

THE ROYAL GREENWICH OBSERVATORY

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Report for the period 1979 October 1 to 1980 September 30

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1 INTRODUCTION

A comprehensive report on the work of the Observatory for this period has been published elsewhere (Wilkins, G.A. & Yallop, B.D., eds 1981. *The Report of the Royal Greenwich Observatory 1979–80*, available from the Librarian, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, East Sussex, BN27 1RP, price £3.00, postage extra). The main purpose of this paper is to describe the highlights of the research programmes to which less than one-sixth of the manpower effort is devoted. The main function of the RGO continues to be the procurement and provision of facilities for ground-based optical astronomy. The long-standing and traditional service rôle of the RGO as the source of astronomical information for navigation and observation together with the provision of the national time service continues essentially unchanged although, with the use of modern techniques, the effort devoted to these services has been reduced considerably over the last decade.

2 ASTRONOMICAL RESEARCH

2.1 Cosmic abundances of the elements. The programme to study nucleosynthesis and the evolution of stars and nebulae has developed since its start in 1961 into a major investigation of the gradients of abundance ratios across galaxies, leading to a new approach to evolution on the cosmic scale. Several major collaborations are involved, and a wide range of observations are made, particularly using optical spectroscopy.

Pagel has determined abundance gradients in the spiral galaxies NGC 7793 and 2997 and made further observations of NGC 300 and 1365, in collaboration with M.Edmunds (Cardiff) and G.Smith (Oxford). The Seyfert nucleus of NGC 1365 has a power-law continuum with Fe II bumps and asymmetric broad Balmer-line components shading off to the violet, it is surrounded by Seyfert-2 like emission extending to a radius of about 400 pc. Outside this distance there are conventional H II regions with large heavy-element abundances continuing the rather shallow trend shown by H II regions in the spiral arms. Further H II regions in the arms and bar are being studied in collaboration with D.Alloin (Meudon) and P.O.Linblad (ESO).

Several studies of globular clusters have been carried out with the aim of improving our knowledge of their ages, primordial chemical compositions and abundance changes in individual stars in the course of evolution. Dickens and T.S.van Albada (Groningen) have completed their analysis of ANS ultraviolet photometry of 27 globular clusters. They deduce a very narrow age spread among the low-metallicity clusters and find that the ‘anomalous’

intermediate-metallicity clusters with a blue horizontal branch in the colour-luminosity diagram have a separate clump of very hot stars on an extension of the horizontal branch. This indicates a particular stage of evolution rather than a 'second parameter' associated with primordial chemical composition. AAT/IPCS spectra have been used by Dickens and R.A.Bell (Maryland) and by Pagel, E.A.Mallia (Oxford) and D.C.Watts (Sussex) to deduce metallicities, $[\text{Fe}/\text{H}]$, of -1.0 in NGC 288 and -0.9 in 47 Tucanae, respectively; the latter result is a somewhat less drastic downward revision of values previously assumed in such 'metal-rich' clusters than has been suggested recently. Dickens and S.P.Caldwell (Sussex) have used the STARLINK node to compare AAT spectra of cluster stars interactively with synthetic spectra by Bell so as to test Sweigart and Mengel's theory of rotationally driven mixing. The cluster ω Cen is of particular interest because of the wide range of metallicity of its members and because the theory predicts a metallicity dependence of the absolute magnitude at which carbon depletion sets in; in this cluster metal-weak members seem to fit the theory well, but the situation among metal-strong members turns out to be more complicated.

2.2 Galaxies and cosmology. Taylor, R.Hook, N.Parker and P.Atherton (ICST) used the TAURUS interferometer at the AAT in 1980 March to obtain seeing-limited radial-velocity-field data on several normal and pathological galaxy systems. The data were reduced using the RGO STARLINK node.

Among objects studied was the colliding system Arp 244 which has a complicated velocity field which may be related to the type of interaction studied by Toomre. However, the most remarkable results from the study of this system are the very large line widths ($\sim 120 \text{ km s}^{-1}$) in individual H II regions, leading to the supposition that these objects are an order of magnitude more massive than the largest extragalactic, or detached, H II regions. This result removes a difficulty with Arp 244, pointed out by Rubin, Ford and d'Odorico; the apparent sizes and magnitudes of the H II regions are now compatible with the distance estimated from the redshift via the Hubble law.

