

Reports from Observatories, University Departments and Research Establishments

THE ROYAL GREENWICH OBSERVATORY

Director: Professor F.Graham Smith, FRS

Report for the period 1978 October 1 to 1979 September 30
(Received 1980 June 10)

1 INTRODUCTION

A comprehensive report on the work of the Observatory for this period has been published elsewhere (Wilkins, G.A. and Yallop, B.D., eds. 1980. *The Report of the Royal Greenwich Observatory 1978–9*, Royal Greenwich Observatory, Herstmonceux) and the main purpose of this paper is to describe the highlights of the research programmes to which about 14 per cent of the manpower effort is devoted.

The long-standing and traditional service role 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 decade.

2 ASTRONOMICAL RESEARCH

2.1 Extragalactic research. In the programme to determine astrometric positions of radio sources a further 335 plates in some 60 fields have been obtained with the two Herstmonceux refractors. Measurement and reduction have been completed by Mr E.D.Clements and a catalogue of optical positions of 38 sources has been published.

Dr R.J.Dickens and his collaborators have produced redshifts for 120 galaxies in the rich cluster field 0330–54 using spectra secured at the Anglo-Australian Telescope (AAT). On the basis of their similar velocities Calan 0340 and Klemola 8 probably form a supercluster, but 0328–557 is a background system. Magnitudes for galaxies in the Klemola 8 cluster have been obtained from UK Schmidt plates by Mr M.J.Currie. Miss A.S.Monk has classified some 550 galaxies of magnitude 16–17 in the Virgo, IC 4329 and Centaurus clusters.

Following a programme of galaxy classification in 21 X-ray clusters, Dr N.V.Vidal has found a correlation between the percentage of (E+So) galaxies in the cluster and its X-ray luminosity; this lends support to the idea that spirals may evolve into S0s by interaction with the intercluster medium.

In collaboration with Axon (Sussex), Dr K.Taylor has continued the work on the velocity field of M82. PDS microdensitometer scans of Johnson *B* and *V* band electronographs of M82, obtained at the Wise Observatory, Israel,

reveal the contours of a normal late-type spiral galaxy, although towards the centre there is evidence for redistribution of light due to dust scattering. The isophotes are distinctly perturbed in the region of the minor-axis emission-line filaments which have been investigated spectroscopically. Narrow-band electronographs of the hot-spot galaxy NGC 1808 obtained by Taylor & Axon with the Danish 1.5-m reflector at ESO, La Silla, will be reduced in the form of two-dimensional maps of the physically important line ratios over the whole nuclear complex. Clearly visible on the *V*-band electronograph, are ~ 5 kpc long filaments emanating from the disc of NGC 1808. This is the first time that jet-like phenomena have been clearly identified with the disc of a galaxy, rather than the nucleus.

Professor B.E.J. Pagel, together with Edmunds (Cardiff) and Chun and M.G. Smith (Oxford), continued to study the composition of H II regions in southern external galaxies, using AAT/IPCS observations. NGC 1313 (SBd) and NGC 6822 (Irr) have uniform oxygen abundances intermediate between those of the two Magellanic Clouds, in agreement with previous indications of small or zero abundance gradients in irregular and barred spiral galaxies.

2.2 Star clusters and variable stars. Mrs E.A. Bingham began the measurement of ω Cen in *B* and *V*. A star field containing many photoelectric standards has been measured and reduced using the PDS microdensitometer. Mr W.L. Martin, Penny (SAAO) and Mr H.E. Davies have been doing similar work on the clusters M15 and M67; they are investigating the use of a beam splitter technique to obtain simultaneous *B* and *V* electronographs.

Dr P.J. Andrews has obtained additional photoelectric *UBV* observations on the SAAO 1.0-m telescope of the double-lined binary κ Crucis II-23 at phases not well covered by previous work. The variation in the ultraviolet and the lack of eclipses are confirmed; the former is interpreted as being due to a gas stream.

Dr R.B. Hanson reviewed estimates of the Hyades cluster distance for IAU Symposium 85, 'Star Clusters'. Recent astrometric progress has substantially improved the accuracy of the observations. Trigonometric parallaxes yield a mean Hyades distance modulus $m-M = 3^m.25 \pm 0^m.06$. The close agreement of the results indicates that the overall mean Hyades distance modulus $m-M = 3^m.30$ may be used with confidence in cosmic distance scale calibrations.

