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# Proceedings of Observatories

## ROYAL GREENWICH OBSERVATORY

(*Director, Sir Richard Woolley, O.B.E., F.R.S., Astronomer Royal*)

## ROYAL OBSERVATORY, CAPE OF GOOD HOPE

(*Officer-in-Charge, G.A.Harding*)

(Report for the year ending 1969 December 31)

### STELLAR KINEMATICS, DYNAMICS AND AGES

*Nearby stars*

The extended catalogue of nearby stars is in press.

Analysis of motions of the later-type stars according to age, as judged from the strength of Ca II reversals, shows that the velocity ellipsoid of the young stars is similar to that of the A stars, in that it is tilted at about 22° to the direction of the galactic centre, whereas the ellipsoid of the older stars shows no such tilt. Backward integration of the orbits of the young stars shows that at about the time of their formation, or half a galactic period ago, they lay in a long spiral arm-like structure, trailing in galactic rotation. It is tentatively concluded that the tilt of the ellipsoid arises from circumstances of formation rather than a perturbation of the motions.

The H and K reversals in a number of the late-type dwarfs have been measured on spectra taken with electronic cameras on the 30-inch coudé spectrograph.

*Radial velocities*

Observations of 300 G stars in four areas have so far been obtained with the Yapp and Isaac Newton telescopes. These will be analysed in conjunction with those of K stars which were observed at Kottamia during 1967 (see *Q. Jl R. astr. Soc.*, **9**, 164, 1968). It has already been found that the solar velocity depends on the distance of the stars from which it is determined, in a way which indicates perturbations by large concentrations of matter in the galactic disc.

Radial velocities have been obtained with the I.N.T. for 50 A0 stars in the region of the North Galactic Cap. This is to search for possible variation in $w$-velocity with distance from the galactic plane, such as that found in the South Galactic Cap.

*Selected areas*

The re-observation of the Radcliffe proper motion plates in the northern Kapteyn selected areas is now more than 60 per cent complete. The Radcliffe and Herstmonceux plates will be measured on the GALAXY machine at Royal Observatory, Edinburgh. A pilot investigation for the main programme will consist of the seven selected areas in the region of the anticentre and North Galactic Pole for which *UBV* photoelectric sequences have recently been published by Purgathofer (Lowell Bulletin No. 147). Photographic photometry is being obtained for these areas from plates taken with the 26-inch refractor. Photoelectric standards in the other northern areas are being included in the general photometric programmes at the Cartuja Observatory in the Sierra Nevada.

## TRIGONOMETRIC PARALLAXES

Computer monitoring of the Herstmonceux parallax programme has worked successfully throughout the year. Observations of 20 stars have now accumulated sufficient weight for parallax determination and are currently being measured. The computer reduction programmes are nearly complete.

At the Cape, 739 plates were obtained with the Victoria telescope during the year. The relative photographic magnitudes of the reference stars, and the parallax stars as reduced by the rotating sector, have been determined for a number of fields which have already been measured for parallax.

## STAR CLUSTERS

The determination of masses, luminosities and helium abundances of the RR Lyrae stars in NGC 6171 has been concluded. The existence of a large helium abundance in such old objects may be of cosmological significance.

Light curves, in *B* and *V*, of RR Lyrae variables in NGC 6981 are being studied. So far, about 20 stars have been completed and these curves will be analysed in a similar way to those for NGC 6171. A number of long-period variables in globular clusters have been monitored on the McClean telescope at the Cape.

Plates have been taken at the Cassegrain focus of the I.N.T. for photometric studies of the globular clusters M3 and M92.

Proper motions of nearly 700 stars in the region of Boks' galactic cluster in the direction of the LMC have been measured. The common proper motion of most of the bright stars originally noted (**31**), has been confirmed. The extended proper motion survey will be used to isolate

fainter members of the cluster if they exist, and to delineate the spatial extent of the cluster.

## VARIABLE STARS

### *Photometry*

Photoelectric observations have been made, at the Cape, of a number of variable stars, including a new RR Lyrae variable CPD $-74^\circ$ 214 (= BV 1041), the cepheids $\kappa$ Pav and HR 4768 (= BV 476), which is a small-amplitude cepheid with a period of 3·34 days, and several eclipsing stars.