Fosbury, with collaborators in Groningen, ESO, CSIRO, AAO, Maryland, VILSPA and Cardiff, is making a detailed study of a class of radio galaxies which show very extended optical emission lines. In the case of PKS 2158-380 it has been shown with *IUE* observations that gas out to radii $\sim 20 \text{ kpc}$ is ionized by an intense ultraviolet source located in the galactic nucleus. From considerations of this ionization process and from observations of the velocity field of gas and stars, it is concluded that gas has been recently acquired by an elliptical galaxy and now exists in the form of a transient warped disc. This and the analogous case of PKS 0349-27 add strong support to the hypothesis that the radio and nuclear activity in elliptical galaxies is triggered by the capture and subsequent infall of gas.

Fosbury and Wall have continued their collaboration with W.M.Goss (Groningen), R.Ekers (VLA), I.J.Danziger and P.Shaver (ESO/Garching), and D.Malin (AAO) to study 104 radio galaxies forming a sample from the Parkes 2.7-GHz catalogues which is complete to both radio and optical limits. This major study has both astrophysical and cosmological objectives,

and it has now produced a wealth of data, including digital spectrophotometry for all the galaxies, obtained with the AAT, the 3.6-m reflector of ESO/La Silla and the 2.5-m reflector of Hale/Las Campanas. During the past year, these spectral observations were completed, while IR data in several bandwidths were obtained for more than half the galaxies. Moreover, superbly detailed maps at 5 GHz (resolution < 1 arcsec) were obtained with the VLA for all sources. Many of the galaxies show spectacular radio and optical morphologies, the latter revealed by the photographic enhancement techniques of D. Malin (AAO). Detailed comparison has begun, and Pocock has now measured accurate optical positions for all galaxies in the sample.

M.A.J. Snijders, A. Boksenberg and J.D.J. Haskell (UCL), Fosbury and M.V. Penston (VILSPA) have obtained *IUE* spectra of the Seyfert galaxies I Zw 1, II Zw 136 and Mk 231, all of which are known to have strong optical Fe II emission. The data strongly support the hypothesis that the optical Fe II lines are primarily due to collisional excitation, resonance fluorescence making only a minor contribution. The nucleus of Mk 231 is highly obscured and the ultraviolet data lend support to a model in which most of the observed continuum comes from a population of early-type stars.

Fosbury, in collaboration with D. Alloin and D. Pelat (ESO and Meudon) and M. Whittle (IOA) have made high-resolution observations of forbidden-line profiles in Seyfert galaxies. These show the universal presence of broad components which are usually blue shifted ($\sim 100 \text{ km s}^{-1}$) with respect to the systematic velocity. In the particular case of NGC 3783, there are correlations between the FWHI of the main component within a line and: (i) the blue shift and (ii) the ionization potential (or alternatively the critical density for collisional de-excitation of the forbidden line). If it is assumed that the gas is photoionized by a central source, the forbidden line region is dominated by a radial velocity field increasing in amplitude towards the centre.

Fosbury and M.V. Penston (VILSPA) in collaboration with M. Ward (IOA), A. Wilson (Maryland) and A. Boksenberg (UCL) have completed a spectroscopic survey of the [Fe X] $\lambda 6374$ line in active galaxies. A correlation between the [Fe VII] and [Fe X] line fluxes strongly supports the photoionization model. It was not possible to distinguish between inflow and outflow as the cause of the blueshift observed in these high ionization lines.

Dickens, J.A. Dawe (UKSTU), J.R. Mould, M. Aaronson (Kitt Peak) and J.B. Murray (CSIRO, Epping, Australia) have measured infrared magnitudes and 21-cm velocity widths for galaxies in the Fornax and Grus clusters. The Tully-Fisher relation for Fornax is very well defined and yields a distance modulus of 30.9 ± 0.2 . For Grus the relation is looser (the group not being fully separated from the Hubble flow), with a derived mean modulus of 31.1 ± 0.3 . Neglecting deceleration effects of the local supercluster, their distances and redshifts are consistent with an infall motion of the local group towards the Virgo cluster of 200 ± 80 and $280 \pm 120 \text{ km s}^{-1}$ respectively.