Mr H.E. Davies has analysed *BVI* observations and a mean velocity curve of the *ab* type RR Lyrae star UV Octantis, to obtain radii using the van Hoff method. Using the 1.0-m telescope at SAAO, Dr P.J. Andrews has made photoelectric observations of the RR Lyrae variable V3 in NGC 4590. The star has been shown to be a multi-mode pulsator, with a mean colour corresponding to that expected at the changeover from *ab* to *c* type pulsation. Mr S.K. Mayo, Mr R.E. Wallis and Dr D.H.P. Jones secured *UBVRI* colours of dwarf novae at quiescence and at outburst using the Tenerife flux collector. Their aim is to amass data for about 30 such systems with a view to disentangling the light contributions of hot spot, accretion disc and stars. Dr P.J. Andrews has secured more *UBVRI* observations of southern super-supergiants; he confirms that HR 5171 is now redder and cooler than it has been for 20 years. Dr P.G. Murdin and collaborators found a variable radio

source ($\lambda = 2$ cm) to be coincident with the improved position of X-ray source A1710-34 as measured by the *SAS-3* satellite.

Monitoring of Cygnus X-1 in the *V* and *B* photometric bands by Mr E.N. Walker has continued in collaboration with the staff of the Instituto de Astrofísica de Andalucía. Analysis of a year's data suggests that a single unchanging period does not fit the observations and a re-analysis using independent data obtained in the USA is now being undertaken.

Dr P.G.Murdin and several collaborators concluded a theoretical study of Cir X-1 in which several lines of evidence (the shape of the X-ray intensity curve, its X-ray spectrum, the way the X-ray intensity curve has changed, the radio outbursts) all point to it being an eccentric binary star. This evidence is further suggestive of Cir X-1's origin as a runaway star from the nearby supernova remnant G321.9-0.3.

2.3 Stellar atmospheres, structure and evolution. With Stickland at the *IUE* ground station near Madrid, Professor B.E.J.Pagel has observed stellar Mg^+ features using the *IUE* satellite and analysed them with Mr D.Wilkins (temporary ASO). The FWHM is proportional to W_0 (Ca^+) measured by O.C.Wilson over a range of 12 magnitudes in luminosity and has been interpreted in terms of a simple Doppler broadening model simulating micro-turbulence in an optically thick atmosphere.

[O I] λ 6300 electronographic imagery of the Orion nebula by Dr K.Taylor, Dr S.P.Worswick and Axon (Sussex) has revealed a family of semi-stellar knots that are invisible on comparable $\text{H}\alpha$ exposures. They are in a region near to the high-velocity Herbig-Haro object discovered by Munch & Taylor (1974, *Astrophys. J.*, **192**, L93) and they appear to be associated with the Becklin-Neugebauer infrared source. Their anomalous [O I] intensity leads to the suggestion that they are also Herbig-Haro objects, possibly generated by the stellar wind of the BN source.

Dr R.G.Bingham continued his work with Scarrott (Durham) on nebular polarimetry. The previous work with the Durham group and Dr P.G.Murdin on η Carinae was published. A polarization study of M42 (the Orion nebula) and M43 suggests that the two are physically contiguous and that the dividing dark lane is internal to the nebulae rather than a foreground feature. A major programme of observation of Herbig-Haro objects has been started to investigate whether some are reflection nebulae rather than the intrinsically luminous shocks suggested by Dopita.

Dr D.H.Clark and Dr P.G.Murdin identified the optical/radio/X-ray source at the centre of the supernova remnant W50. This object, SS 433, has excited world-wide interest because of its extraordinary properties, notably the very large and variable red and blue shifts displayed by $\text{H}\alpha$ and other emission lines, probably due to relativistic Doppler shifts (0.25 c). Many theoretical models have been proposed, and an entire session devoted to SS 433 formed one of the highlights of the IAU General Assembly in Montreal. Clark and Murdin took spectra of filaments associated with W50 while commissioning the La Palma IPCS at SAAO; it showed a Puppis A-like spectrum with nitrogen enrichment and they have speculated that the filaments have been excited by SS 433.

2.4 *Galactic astronomy.* Dr R.B.Hanson has evaluated the frequency distributions of trigonometric parallaxes determined at the four observatories which have published the greatest number. He has studied their absolute zero points, systematic differences and external errors. His method is to fit the observed distribution by convolving power-law space distributions with Gaussian observational errors. Given a nominal correction to absolute, the zero point of the *General Catalogue of Trigonometrical Parallaxes* is confirmed to within 0.001 arcsec without the systematic observatory differences generally found from comparisons using multiple observations. The external error estimates agree with other recent determinations and indicate precepts for a new General Parallax Catalogue. The space distributions of stars selected for parallax observation give useful information to aid luminosity calibrations.

