

Reports from Observatories, University Departments and Research Establishments

THE ROYAL GREENWICH OBSERVATORY

REPORT FOR THE PERIOD 1976 OCTOBER 1
TO 1977 SEPTEMBER 30

Director: Professor F.Graham Smith, FRS

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1 INTRODUCTION

The main function of the Royal Greenwich Observatory continues to be to procure and operate facilities for ground-based optical astronomy for UK astronomers and to provide astronomy-based services. However, the main purpose of this report is to describe the highlights of the supporting research programmes, to which about one-quarter of the effort of the observatory is devoted. A comprehensive report of the observatory for this period has been published elsewhere (Thomas, D.V. & Perry, J.E., (eds), 1978. *The Royal Greenwich Observatory: Report 1976/7*, Royal Greenwich Observatory, Herstmonceux).

2 ASTRONOMICAL RESEARCH

2.1 X-ray and radio sources. Mr L.V.Morrison has continued to issue predictions of occultations of X-ray and radio sources and to collaborate in the interpretation of the resulting observations. Mr E.N.Walker's analysis of five years of observations of Cyg X-1 in blue light suggest that there is a significant variation with a period of about 150 day, and that the form of the 5-6-day light curve is significantly different near maxima from that near minima at this period (82). A group led by Dr D.H.P.Jones has obtained intensive observations of the X-ray binaries AM Her, Cyg X-1 and X Per with the RGO high-speed photometer in its polarimeter mode. The flickering of AM Her, its variation with wavelength and association with linear polarization, was followed for three binary periods. No fast phenomena were detected on time-scales of between 10 ms and 1000 s for either Cyg X-1 or X Per. The RGO programmes of photographic astrometry in radio-source fields have continued under the direction of Mr C.A.Murray, and results have been obtained for a further 72 fields. Over 150 Cambridge Schmidt plates have been measured in collaboration with Argue (Cambridge).

2.2 Extragalactic research. The absence of a detectable differential mass-shift between Lyman and other absorption lines in the spectra of quasars has been used by Professor B.E.J.Pagel to deduce that the proton-electron mass-ratio has remained within a few tenths of its present value since the Universe had slightly under one-third of its present scale. 21-cm observations of the

BL Lac-type object AO 0235 + 164 then impose the same limits on the gyro-magnetic ratio of the proton (45).

Dr P.A. Wehinger and Dr S. Wyckoff have obtained more electronographic observations of quasars and Seyfert galaxies with a McMullan camera. Isophotes were mapped for 12 Seyfert galaxies with large redshifts and structure has been resolved for the quasars with the smallest redshifts. Two emission-line galaxies have been mapped in [O III] and in the continuum (84, 85, 86, 87). Mrs A. Savage, in collaboration with Bolton (NRAO, Parkes) has determined $N-m$, $m-z$ and $N-z$ relationships for optically selected quasars in two southern fields. Plates with a 10-year difference in epoch (Palomar and UK Schmidt) show no magnitude variations in radio-quiet quasars, in strong contrast to the large variations in radio quasars in these fields (59, 60).

Dr R.J. Dickens, in collaboration with Dawe (Royal Observatory Edinburgh) and Peterson (Anglo-Australian Observatory) has obtained mean velocities and velocity dispersions for nine clusters of galaxies (15, 16, 37). Dr R.G. Bingham has continued to collaborate with Scarrott (Durham) in polarimetric studies of galaxies. A wavelength-dispersing device (grism) for the polarimeter has been designed, procured and tested, and a model of the light-scattering medium in M82 has been developed from the results of previous observations (7).

Dr P.J. Andrews has obtained from spectra of red globular clusters in the Large Magellanic Cloud a value for the velocity dispersion which is higher than that for any other class of LMC object. This result confirms the tendency for the older objects to possess higher velocity dispersions.

Drs S. Wyckoff and P.A. Wehinger have completed an analysis of spectra previously obtained of the 1976 supernova in NGC 4414. An absolute magnitude at maximum light, the radius of the expanding envelope 14 day later and the mass of ionized hydrogen in the envelope were determined. An independent distance to NGC 4414 was also obtained (100).