Most effort during the year on photometry of clusters of galaxies has gone into scanning and calibrating the cluster fields. The major part of defining *J* and *F* photoelectric standards has been completed by Wood and the technique of using electronography for calibration established by Currie.

For the two overlapping Centaurus clusters, about 25 square-degree regions on eight Schmidt plates have been scanned by Currie and production of J , F photometry for several hundred galaxies to magnitude 18 is in its final stages.

J.R.Lucey (RGO and Sussex), Dickens and J.A.Dawe (UKSTU) have continued to work on these clusters. Although a definitive relative distance determination is not yet available, the much smaller virial mass derived for the higher redshift cluster suggests it may be considerably less rich, favouring the interpretation as two merging subclusters rather than chance superposition.

I.J.Danziger (ESO), Fosbury, A.Boksenberg (UCL) and W.M.Goss (Groningen) have detected Ca II absorption lines in the spectrum of PKS 2020-370 at a redshift which is close to redshifts of two galaxies of the nearby group Klemona 31. This observation adds to the evidence that the narrow-lined heavy-element absorption systems in quasar spectra generally arise in the haloes of intervening galaxies. Extensive observations of another quasar have been made and it is hoped to study the material around an elliptical galaxy using this technique.

Wall, in collaboration with T.J.Pearson (Caltech) and M.S.Longair (ROE), has developed a self-consistent technique to determine cosmological evolution for the different populations of extragalactic radio sources. The statistical technique makes near-optimum use of the present data, source counts ($\log N$ - $\log S$ curves), optical identifications, and redshifts. The scheme has been applied to data at 408 MHz and at 2700 MHz. The results confirm the general features suggested by earlier analyses: powerful extended radio sources of the steep-spectrum type were more abundant at earlier epochs of the Universe ($z > 1$) by factors in excess of 1000, while the compact sources of the 'flat-spectrum' type, the majority of which are identified with QSOs, undergo a change in density with epoch which is somewhat less extreme.

2.3 Rapid phases of stellar evolution. Murdin and D.H.Clark studied the optical spectrum of SS433. They showed that the continuum was a low-surface-gravity black-body with about eight magnitudes of visual absorption. They described the behaviour of the rest system of emission lines in terms of mass loss from a primary star and the moving features in terms of bullets shot out in opposing jets. The massive secondary, now thought to be a black hole, is responsible for the very energetic jets.

Mayo and collaborators have computed the JHKL colours of accretion discs, such as occur in cataclysmic variables, using a simplified effective-wavelength approach. The results were compared with the infrared data of Skody. As found earlier for UBV colours, the infrared colours of dwarf novae in outburst are in general agreement with the theoretical colours of discs, while in quiescence the secondary star or bright spot may dominate. The VRI colours of theoretical discs were also calculated to compare with the observations of dwarf novae by Mayo, Jones and Wallis under way in Tenerife. They observed about 40 such variables in UBVR during the year and followed several through outburst. In addition they obtained long continuous runs in several colours of the AM Herculis object 2A 0311-227.

Clark and Murdin and A.Furr (Sussex) have analysed their velocity map of the Crab nebula and demonstrated the existence of two co-originating shells in the nebula. Clark and Murdin discovered the spectrum of the supernova remnant W50 to be nitrogen-rich like the southern supernova remnant Puppis A. This is surprising in an old remnant which would be expected to be primarily interstellar medium and the remnant material may be ejecta presently being emitted by SS433.

2.4 Galactic astronomy. Using his new photoelectric data, Corben has studied the photometric calibration of UK Schmidt plates of the South Galactic Cap region. There are very large, as yet unexplained, variations in plate quality. Provisional magnitudes for some 10^4 stars with $V < 17^m$ have been obtained.

The trigonometric parallax programme with the 26-inch refractor has continued at a lower level than last year; 174 parallax plates were exposed and 92 measured. Three fiducial fields proposed by the IAU working group on parallax standards have been included; they are intended to provide common controls of all telescopes engaged in parallax work.

van Breda has continued his collaboration with D.C.B.Whittet (UCL and Preston Polytechnic) in the study of interstellar extinction. The SAAO 30-inch telescope was used in January with the St Andrews scanner to carry out spectrophotometric scans of reddened stars in Orion. BVRI polarimetric observations were obtained during a 20-inch observing run in March in order to determine the wavelength of maximum polarization ($\lambda_{\max}$) for reddened stars. The data are being used to study the correlation between $\lambda_{\max}$ and the ratio of total to selective extinction, R .