Dr D.H.P.Jones in collaboration with Clube (ROE), Dawe (UKSTU) and Heck (IUE, Villafranca), has compared the maximum likelihood algorithm for determining statistical parallax due to Clube and Dawe with that of Heck. Fictitious data showed that both algorithms gave the correct solution; previous differences must have arisen for astronomical rather than statistical reasons.

Dr D.H.P.Jones, Mr J.B.Alexander and Mrs J.E.Sinclair have completed analysis of narrow-band photometry of 1251 faint red stars. Of these, 91 are newly discovered or confirmed red dwarfs; their space density is still insufficient to account for the 'missing mass' in the solar vicinity but considerable uncertainty remains due to the small sample size.

2.5 *Solar system.* Mr L.V.Morrison has reduced and analysed timings of lunar occultations 1600–1860 and solar eclipses 1600–1700, to improve upon previous determinations of variations in the Earth's rotation. Investigations have continued into the shape of the lunar profile deduced from grazing occultations, and into the causes of 'fading' occultations.

Dr A.T.Sinclair, in conjunction with Dermott and Gold at Cornell University, worked on a theory of the nature of the rings of Uranus. Subsequently, Dr D.B.Taylor and Sinclair have been examining the nature of orbits at 1:1 resonance, which is the type of orbit postulated for the ring particles. Taylor has been investigating existing theories of the secular motion of planets, with a view to extending this work. The programme of observations of the position of Saturn's satellites has continued.

To mark the centenary of Einstein's birth, the astrometric plates taken at the time of the 1919 solar eclipse by the expedition from the RGO to Sobral in Brazil were re-measured and reduced by Mr E.D.Clements and Mr G.M. Harvey. The use of a modern measuring machine and a different method of reduction produced a much less ambiguous result from the Astrographic plates and a lower standard error from the 4-inch plates than had been obtained previously. The accordance of the observed deflection of light by a gravitational field with the prediction of Einstein's theory is now stronger.

3. INSTRUMENTATION RESEARCH AND DEVELOPMENT

3.1 *Astronomical instruments.* Dr R.G.Bingham has described a new approach to the design of grating spectrometers and spectrographs. He has shown that

the emphasis commonly placed on the size of the collimator aperture as a criterion of efficiency has little rigorous applicability, even in principle.

Taurus, an imaging Fabry-Pérot interferometer designed by Dr K. Taylor and Atherton of Imperial College, gives two-dimensional seeing-limited velocity fields of emission line objects. The system uses the IPCS as a detector and can operate at a variety of spectral resolving powers chosen so that galactic nebulae, spiral galaxies and active galaxies can all be studied at an optimum velocity resolution.

A cross-dispersing grism system for the Unit Spectrograph was developed from specifications by Mrs D.L. Harmer, Mr C.M. Lowne and Mr C.F.W. Harmer. In collaboration with Dr S.P. Worswick and Goldsmith (MSc student) the system was tested on the 36-inch telescope and it was shown that good relative line fluxes can be obtained.

3.2 Electronic imaging devices. Work has continued on the application of a General Electric charge injection device (CID) as a two-dimensional astronomical detector. Dr P.R. Jorden has established the conditions for non-destructive read-out and has designed new circuit boards which will enable multiple read-outs to be summed to give a high signal-to-noise ratio. An LSI-11 microprocessor is being incorporated for control and data handling, and a Ramtek image store will be used for image display.

Following the work done by Shectman (Michigan State University) and others on the use of intensified Reticon silicon diode linear arrays for photon counting, a detector of this type is being built by Mr A.R. Jorden and Mr P.D. Read for use with the image tube spectrograph at SAAO. A two-row 936 element array has been chosen and there will be two or three additional single-stage electrostatic image intensifiers following the existing three-stage intensifier at present used with photographic recording.

3.3 Optical design. Professor C.G. Wynne investigated the design of prime-focus field correctors with aberrations as low as 0.25 arcsec for use at sites with very good seeing. Dr R.G. Bingham investigated theoretically the use of a two-mirror prime-focus focal reducer on various telescopes and found that a larger scale reduction can be obtained for parabolic primary mirrors than the primary of a Ritchey-Chretien telescope. As most of the optical power is obtained with mirrors, the device has a very wide spectral range and is especially appropriate for solid-state detector arrays.

