

Reports from Observatories, University Departments and Research Establishments

THE ROYAL GREENWICH OBSERVATORY

Report for the period 1975 October 1 to 1976 September 30
(Received 1977 July 30)

Director: A. Hunter – to 1975 December 31

F. Graham Smith – from 1976 January 1

1 INTRODUCTION

The role of the RGO as a principal provider of central facilities for UK ground-based optical astronomy was consolidated during the year, and the Observatory continued to be largely responsible for the UK's international obligations in the provision of global astronomical services, and to provide related national services. Although 45 per cent of the effort of the RGO was devoted to the provision of central facilities and 30 per cent to national and international services, the purpose of this report is primarily to highlight the results of the research programme, which absorbed only 25 per cent of the total effort. A comprehensive review of the activities of the Observatory has been published elsewhere*.

2 ASTRONOMICAL RESEARCH

2.1 X-ray and radio sources. Mr E.N. Walker has analysed all available X-ray data of Cyg X-1 and found that the power obtained at the orbital period of 5.6 day is much less than the power at half that period, so that variations of the X-ray flux are not necessarily due to the changing aspect of the binary system. Analysis of observations obtained over several years has revealed significant changes occurring in the optical light curve.

Mrs A. Savage, in collaboration with Bolton (NRAO, Parkes) has made many new optical identifications of Parkes radio sources. The relatively small number of identifications made south of -65° declination indicates either that there is real anisotropy in the distribution of bright galaxies or that there is substantial obscuration over a large part of the southern sky.

Observations to determine optical positions of radio sources have continued under the direction of Mr C.A. Murray, and in collaboration with Ryle and Argue (Cambridge).

2.2 Extragalactic research. Electronographic observations of Markarian Seyfert galaxies have been obtained by Dr P.A. Wehinger and Dr S. Wyckoff

*Thomas, D.V. & Perry, J.E., 1977. *The Royal Greenwich Observatory: Report 1975/6*, Royal Greenwich Observatory, Herstmonceux.

using a McMullan camera on the Wise Observatory 1-m telescope. The majority of the galaxies exhibit spiral or disturbed structures. Dr M.J. Disney is investigating the continuity between active galaxies and quasars, by means of multi-aperture *UBV* photometry of radio sources and BL Lac objects. Mrs A. Savage and Bolton (NRAO, Parkes) have set out to identify and study radio and radio-quiet quasars in the South Galactic Cap, utilizing *B* and *V* plate-pairs and objective-prism plates obtained with the UK 48-in. Schmidt telescope, AAT spectroscopy, and a deep radio survey to 0.1 mJy. Optical monitoring of extragalactic radio sources with the 26-in. refractor has continued. A six-year light curve of 3C 273 shows that the nature of its variability has changed, following a recent X-ray outburst.

Dr R.J. Dickens and Mr C. Moss (research student) have completed an investigation of the dynamics of clusters of galaxies based on their own observations of galaxies in the clusters Abell 262 and 1367 and other material. The results provide support for the hypothesis that clusters form by a collapse process, and there is evidence that some clusters may still be collapsing.

Disney has continued trying to determine what properties of a galaxy predispose it to become a radio source. A sensitive 5-GHz survey of southern E/So galaxies, undertaken at Parkes by Disney and Wall (NRAO) has been examined and spectra and multi-aperture *UBV* photometry of 39 detected radio galaxies have been obtained. A search for young galaxies by Disney has produced, in NGC 1510, the best candidate yet. NGC 1510 is an elliptical galaxy as blue as any irregular and with low abundances. It is a companion of NGC 1512, which is itself extremely peculiar being classified as SBo yet containing vast amounts of hydrogen. Disney has suggested that the observed luminosity-radius correlations for different types of galaxies can be explained as a selection effect, in that galaxies of a fixed total luminosity will have large apparent radii only if their surface brightnesses lie in rather narrow and predictable ranges. If this is correct, the total luminosity, and hence mass, which is locked up in galaxies may have been seriously underestimated.

Dr R.G. Bingham has continued to collaborate with Scarrott (Durham) in polarimetric investigations of galaxies.