Andrews, Argyle and J.E.Sinclair have obtained further UBV photoelectric photometry of the variable star V3 in NGC 4590. Analysis of the photometry using an interactive period-finding program written for the STARLINK computer has confirmed the presence of the two previously detected pulsation modes, and has indicated the presence of a second overtone and a mixed mode.

Argyle, Andrews and D.H.P.Jones have shown that IK Hya, suspected of being another multi-mode RR Lyrae, shows Blashko type variation with a period of more than seven days as well as the pulsation period of 0.65 days.

Worswick has obtained IPCS spectra of several planetary nebulae using the SAAO 1.9-m telescope. The 'long slit' mode of the detector has been utilized to study the spatial variation of physical conditions in these objects. Of particular interest are the data obtained for NGC 5189; these show pronounced changes in electron density on a scale of a few arcseconds and an associated wide range in excitation conditions. The object appears to be a member of the small class of helium and nitrogen rich nebulae which may be associated with progenitors at the higher end of the mass range.

Polarization maps of NGC 1999, the nebulosity surrounding V380 Orionis, were found by Bingham and Murdin, with Durham collaborators, to show that the star is embedded in the near side of a dust cloud which has an oblique boundary in front of the star. The dark globule silhouetted against

NGC 1999 is physically associated with the nebula. Maps of the Red Rectangle show it to be a hollow bicone of dust scattering the light of an apical star. A broad emission feature at $H\alpha$ wavelength originates on the bicone, rather than by scattering of light from an exotic object near the apex.

2.5 Solar system. Morrison has continued the analysis of lunar occultations during 1600–1860 and solar eclipses during 1600–1700 in order to improve upon previous determinations of the variations in the Earth's rate of rotation. He has collaborated with the Meteorological Office in comparing the changes in the angular momentum of the atmosphere and the mantle observed during four months in 1979. Investigations have continued into the shape of the lunar profile deduced from occultations and into the personal equation in timing occultations.

The search for occultations of stars by planets, minor planets and satellites was continued by G.E.Taylor.

D.B.Taylor has investigated orbits of minor planets in the restricted three-body problem. He has continued to investigate theories of the secular motion of planets.

3 INSTRUMENTATION RESEARCH AND DEVELOPMENT

3.1 Astronomical instruments. After the initial trials on the 36-inch reflector and the INT, TAURUS, the new imaging Fabry–Pérot interferometer, was transported to SAAO and then on to the AAT. TAURUS has operated very satisfactorily at all telescopes and has observed velocity maps of the galaxies Cen A, NGC 5253, Arp 244, M83 and others, as well as the planetary nebulae NGC 5189 and NGC 2392 (the Eskimo Nebula).

The sensitivity of the device as measured at the AAT corresponds very well to that predicted, and objects whose emission-line flux is comparable with the faintest emission material visible on the Palomar Sky Survey plates can be studied.

Extensive testing of the prototype autoguider for the LPO has taken place on the 36-inch telescope, including its use for testing the CID detector. Initial tests suggest a guiding limit of about 13th magnitude on that telescope. The specially developed microprocessor graphic display has proved very valuable in the assessment and use of the system, and it makes acquisition of a guide star particularly easy.

3.2 Electronic imaging devices. The routine processing of electronographic tubes continued at Herstmonceux until 1980 February with personnel from Instrument Technology Ltd (ITL) progressively carrying out more of the work. Since 1980 April 1 ITL have been under contract to reprocess tubes for RGO.

A prototype instrument incorporating a charge-injection device (CID) has been completed by van Breda and P.R.Jorden and has come into use. The device operates in a specially designed liquid-nitrogen cryostat and generates an image of 188×244 picture elements. It is linked to an LSI-11 microprocessor and various flexible modes of use have been implemented. The detector has been used successfully at the Wise Observatory, Israel, by S.M.Scarrott (Durham) with P.R.Jorden.

Good progress has been made on the photon-counting RETICON detector for the SAAO to enable tests on the 30- and 36-inch telescopes before delivery to SAAO in 1981 July.

A CCD camera system is being constructed under contract from the Anglo-Australian Observatory, for delivery in 1981 July (Wall, van Breda, P.R.Jorden, Thorne). The system uses an RCA 320×512 element detector.