2.3 Clusters and variable stars. Work on ω Cen variables by Mrs E.A. Bingham and Dr R.J. Dickens has been completed. A range of a factor of 10 in metal abundance has been confirmed, together with limits on the mass-range, luminosity and helium content of the RR Lyraes. There is strong evidence for a radial abundance gradient. The spread of metal abundance and the luminosity function of the giant branch have been determined. The study of the colour curves of variables in IC 4499 is also complete. Dr C.D. Pike has completed a study of the variables in M3, and is engaged in studies of stars in M5, M13, M22 and M71 (51, 52).

Dr P.J. Andrews has analysed the radial distribution of stars in the galactic clusters NGC 6268, 6192 and 6252, and has shown that the brighter more massive stars are more concentrated towards the centres than the fainter less massive ones.

Mr C. Lloyd has obtained a set of orbital parameters from spectra of the suspected spectrum-variable binary 55 UMa. The apparent changes in spectrum previously reported by a separate investigator were not confirmed, and may have been due to blending effects from the two spectra (26).

Computer syntheses have been made by Drs D.J.Stickland and P.J.Andrews of several regions of the pre-maximum spectra of Nova Cygni 1975 to match sections showing strong nitrogen, oxygen and helium lines. These indicate a high value for the microturbulence and a significantly enhanced nitrogen abundance. Mr R.Korakitis (research student) has analysed the emission profiles in Nova Cygni near maximum light in terms of a four-component fragmented shell model (24). Dr S.Wyckoff has obtained astrometric positions for 25 old novae from Palomar Survey prints, and confirmed these by means of IPCS spectra obtained on the Anglo-Australian Telescope. From SIT vidicon spectra obtained at Cerro Tololo she has shown that several old novae exhibit both emission-line and continuum variations with time-scales as short as minutes, and that RR Pic is a binary star with a period of about 3 hr.

2.4 *Interstellar matter.* Dr I.G.van Breda and Whittet (St Andrews), continuing their study of the law of interstellar extinction and its variations, have obtained *JHKL* photometry during two observing runs at SAAO. Infrared photometry has now been obtained for a considerable number of early-type stars in the southern Milky Way. Recent analysis has concentrated on the relationship between *R*-value and the wavelength of maximum polarization, and also on the very broad-band structure found in extinction curves obtained with an optical spectrum scanner. It has been shown that *R* varies by only small amounts outside compact dust clouds (77).

2.5 *Stellar atmospheres, structure and evolution.* Professor B.E.J.Pagel has completed the survey of abundances in Magellanic Cloud H II regions in collaboration with Edmunds (Cardiff), Fosbury (AAO) and Webster (AAO). The low abundance of oxygen in the SMC is now confirmed from a large sample and it has been found that, while nitrogen is deficient relative to oxygen in both Clouds, neon, sulphur, chlorine and argon are present in quite normal proportions relative to oxygen. A small spatial abundance gradient may be present in the LMC, but there is none in the SMC. Overall heavy-element abundances in both Clouds, and in H II regions of the Scd galaxies M33 and M101 (but not our own Galaxy), are consistent with simple enrichment theory.

T.E.Lutz (Washington State University), on sabbatical leave at RGO, carried out a statistical analysis to determine the dependence of the width of $\text{Ca}^+ \text{K}_2$ emission (Wilson-Bappu effect) on effective temperature, surface gravity and chemical composition determined from spectroscopic analysis. The resulting relation, in which the width at a given temperature and gravity has a clear dependence on metal abundance, gives a good fit to the semi-theoretical scaling law proposed by Pagel.

