investigations will be used to obtain an initial interpretation of line profiles to be obtained from ISO, the Infrared Stellar Observatory, a satellite scheduled for launch in the autumn of 1995. More detailed analyses of these profiles will be obtained using a non-LTE atmosphere code and a wind code. Zaal, Waters, Marlborough and T. Geballe (Joint Astronomy Center, Hilo, Hawaii) have detected infrared hydrogen emission lines in a number of hot stars; Zaal is currently preparing all of these data for publication. J. Coté ((Astronomical Institute 'Anton Pannekoek', University of Amsterdam), Waters, and Marlborough have completed a study of the structure and dynamics of Be stars with small circumstellar discs. Two stars in this category, HR 7739 and eta Cen, have far IR energy distributions which are much steeper than the bulk of Be stars. Eta Cen is most likely surrounded by a flat, slab-like disc. HR7739 is also surrounded by a small disc, but its geometrical shape is uncertain. This investigation will be published in Astronomy and Astrophysics. Marlborough and A. Procter (Astronomy Department, Yale University) are continuing their investigations of Balmer line profiles in the model of the wind of a B[e] supergiant (Ap. J. 369, 191,1991). Balmer line profiles have been computed for a variety of inclination angles of the observer's line of sight relative to the rotation axis. These results are being prepared for publication. Marlborough and Waters are continuing at-

tempts to model the observed H-alpha line and infrared lines such as Brackett-alpha in P Cyg in order to deduce physical conditions in the inner part of the massive wind of this star. Marlborough, Procter and Waters are continuing their attempts to construct rotating stellar wind models for the O6 I star lambda Cep to see if the inclusion of rotation can produce line profiles which agree better with the observed ones. Double peaked profiles are obtained but overall agreement between the model and the data is still not sufficiently good.

5. STELLAR ATMOSPHERES, MAGNETIC ACTIVITY, AND STELLAR CYCLES OF COOL STARS

David F. Gray analyzed the magnetic-cycle behavior of β Comae (G0 V) and ξ Boo A (G8 V) using precise temperature and granulation measurements from coudé spectroscopic observations taken at UWO combined with *b,y* photometry from the Lowell Observatory and Ca II HK emission measurements from Mt. Wilson. The observations span approximately one decade. Temperature excursions of several degrees are seen for both stars. The pattern of variation is the same as for the HK chromospheric signal, but delayed in time by 2.9 years for β Comae and 1.8 years for ξ Boo A. These lags agree with the trend of decreasing lag with later spectral types found in earlier studies. Other parameters also show time delays, and the details are being published in the *Astrophysical Journal*.

Gray is working with W. Livingston (NOAO) on Livingston's whole-disk spectroscopic monitoring data taken at Kitt Peak and spanning 15 years of time. The main aim is to measure any change in solar temperature during the magnetic cycle. The temperature sensitivity of the C I line at 5380 Å has been calibrated using stars with temperatures near the sun's. Although analysis is still proceeding, preliminary results indicate a temperature change of 1.4 K.

Gray studied the relative temperature of the sun within a stellar grid using precise measurements of spectral line-depth ratios. Although several stars have temperatures similar to the sun's, the closest one found to date is 16 Cyg A (solar + 5 ± 12 K), while 16 Cyg B is considerably cooler (solar -45 ± 12 K).

A chemical abundance analysis of γ Dra (K5 III) was completed in collaboration with K. Sinha and B.B. Sanwal (Uttar Pradesh State Observatory, India). Although there is some uncertainty because of the low effective temperature (3915 K) and lack of *gf* values, the values for Co, Fe, La, Mn, Ni, Sc, Ti, V, and Y are close to the solar values.

Weak telluric lines in stellar spectra were used by Gray and D. Holmgren as a reference for radial velocities of cool giants. Although there is no obvious way to fix the absolute zero-point of the measured velocities, star-to-star consistency of approximately 100 m/s can be attained. This work is continuing.

Gray is looking into the changing rotation period of Beta Comae, presumably a result of differential rotation with latitude coupled with the changing latitude of magnetic activity during the stars magnetic cycle (analogous to the solar 'butterfly' diagram). Rotational modulation is best seen in the

HK data from Mt. Wilson, and shows two period near 11 days. Both period have been declining slowly for the past 15 years.

C. Blake and Gray continue to acquire data toward further delineation of the granulation boundary for Blake's thesis.

E. Tittley and Gray used the high-resolution coudé spectrograph to monitor α Cas (K0 III), α Per (F5 Ib), and α UMa (F5-8 Ib Cepheid) all night long during several nights. They looked primarily for small temperature changes using line-depth ratios, but found none of short period.

6. STELLAR STRUCTURE

Mitalas has derived new, rigorous upper and lower limits to pressure in stars. The work will appear in *A&A*. He has also shown that the lower limit of Theorem 6 in Chandrasekhar's "Introduction to the Study of Stellar Structure," which gives the limit of the pressure decrease from the centre of a star, can be improved by the ratio of the central to mean interior density raised to the power two thirds. This is a significant improvement of a now academic result first presented by Eddington almost 70 years ago. The progress with the text book on stellar structure and evolution is disappointingly slow. With Martin Beech he is looking at destruction of lithium in pre-main sequence stellar models.

7. COSMOLOGY

P.A. Thomas and F.R. Pearce (Sussex) visited for three weeks in the summer of 1994 with Couchman making a return visit to Sussex and Durham this year. This collaboration has just completed a project to incorporate the Smoothed Particle Hydrodynamics technique into Couchman's adaptive N-body cosmology computer code. The new code 'Hydra' is soon to be made publicly available and a paper describing it is due to be published this autumn. The visits for this collaboration are sponsored by a NATO Collaborative Research Grant.

This year Couchman was invited to join the 'Virgo' consortium. This is a group of UK cosmologists who plan to use the Hydra code mentioned above to simulate the universe at very high resolution using the Cray T3D massively parallel supercomputer which is located in Edinburgh. This collaboration is based in Durham with C.S. Frenk as principal investigator.

Couchman is collaborating on two projects to investigate analytic aspects of the non-linear gravitational growth of fluctuations in cosmic fluids. One is with P.J.E. Peebles (Princeton) using the ideas of renormalization to avoid some of the pitfalls associated with the limited dynamic range and boundary conditions of conventional numerical simulations. The other is with P. Colin and R.G. Carlberg (Toronto). In this latter collaboration we are using a standard N-body approach to investigate growth in a variety of different background cosmologies and with various initial fluctuation spectra. In both cases the idea is to elucidate some of the important features of the transition from linear to non-linear gravitational evolution.

Couchman is continuing a collaboration with W.P. Petersen (ETH, Zurich) to port his N-body computer code to parallel supercomputer architectures as part of the NASA

“High Performance Computing and Communications Grand Challenge Project” based at the University of Washington in Seattle. The aim is to use parallel computers to simulate the formation of cosmic structure at high resolution. It is hoped that the power of parallel computers will allow a extremely large number of particles to be simulated and will result in

new insights into the formation of galaxies and galaxy clusters. Several important improvements have been made to the code and it is expected to be used for scientific production runs later this year.

John D. Landstreet