Dr A.J. Penny has obtained colour-magnitude diagrams of two more clusters in the LMC, using the SAAO 40-in. reflector. The RR Lyrae variables in NGC 2257 indicate a distance modulus of about 18.4, in agreement with that derived from a theoretical fit to the upper main sequence of the open cluster NGC 2214. Professor B.E.J. Pagel has completed a preliminary analysis of observations of 15 H II regions in the SMC made by Webster and Fosbury (AAO) and Edmunds (Cardiff) with the AAT and found oxygen to be deficient by a factor of about six compared with the solar neighbourhood.

2.3 Clusters and variable stars. Dr R.J. Dickens and Bell (Maryland) have continued their analysis of the spectra of red giant stars in globular clusters. Carbon deficiencies of a factor of about three relative to other metals have been determined in M 92 and NGC 6397. Mr C.A. Murray and Mr

W.Nicholson have commenced a study of the open cluster χ Persei. They are also collaborating with the Leiden Observatory in an investigation of the internal motions in the Pleiades, with the aim of estimating the total mass of the cluster.

Mr J.B.Alexander has obtained narrow-band photometry of the C_2 Swan band in giant stars of M 67 and dwarf stars of the Hyades. The M 67 giants do not have the strong C_2 bands shown by 'super-metal-rich' field stars. No intrinsic scatter is noticeable amongst Hyades dwarfs at a given effective temperature.

Dr P.J.Andrews has continued his study of R CrB stars. With slight variations, his previously published model of the R CrB phenomenon appears to be applicable to the well-observed star RY Sgr and to most other stars with much more scattered data. Further spectra of V 1500 Cyg (Nova Cygni 1975) have been obtained by Mrs D.L.Harmer and Andrews. All the emission lines show the same basic velocity characteristics, and the same individual velocity peaks have been present from 1975 September to 1976 August. The velocity structure is very complex, indicating that simple nova models are in need of considerable development.

In collaboration with Münch (Hale Observatories) Dr K.Taylor has obtained high spectral resolution Fabry-Perot observations of three knots of emission in the neighbourhood of θ_2 Ori. These objects were found to be moving away from θ_2 Ori at highly supersonic velocities. The region between the shock compression wave in the neutral material and the ionization front may be highly unstable to the formation of globules and subsequent star formation; this process might then give rise to the highly supersonic velocities observed.

2.4 Stellar atmospheres, structure and evolution. Professor B.E.J.Pagel has developed a new theoretical scaling law for the Wilson-Bappu effect in the Ca^+ and Mg^+ emission-line widths of F-M stars, assuming Doppler broadening by a field of upward propagating acoustic waves carrying a nearly constant fraction of the total stellar radiation flux. The scaling with gravity and effective temperature, and the ratio of Mg^+ FWHM to Ca^+ FWHM, are reproduced with a very satisfactory degree of precision. The distribution of metal abundance in F stars close to the zero-age main sequence has been studied by Pagel, who finds that the early F stars have virtually no scatter above that attributable to observational errors. This implies that the interstellar medium is quite well mixed within a narrow band of distances from the centre and plane of the Galaxy.

A first examination by Dr J.R.Mould of the distribution of metal abundance in M dwarfs, using TiO band strengths as a coarse abundance indicator, has suggested a deficiency of metal-poor stars relative to the simple model of galactic enrichment, similar to that observed among G dwarfs.

Spectra of the intermediate CS Mira variable VX Aql have been obtained by Drs S.Wyckoff and P.A.Weinger over two light cycles. CaCl systems are strong near minimum light but invisible at other phases. Wyckoff and Clegg (Sussex) have deduced on theoretical grounds that the CaCl concentration is strongly temperature and pressure dependent but almost independent

of the C/O ratio at a given pressure. With a C/O abundance ratio of 1.0, VX Aql represents the missing link in the evolutionary sequence of M stars ($C/O = 0.6$) to carbon stars ($C/O \geq 2$). A list has been compiled of 30 stars in which CaCl has been detected.