Light curves of three long-period variables have been obtained from plates taken with the 13-inch refractor at Herstmonceux.

At the observatory in the Sierra Nevada, photoelectric light curves of two RR Lyrae variables have been obtained.

Regular visual observations of long-period variables have been continued at the Cape, on the 6-inch refractor.

### *Spectroscopy*

A velocity curve of the RR Lyrae variable RZ Cep was obtained on a single night with the I.N.T., as part of a programme to improve the determination of radii by the Baade-Wesselink method.

A further search is being made with the I.N.T. for high-velocity W Virginis stars.

Plates of Procyon have been obtained with the 30-inch coudé spectrograph in a search for small amplitude variations in radial velocity and temperature; this star is important as it lies on the edge of the instability region in the HR diagram.

The determination of the masses and temperatures of F stars, which are suspected $\delta$ Scuti variable stars has continued. Light variations in six of these have been looked for at the Cartuja Observatory in the Sierra Nevada, but none greater than $0^m{\cdot}02$ have, in fact, been found so far.

### *Proper motions*

The reductions for stars in the Groningen list in the Cape Astrographic Zone are nearing completion. The measurements on 18 RR Lyrae variables have been sent to Herstmonceux for reduction.

At Herstmonceux the determination of proper motions of semi-regular and RV Tauri variables is continuing. A number of these are being observed with the transit circle.

## STELLAR ATMOSPHERES AND ABUNDANCE STUDIES

While in general the heavy-element mixture in extremely metal-deficient stars of the galactic halo population is remarkably similar to

that of the Solar System, certain elements undergo differential changes that are of great interest in connection with the theory of nucleosynthesis. One such element turns out to be nitrogen, although it is somewhat difficult to study because one has to use the ultra-violet CN band near λ 3883 and CN bands disappear altogether when the degree of metal deficiency is very high (~100), though they are visible when the deficiency factor is of the order of 10. Furthermore, all earlier deductions based on the λ 4215 band are probably wrong, because of blending with lines of other species. So far the λ 3883 band has been studied in two weak-lined stars. One of them is ν Indi, where coudé spectra taken at the Radcliffe Observatory reveal that nitrogen is overdeficient compared to carbon and metals, by a factor of about 5. This result may be directly related to the fact that recent models of explosive nucleosynthesis in supernovae do not predict the production of nitrogen and to the suggestion that primary cosmic rays may contain no nitrogen before they have undergone spallation in the interstellar medium. However, another star of otherwise similar composition, the subdwarf HD 25329, has strong CN bands as was pointed out by O.C.Wilson in 1962. Analysis of a Palomar plate kindly supplied by Dr Wilson shows that nitrogen is not overdeficient, and may indeed be deficient by a smaller factor than other elements. Consequently any nuclear interpretation of the nitrogen effect is likely to be intricate.

Dr R.A.Bell, on leave from the University of Maryland, has developed a theoretical spectrum synthesis programme, using a computer, by which he has studied the calibration of broad and narrow-band photoelectric colour indices. He has shown that the difference in (*U–B*) between the stars on the asymptotic and subgiant branches in the HR diagram of the globular cluster M92, found by Sandage and Walker, cannot be accounted for by a difference in line absorption. The same technique is being used to interpret the blanketing observations of Spinrad and Taylor and the spectrum of ν Indi. A study of isotope shifts in the Mg H lines in the spectrum of Arcturus, carried out by Bell and by Dr D.Branch, now at California Institute of Technology, has given the ratios $^{24}Mg : {}^{25}Mg : {}^{26}Mg = 8 : 1 : 1$ in agreement with the terrestrial and meteoritic values.

The differential curve of growth analysis of the binary system α Cen shows that both members have a composition similar to that of the Sun. This result is at variance with the fact that α Cen B exhibits an ultraviolet deficiency with respect to a mean Hyades dwarf with the same value of (*G–I*). A similar anomaly was found recently by Dr A.W. Rodgers in the analysis of δ Pav and it was concluded that this was a result of the increased micro-turbulent velocity. If anything the microturbulent velocity of α Cen B is slightly less than that of the Sun. The possible errors inherent in the photometry of such a close pair of stars

may be responsible for the anomaly in $\alpha$ Cen B. Also any such error will be accentuated by the steepness of the mean Hyades relation in this region of the two-colour index diagram.