Mrs D.L.Harmer and Dr D.J.Stickland have measured the plates of the apparently mass-losing supergiant HR 8752 taken in 1975 and 1976. Emission lines were weaker and fewer in 1976 August than in 1975 August, but probably many absorption features are partially filled in by variable emission, and the lines show asymmetry to differing degrees. Inspection of more recent spectra suggests that emission has decreased still further and some absorption lines seem to have doubled. Stickland has measured line-blocking coefficients in a number of MK standard giant and subgiant stars. Scanner observations of

stars of these types can now be reduced to the 'true' continuum and compared with unblanketed models. Rotational speeds are being determined as a by-product.

Drs S. Wyckoff and P. A. Wehinger have identified CeO bands in the S stars R Cyg, R Gem and S UMa, and noted that only the oxides of *s*-process elements appear to be observable in the optical spectra of pure S stars (98, 99, 102). Together with Clegg (Sussex), they have compiled a spectral atlas of R Cyg, identifying many previously unidentified band-heads with the newly discovered ZrO singlet system, while others are due to ZrO (triplet), YO, CaO and CeO. High-dispersion spectra of R Cyg and S UMa showing atomic lines not seen at lower dispersions are being analysed. S UMa shows complex structure in H α at maximum light.

Dr S. Wyckoff and Mr C. A. Murray have completed their study of the Crab Pulsar. The results provide conclusive kinematic evidence linking the filaments to the pulsar and predict an outburst date AD 1120 $\pm$ 7, earlier than found previously. The projected motion of the pulsar is along the major axis of the nebula towards the centroids of optical continuum and X-ray emission, and parallel to the E-vector of polarized radiation in its vicinity (95, 96, 97, 101).

A hard-wired synchronous data-logger, designed by Dr D. H. P. Jones, Dr K. F. Hartley and Mr G. B. Wellgate, was taken to the AAT where, in parallel with experiments developed by Australian groups, it was used in a successful search for the Vela Pulsar. The doubly pulsed optical pulsar has an integrated magnitude 24.2. An almost-certain optical identification was secured (39).

Dr K. Taylor has continued his work on velocity-field mapping in old supernova remnants, using Fabry-Perot interferometry. In contrast to the Cygnus Loop, the southern supernova remnants Vela, RCW86 and RCW89 show no features exceeding 60 km s⁻¹. RCW103, however, shows a clear velocity splitting, implying expansion at about 300 km s⁻¹. Taylor has also obtained high spectral resolution observations in various emission lines for several brighter galactic H II regions.

2.6 Galactic astronomy. Proper motions have been obtained for 10 000 stars in a region near the North Galactic Cap from GALAXY measurements of Palomar Schmidt plates (survey copies and new originals) and plates for the Oxford Astrographic Zone. Analysis of GALAXY *V*, *I* measures of these stars has proceeded, but since GALAXY cannot distinguish between stars and galaxies a visual examination of every image is necessary.

Excellent progress has been made in the parallax search of the South Galactic Cap fields being directed by Mr C. A. Murray. During the year, 43 plates containing over 16 000 images were measured in two opposite orientations on GALAXY. Considerable progress has been made with the analysis of the brightest 1000 stars (*B* < 14 mag) in the field. First analysis of 48 plates indicates that random errors of parallaxes will be of the order ± 0.01 arcsec; although systematic errors are clearly present, several hitherto unsuspected stars within 20 pc appear to have been detected (22, 40). The current observing programme for trigonometric-parallax determination with the 26-inch refractor is nearing completion. A second list of 26 parallaxes is ready for publication, and more than half the programme fields have now been measured and reduced.

2.7 Solar system. Mr G.E.Taylor has continued his long-standing programme designed to obtain improved data on the shapes and sizes of bodies in the solar system and of their atmospheres, if any, by means of the prediction and observation of occultations of stars (74). Predictions of occultations by planets, minor planets and satellites have been calculated and published annually in the *Handbook* of the British Astronomical Association and elsewhere. Since 1953 these have led to observations of occultations by: Venus, Mars, Saturn and its rings, Neptune, Io, Gannymede, Rhea, Iapetus, Pallas, Juno and, during the past year, by Uranus and Hebe. The prediction of the occultation by Uranus was first published in 1973, and resulted in the planning of expeditions to observe the occultation by several groups in various countries. The updated predictions issued early in 1977 were sufficiently accurate to enable several groups to observe the occultation on 1977 March 10 and simultaneously discover the previously unsuspected ring system.