4 NATIONAL FACILITIES

4.1 La Palma Observatory. The international agreements to establish an international observatory on La Palma were signed on 1979 May 26. Access roads have been built and the site has been opened up for construction. The 1.0-m telescope is being built at Messrs Grubb Parsons in Newcastle. The 2.5-m INT was removed from Herstmonceux in 1979 June and is now undergoing modification in Newcastle: work on its building on La Palma has started. The Cervit blank for the 4.2-m telescope has been purchased and rough machined. The design of the telescope and building according to the original specification was completed during the summer. However, the cost of building on Roque de los Muchachos as indicated by the contract price

for the new INT building meant that the building, as designed, would exceed the previously estimated cost by a large factor. Investigations into ways of economising on building costs, whilst retaining the scientific qualities of the telescope, are therefore in hand.

4.2 *RGO telescopes and instruments.* The INT was used continuously until its closure on 1979 March 4. The Boksenberg IPCS system destined for La Palma was commissioned on the 90-cm telescope during the first six months of 1979 and later at SAAO. Two 'travelling' 40-mm electronographic cameras have been built and used at Calor Alto in Spain and on the Soviet 6-m telescope.

4.3 *Digital-image processing.* Substantial modifications to software by Mr D.J.King have improved facilities for handling large format data produced by the IPCS with an external memory.

5 NATIONAL AND INTERNATIONAL SERVICES

5.1 *Time and latitude services.* Dr G.A.Wilkins assisted in drafting a proposal for Project Merit which is primarily concerned with the introduction of modern techniques, such as laser ranging and VLBI, for regular monitoring of the rotation of the Earth. There will be a special campaign during 1983-4 to compare classical and modern techniques.

5.2 *Publications, information and data services.* From 1981 onwards *The Astronomical Almanac* will replace *The Astronomical Ephemeris* and *The American Ephemeris and Nautical Almanac* and will be printed entirely in the USA.

More than 2300 enquiries from the general public were answered.

5.3 *Satellite laser ranging.* The proposal described in last year's report for a UK satellite laser ranging facility was approved by the Council and subsequently by the Department of Education and Science on November 27. Planning and preparatory work was carried out in collaboration with staff at the University of Hull (which is responsible for the design, assembly and testing of the laser, detection and timing subsystems) under the general supervision of Dr G.A.Wilkins and Ramsden; the project manager is Mr J.D. Pope. Visits were made to several European laser-ranging stations to discuss technical matters and future cooperation. Staff from the Technical University of Graz, Austria, which is about to build a similar system, visited both RGO and the University of Hull to discuss the specifications for the optical subsystems, mount and other aspects of design.

5.4 *Stellar reference frame.* Cooke Transit Circle observations of FK4 stars over a 16-year period have been used to investigate various instrumental parameters and establish the first independent Herstmonceux system, to which all observations are now being reduced. Results for FK4 and FK4 Supplement stars have been sent to Heidelberg for inclusion in FK5.

Computer programs have been developed on the NOVA mini-computer, to enable much of the GALAXY setting-up procedure to be performed on the Coradograph, leading to a more efficient use of GALAXY. Of the 6000 plates in the Cape Photographic Survey some 370 plates were measured during the year; a peak rate of measurement of 100 plates per month has been achieved.

Programs for collating and examining the overlapped plates have also been developed.

5.5 Services to universities. Eleven students from the University of Sussex have worked regularly at RGO during the year while studying for higher degrees. Six sandwich students spent a total of 28 months at RGO, working mostly in the fields of computing and electronics, and ten other students attended the annual summer vacation course. Technical assistance of various kinds was provided to seven university groups.

6 CONFERENCES

6.1 XVIIth General Assembly of the International Astronomical Union. Nineteen members of staff attended the assembly in Montreal, many in their capacities as office-holders in several Commissions and committees.

6.2 23rd Herstmonceux Conference. The conference on the subject 'Cataclysmic Variables' was held in April and attended by some 50 visitors including Bath (Oxford), Chevalier (Kitt Peak), Goss (Groningen) and Weiler (Bonn).

7 PUBLICATIONS

The following publications have been issued during the period under review, in addition to the regular publications associated with national and international services. Staff whose appointments terminated before September 30 are prefixed by an asterisk; staff on leave of absence and staff seconded to work for other establishments are prefixed by a dagger. Authors who are not members of staff or students working at RGO are shown in italics.

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