Using the relation found between the ultra-violet excess and the value of [Fe/H] (see (**49**)) the age and kinematics of the late F field dwarfs have been investigated. The position in the HR diagram and the kinematics of the stars have been deduced from the extension of Gliese's catalogue made at the R.G.O. The age of the stars has been found from the position in the HR diagram in relation to the dated isochrones of the intermediate age star clusters NGC 752, M67 and NGC 188. The metal-rich and mildly metal-poor stars are found to have a wide range of ages, whereas the very oldest stars are all mildly metal-poor. Also the stars with large values of inclination of the box orbit, eccentricity or modulus of velocity perpendicular to the plane of the galaxy, tend to be metal-poor.

Computer programmes are being developed to undertake the reduction of the data obtained on magnetic tape from a digitized Joyce-Loebl microdensitometer. These will identify the features of interest in the stellar spectra and calculate the equivalent widths and the parameters of the profiles of individual lines. The reduction of low-dispersion spectra of red giants which requires only the measurement of line depths is ideally suited for this type of reduction.

An investigation of metal-poor red giants is being made using a model atmosphere programme developed for use on the ICL 1909 computer. So far the spectroscopic parameters derived from differential curve of growth analysis have been compared with those calculated from the flux constant model atmosphere calculations. The large difference between the reciprocal excitation temperature parameter for the neutral and ionized lines, as found in the case of HD 122563 for example, is not reproduced by the models. Also these models are being used to study the differences in the chemical composition deduced from molecular lines between scaled solar models and the appropriate flux constant model. For this type of star the choice of model can be important in obtaining a consistent set of physical parameters.

Studies of low-dispersion spectra of red giants taken with the Isaac Newton Telescope show that a good measure of $(B–V)$, independent of reddening, can be derived using methods developed earlier by F.Spite and J.B.Alexander. This method will provide a valuable check on current controversies about M67, when enough spectra of cluster members have been secured.

Further studies of the spectrum of $\eta$ Carinae (**36**) have revealed that, if the optical continuum (corrected for reddening) is extrapolated to the ultra-violet assuming either stellar or two-photon emission, the total

luminosity predicted is of the right order of magnitude to account for the enormous infra-red flux observed near 20 $\mu$ by J.Westphal and G.Neugebauer. This result offers strong support to the dust model for $\eta$ Carinae and similar infra-red objects. Despite a criticism by D.L.Lambert, the reddening derived earlier by Pagel (**34**) from [Fe II] lines has been shown to be essentially correct by a study of permitted Fe II lines having common upper levels on the basis of equivalent widths kindly supplied by Dr A.W.Rodgers.

## EXTRA-GALACTIC STUDIES

Optical monitoring of the light variations of quasars, N-type galaxies and Seyfert galaxies, with the 26-inch refractor, has continued. A number of quasars are also under observation with the Cape 24-inch refractor.

Spectra of six recently discovered radio galaxies with magnitudes in the range $12^m$–$13^m$, and of six of the brightest objects in Zwicky's seventh list of compact galaxies, have been obtained with the low-dispersion camera at the Cassegrain focus of the I.N.T. Direct photographs of 29 of Zwicky's objects have also been obtained at the prime focus of the I.N.T.

Astrometric positions of 16 optical objects associated with small-diameter radio sources have been published (**32**) and a detailed description of the methods used has been prepared for publication. Observations of a second list of sources have been started.

An analysis of published 12-colour photometry of galaxies has shown that the 12 colours can be adequately represented by models containing only three parameters, and that the variation between the integrated spectral types of galaxies is due more to variations in metallicity than in mean temperature of constituent stars.

A new method for analysing the integrated colours of galaxies and globular clusters has been developed.

## THEORETICAL STUDIES

Recently Dr Lynden-Bell has put forward the hypothesis (**27**) that at the centre of many galaxies matter has collapsed to form a Schwarzschild singularity which is slowly swallowing surrounding material and releasing gravitational energy. Some of this energy is transferred to the magnetic field which is being tightly wound up by the fast central rotation, producing neutral points in the field where charged particles may be accelerated to high energies. The detailed theory explains the high-energy phenomena observed at the centres of quasars, Seyfert galaxies and normal galaxies.