Mr L.V.Morrison has completed his analysis of 50 000 lunar occultations in the period 1943–74: the final results confirm those reported previously. About 10 000 occultation observations in the period 1861–1900 have been reduced and analysed, and have yielded an improved measure of the fluctuations in the rate of rotation of the Earth during this period. The use of timings of solar eclipses to supplement occultation observations, as a means of determining the rate of rotation of the Earth during the seventeenth and eighteenth centuries, has been discussed and evaluated.

3 INSTRUMENTATION RESEARCH AND DEVELOPMENT

3.1 Astronomical instruments. Dr K.Taylor has instigated the design and manufacture of a two-dimensional Fabry–Perot interferometer. It will incorporate a capacitatively scanned and monitored Fabry–Perot étalon designed and built collaboratively with Reay at Imperial College (London). The interferometer is designed to obtain emission-line velocity-field information over a 9 arcmin field at the $f/8$ Cassegrain focus of the AAT. It will be possible to study very faint objects at resolving powers in the range 10^3 to 6×10^4 . Design work has been completed on a four-star photometer, proposed by Mr E.N.Walker, and manufacture and buying-in of parts is well advanced. The photometer will enable four stars in the field of a telescope to be monitored simultaneously in order that small brightness changes may be detected and monitored and the stars concerned securely identified. Development of the low-dispersion (22 Å mm^{-1}) Griffin-type radial velocity spectrometer has continued under the direction of Mr R.E.Wallis. In use on the INT and 36-inch reflector, the spectrometer has proved capable of determining radial velocities of bright standard stars with high accuracy.

3.2 Electronic imaging devices. Good progress has been made on increasing the resolution of electronographic cameras by improving the contact between the film and the mica window. A combination of pressure behind the film by a loaded membrane and a relatively low electrostatic field has been found to give good contact without the fogging of the emulsion produced when a high electrostatic field is used on its own. A new film applicator working on this principle has been designed (28, 29, 30). Investigations have been made on

the deflection of electron images, and a method has been devised for the rapid deflection under computer control of a small central image to 25 or more different positions on the mica window of an electronographic camera. One application is the taking of phase-resolved pictures in order to detect optical pulsars of known periods, and a system for possible initial use on the AAT for studying the Vela Pulsar has been built and is undergoing tests on the 36-inch telescope. A General Electric charge-injection device (CID) camera is being evaluated as an astronomical detector. The circuits have been modified in order to achieve non-destructive read-out, and a liquid-nitrogen cryostat for cooling the chip, has been designed and built.

3.3 Optical design. Professor C.G. Wynne has worked on a range of designs for fast spectrograph cameras (about $f/2.4$) of the forms: Maksutov with divided corrector; shortened flat-field Schmidt (103); figured meniscus corrector. He has also investigated a survey-type Schmidt camera of achromatized and shortened form, and a method of secondary spectrum correction with normal glasses (104).

3.4 Microprocessor applications. Dr I.G. van Breda is directing the setting-up of a hardware and software development system for the design of microprocessor-based electronics.

4 NATIONAL FACILITIES

4.1 Northern Hemisphere Observatory. Negotiations have continued, which it is hoped will result in the telescopes of the UK Northern Hemisphere Observatory being amongst the first to be erected at a new Spanish international observatory on La Palma (Canary Islands). An access road to the observatory site has been completed by the Spanish authorities, and precise building locations have been identified. The functional and technical specifications for the 1.0-m Cassegrain reflecting telescope with Harmer-Wynne optics have been completed. Preparations for the modification and removal of the Isaac Newton Telescope to La Palma are on schedule. The new automated prime-focus assembly for the INT has been completed, and designs for Cassegrain and coudé spectrographs are well advanced. Design studies for the 4.2-m altazimuth telescope have continued.