Dr D.J.Stickland has extended his studies of spectrum synthesis to rotating stars. Ultraviolet data from the *TDIA* satellite on β Car (A1 IV) and δ Vel (A0 V) has provided evidence for microturbulence increasing with depth. In the visible, coude spectra of sharp-lined stars have been convolved with rotational profiles in order to study the resulting effect of line blending on abundance analysis.

Dr K.Taylor has been analysing observations of planetary nebulae previously obtained with the Taylor-Münch nebular interferometer on the Hale Observatories 1.5-m telescope. In some cases it has been possible to define a three-dimensional geometry: NGC 650-1 shows unusual triple structure in its emission which cannot be explained by normal expanding spherical or toroidal shell models.

Wyckoff and Wehinger have derived evidence that the Crab Pulsar is a high-velocity star. An unwidened spectrogram of the Crab Nebula obtained at the Wise Observatory, together with older Lick Observatory spectrograms, show the Doppler ellipses of the emission lines plus the continuous spectrum of the pulsar. The position of the pulsar is offset from the centre of the Doppler ellipses, giving a measure of the pulsar's motion relative to the centre of the nebula over 920 years (1054-1974). Astrometric measurements by Wyckoff and Mr C.A.Murray confirm the high velocity obtained from the spectrograms. Wyckoff and Wehinger have also obtained electronographic observations of the Crab Nebula with a McMullan camera on the Wise Observatory 1-m reflector which show that the pulsar is moving towards the centre of optical activity (where the radio and X-ray centroids are also located). It is suggested that the centroid of the synchrotron emission may be identified with a bow shock ahead of the pulsar.

2.5 Galactic astronomy. Under the general direction of Dr D.H.P.Jones, a major programme is now in progress aimed at eliminating gaps in the currently patchy knowledge of the motions and space density of stars near the Sun, and in particular at reducing the bias towards stars of high space velocity in the existing data. Several methods are being used to detect dwarf stars in both galactic caps. The basic data include: a survey of the North Galactic Cap based on *V* and *I* Palomar Schmidt plates calibrated photo-electrically; an objective prism survey by Thé (Amsterdam), backed up by spectroscopy on the AAT; a parallax search on UK Schmidt plates of the South Galactic Cap involving up to 16 000 stars. Preliminary analyses indicate a lower value for the mass-density derived from the observed luminosity function than that inferred from dynamical studies of stellar motions perpendicular to the galactic plane. As bias in the observational data is being progressively removed, it is difficult to escape the conclusion that this discrepancy must be genuine.

2.6 Solar system. An analysis by Mr L.V.Morrison of 50 000 occultations observed during the period 1943-74 has shown that the accuracy of the

current lunar theory is limited by the inadequacy of the treatment of the planetary attractions. Reliable corrections to the eccentricity and perihelion of the Earth's orbit and an estimate of the tidal component of the acceleration of the Moon's motion have also been obtained, as well as clear indication that the equinox of the FK4 system requires a substantial correction.

Mr G.E.Taylor has deduced a preliminary value for the oblateness of the Martian atmosphere from observations of the occultation of ϵ Gem by Mars on 1976 April 8. Mr K.C.Blackwell has studied the meridian observations of the Sun recorded over the last 200 years, and has found evidence for a small residual acceleration in the motion of the equinox.

2.7 Photometry. A high-speed computer-controlled two-channel photometer is being developed by Dr D.H.P.Jones, Mr G.B.Wellgate and Dr K.F.Hartley. Sample length is 1 ms, or any integral multiple, and the counts are displayed in real time and may be stored on magnetic tape or disk.

Under the direction of Professor F.G.Smith, a device for synthesizing the necessary pulse trains for the observation of optical pulsars, for use with an instrumentation computer and/or a multi-channel analyser has been designed by Wellgate and constructed. Provision has been made for compensating for the variation of repetition-rate due to Doppler effect and for accurate timing. At the end of the report period this unit was undergoing tests in the laboratory.