3.3 Optical design. A general study has been undertaken by Wynne of different possible forms of spectrograph camera of high relative aperture ($f/1.4$ or faster). Wynne has also designed a corrector for atmospheric dispersion, tunable for stars at different zenith distances; one is being manufactured for the 30-inch telescope.

Considerable progress has been made by Bingham and Wynne on the design of the coudé spectrograph equipment for the INT. This includes improving earlier designs and fresh work on new requirements for the 3.4-m and 1.6-m cameras, and the $f/4.2$ and $f/3.3$ echelle cameras.

The necessity to reduce the focal length of the 4.2-m telescope required an investigation of possible field correctors for the prime focus at $f/2.5$ or $f/2.0$ (including ghost-image calculations). Both three- and four-lens correctors were studied (by Wynne).

4 NATIONAL FACILITIES – LA PALMA OBSERVATORY

Work on the widening and upgrading of the access road via Mirca is well advanced and the road should be available by the end of 1980. Arrangements for electrical power and telephones are proceeding on schedule and it is hoped that work on the service area buildings will start in the spring of 1981.

The 2.5-m Isaac Newton telescope has been reassembled at Grubb Parsons works. The first parts of the telescope should reach La Palma by 1981 June. Work on the building, although delayed by bad weather and the need for additional foundation works, is well under way and dome-rail level should be reached in 1980 November. Erection of the dome should be completed in 1981 June.

The 1.0-m telescope has been accepted from Grubb Parsons. Some additional work on the servo-drive system will be made at RGO.

Financial approval for the 4.2-m telescope was received during the year. The rough machinery of the Cervit blank is well in hand and plans for the specification of the figured surface are being made. The decision to adopt an $f/2.5$ configuration was made following a series of design appraisal meetings under the Chairmanship of Dr M.Longair.

5 NATIONAL AND INTERNATIONAL SERVICES

5.1 Time and latitude service. The Time Department has participated in two international campaigns of simultaneous radio-observations of the US Navy (Doppler) Navigation Satellites, one organized by the Institut für Angewandte Geodäsie (FDR) and one by the Austrian Academy of Sciences. Both aimed to establish precise relative positions of European sites involved in time-keeping and/or primary geodetic observations. The receiver used at RGO

was lent by the Oxford University Department of Surveying and Geodesy, and help was also given by Decca Survey Ltd.

5.2 Satellite laser ranging. The general design of the satellite laser ranging facility, which is being built in collaboration with staff of the University of Hull, was completed, most of the equipment was ordered, and the detailed design and development work was continued.

5.3 Stellar reference frame. The plans for the building to accommodate the Carlsberg Automatic Transit Circle on La Palma were approved for tendering.

The main computer (HP 2117) for input, output and data processing has been delivered at Herstmonceux and an observation-validation program has been implemented on the ICL 1903T computer, and tested with normal observational data supplied on paper tape by the Copenhagen University Observatory.

Clock and azimuth star lists and data for all FK4 stars have been assembled in readiness for constructing a program for selecting objects for observation.

Murray has continued to serve on the ESA Science Team which prepared the Phase A study report on the *Hipparcos* astrometry satellite; he was responsible for presenting the scientific case at the final selection meeting of the wide scientific community at ESTEC. The project was selected, and discussions have since taken place with the staff of MSSL and Danish astronomers on the possible submission of a joint proposal to ESA for carrying out data analysis.

5.4 Services to universities. Seven DPhil students and four MSc students from the University of Sussex have worked under supervision at RGO. A two-week course in Instrumental Astronomy for MSc students was again held at RGO. Seven sandwich students spent a total of 48 months undergoing training, mostly in the fields of computing and electronics. Eleven students attended the 1980 eight-week summer vacation course in astronomy. Assistance in the development and testing of astronomical instruments has been given to many university groups.

6 CONFERENCE

The 24th annual Herstmonceux Conference on Interstellar Chemistry was held in the Castle in 1980 April and was attended by about 55 visitors.

7 PUBLICATIONS

The following papers have been issued, in addition to the regular publications associated with the national and international services. Staff whose appointments terminated before 1978 September 30 are prefixed by an asterisk, and authors who are not staff or students working at RGO are shown in *italics*.

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