4.2 RGO telescopes. The INT and the renovated 36-inch reflector were in continuous use during the year by visiting astronomers and RGO staff. Renovation of the Steavenson (30-inch) reflector, in preparation for removal to the Spanish Sierra Nevada, has been virtually completed.

4.3 Measuring machines. Over 600 plates were measured on GALAXY during the year. Software development for the PDS microdensitometer continued; the machine has been used round-the-clock by staff, students and visiting astronomers for processing direct and spectroscopic electronography, image-intensifier spectroscopy, coudé spectroscopy, speckle interferometry and for the measurement of Schmidt-telescope direct photographs.

4.4 Instrumentation for national facilities. A McMullan camera was procured for the Anglo-Australian Observatory, and both it and an IPCS constructed at University College London were commissioned on the AAT by RGO staff. More than 10 McMullan electronographic cameras are – or

soon will be – operational in observatories around the world. The ‘slot-window’ tubes (successors to the Spectracon) have proved successful, but availability will be limited until additional processing equipment is operational. Improvements have been made to the People’s Photometer to increase its versatility and convenience in use. Under the control of an appropriate instrumentation computer, it can now be used as a high-speed photometer/polarimeter, and to measure colours independently of variations in sky brightness and transparency.

5 NATIONAL AND INTERNATIONAL SERVICES

5.1 *Time and Latitude Service.* The regular programme of observations with the Photographic Zenith Tube, provision of the BBC ‘six pips’ time signal, the monitoring of GBR and other selected radio time signals, and the reception of signals from the experimental Navigational Technology Satellites, has continued. On 1977 January 1 the rate of the independently-generated RGO atomic time-scale TA(RGO) was adjusted to bring the scale unit into closer conformity with recent determinations of the SI second. (The scale of TAI was similarly adjusted.) Precise time is now available to potential users over a wide area of south-east England by reception of TV synchronizing pulses and reference to regular RGO calibrations.

5.2 *Publications, Information and Data Services.* Preparation and publication of the regular series of almanacs and ephemerides by HM Nautical Almanac Office has continued. The first of a re-titled series of Royal Greenwich Observatory Bulletins has been issued in a new and smaller format. The regular programme of prediction and reduction of lunar occultations has continued. A small Public Information Unit has been set up in order to provide a more efficient service in response to public enquiries and requests for data.

5.3 *Stellar Reference Frame.* Improvements have been made to the Cooke Transit Circle and regular observing of fundamental stars, the Sun, Moon and planets has continued. Reduction of the Cape meridian observations (1961–74) for the last two zones of the SRS programme have been completed. Good progress has been made in preparations for the establishment of a joint RGO–Copenhagen University meridian observatory on La Palma.

5.4 *Solar Activity Service.* The daily photoheliographic programme was terminated at the end of 1976. The programme has been taken over by the Heliophysical Observatory, Debrecen, Hungary, but publication of the backlog of data obtained at RGO will be completed. The results for 1967 (*Royal Observatory Annals No. 11*) have been published. Current information on solar activity has continued to be distributed by means of *Solar Activity Circulars*.

6 OTHER HIGHLIGHTS

6.1 *Herstmonceux Conference.* The twenty-first annual Herstmonceux Conference, on the theme ‘Digital Methods in Astronomy’, was attended by over 100 visitors. Topics covered included measuring machines, telescope control systems, detectors and picture processing.

6.2 *RGO Exhibition*. A permanent exhibition has been set up, which is open to the public annually from Easter to the end of September. Displays and models illustrate the current work and history of RGO, modern astronomy, astronomical instrumentation and the history of Herstmonceux Castle. Over 45 000 visitors were admitted during the 1977 open period.

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 1977 September 30 are prefixed by an asterisk, those on secondment or leave of absence are prefixed by a dagger and authors who are not staff or students working at RGO are shown in italics.

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- (18) *Disney, M.J. and *Wall, J.V.*, 1977. A 5-GHz Survey of Bright Southern Elliptical and So Galaxies, *Mon. Not. R. astr. Soc.*, **179**, 235–254.
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