3 NATIONAL FACILITIES

3.1 Northern Hemisphere Observatory. International negotiations continued during the year aimed towards the establishment of a Spanish International Observatory on the Canary Island of La Palma. Several European nations are concerned; the UK interest is primarily in the erection of the telescopes of the Northern Hemisphere Observatory, for which the RGO has executive responsibility. By the end of the year a rough access road had been completed by the Spanish authorities to within a short distance of the summit site, and a preliminary layout of the site had been made. At RGO, good progress was made in the design study for the 4.2-m altazimuth telescope, and with preparations for the modification and removal of the Isaac Newton Telescope to La Palma. Design of an automated INT prime-focus unit has been completed and manufacture is well advanced. Professor C.G.Wynne has proposed a new optical system which will satisfy the rather demanding scientific specification for the 1-m telescope.

3.2 RGO telescopes. The SRC Panel for the Allocation of Telescope Time allocated 152 nights on the INT to visiting observers, 173 nights to RGO staff and 34 nights to collaborative programmes. The 36-in. reflector underwent extensive renovation during the year, but it and the 30-in. coude reflector were used by several visiting groups as well as by RGO staff and Sussex University students.

3.3 Measuring machines. Extensive use of the PDS microdensitometer was made by visiting groups for a wide variety of projects. Plates were also measured on GALAXY for several visitors.

3.4 *Electronic imaging devices.* Six electronographic tubes with 40 mm mica windows and two with 85 mm windows have now been successfully completed. Two tubes with 30×5 mm mica windows have also been processed and tested and found to have a performance superior to most examples of the Spectracon, which they are designed to replace. Two further McMullan cameras, incorporating 40 mm tubes, have been completed. One of these has been installed on the 40-in. SAAO reflector at Sutherland and is in regular use. The cameras at Herstmonceux and at the Wise Observatory, Israel, have been in frequent use and have suffered only from minor breakdowns.

4 NATIONAL AND INTERNATIONAL SERVICES

4.1 *Time and Latitude Service.* Observations with the Photographic Zenith Tube for the determination of UT and the variation of latitude have continued, and the Greenwich Atomic Timescale (GA2) has been formed by combining the scales of a selection of six caesium-beam time standards at RGO. Studies of ways of comparing the clocks at RGO with those of the National Physical Laboratory have been started; both establishments have begun to measure the times of arrival of selected field-synchronization pulses on BBC TV. RGO has continued to provide the BBC 'six pips' time signal and to monitor the GBR and other radio time signals. Collaboration with the US Naval Research Laboratory in the testing of the Navigational Technology Satellite (*NTS-1*) has continued. Analysis of the early data has shown that the technique is potentially more precise than LORAN-C for global clock comparisons.

4.2 *HM Nautical Almanac Office.* Preparation and publication of the regular series of almanacs and ephemerides has continued. The design and computation of a new volume, *Planetary and Lunar Coordinates for 1980–84*, has continued. The regular programme for the prediction and reduction of occultations of stars by the Moon has continued. Special predictions have also been made for forthcoming lunar occultations of X-ray and radio sources and for potential occultations of stars by planets and their satellites.

4.3 *Stellar reference frame.* The regular observing programme has continued on the Cooke Transit Circle at RGO. Installation of the new automatic digital circle-reading system has been delayed due to problems encountered by the manufacturers. Preliminary results have been obtained in the reduction at Herstmonceux of all star observations made with the Gill transit circle at the Cape during 1961–74. Preparatory work for the proposed collaboration between RGO and the University of Copenhagen, aimed at the establishment of the automated Brorfelde transit circle on La Palma, has continued.

4.4 *Solar Activity Service.* Daily photography of the Sun in white light, the preparation of a detailed daily record of the positions and areas of sunspots, and the monitoring of solar activity have continued.

5 PUBLICATIONS

The following publications have been issued anonymously:

The Astronomical Ephemeris 1977

The Nautical Almanac 1977

The Air Almanac 1976 (3 parts)

The Star Almanac for Land Surveyors 1977

Greenwich Time Reports 1974 October–1975 December (quarterly)

Royal Observatory Annals No. 10 (Photoheliographic Results 1966).

In the following list of published papers, staff whose appointments terminated before 1976 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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