The decametric radio bursts from Jupiter, which are correlated with the position of Io in its orbit, have been explained (**28**) as coherent

cyclotron radiation due to the action of the satellite as a unipolar inductor on the planet's magnetosphere.

The final state of dying stars which are completely degenerate and subject to fast uniform rotation, has been investigated. A numerical analysis of the stability of these models against cylindrical radial disturbances shows that they are unstable. The investigation will be extended to include the non-uniformly rotating case.

## PHOTOELECTRIC PHOTOMETRY

*Cape.* The Elizabeth 40-inch telescope at the Cape has been used exclusively for photoelectric photometry. The *UBV* observations of 166 A stars in the south galactic cap have been completed and are being reduced. Standard stars near the globular cluster $\omega$ Cen have been re-measured, and the results show systematic differences when compared with published values, particularly in the case of *U–B*. *UBV* obsevations have also been made of the foreground cluster, discovered by Bok, in the direction of the LMC, and of a variety of stars in the general field. Many nearby stars are included.

Photoelectric measurements on a four-colour system, similar to that of Strömgren and his associates, have been continued. Observations have been made of stars from Gliese's catalogue of nearby stars, of possible horizontal branch stars and various metal-deficient stars.

The Elizabeth Telescope has also been used by four visiting astronomers for *UBV* observations.

Three-colour observations of early-type stars have been made with the 24-inch Victoria Telescope, at the request of the Radcliffe Observer.

The programme of photoelectric photometry with the Cape Astrographic Telescope, started in 1953, to determine, at first *V* and *B–V* and later $(U-B)_c$, a refractor counterpart of *U–B*, for all HR (= BS) stars in the Southern Hemisphere has been completed, but the observations have not yet been fully reduced. Observations are in progress around the south polar cap to check the $U_cBV$ system in that area, and further work is contemplated to investigate other suspected inhomogeneities in the southern magnitude system. Some of this is being done with the 18-inch reflector. A new determination of the zero points has been made for a *UBV* standard sequence in the SMC.

*Sierra Nevada.* In addition to the programmes referred to elsewhere in this report, observations were made on stars in the extended catalogue of nearby stars, and to provide standards in the fields of the variable quasars which are being monitored on the 26-inch.

## POSITIONAL ASTRONOMY

### *Meridian observations*

*Herstmonceux.* Observations of the Sun, planets and fundamental

stars, together with selected variable stars, have continued with the Cooke Transit Circle.

Progress continues with the development of computer methods for monitoring the number of observations obtained for each star, reducing the observations and establishing a fundamental system.

Computer processes are being developed for the storage, retrieval and application of the systematic corrections required by individual catalogues in proper-motion determination.

*Cape.* The observations of southern reference stars (SRS) in the $-30°$ to $-40°$ zone have been completed, except for some of the fainter stars observable only during the winter months. Observations in the $-52°$ to $-64°$ zone were commenced in December. Observations for the 3rd Cape Fundamental Catalogue for 1950 commenced in 1961, are being made concurrently with the SRS programmes. The preliminary reductions of declination measures are now being done with an Olivetti Programma computer but the main reductions are still being done at the U.S. Naval Observatory by courtesy of Mr F.P.Scott. However, the reductions have now been programmed for the ICL 1909 computer at Herstmonceux and this system should be running on a routine basis in the near future. The star lists required by the Cape for observing the $-52°$ to $-64°$ zone of SRS have been produced at Herstmonceux.

*Astrolabe observations*

The astrolabe observations were continued at the Cape until the end of April and are now being discussed. The instrument is being returned to Herstmonceux.

*Photographic star positions*

*Cape.* The photography of the zones $0°$ to $-28°$ and $-54°$ to $-90°$ is nearing completion. 438 plates of the zone $-40°$ to $-52°$ have been measured with the Zeiss two-coordinate machine at the Cape and are being reduced at Herstmonceux. Observations of selected minor planets whose paths lay in the $0°$ to $-30°$ zone were made on 34 occasions. Experimental plates have been taken to investigate the feasibility of determining the positions of bright galaxies relative to a stellar reference frame with the 10-inch Taylor Hobson astrometric camera.

*Planets and comets*

*Cape.* The minor planet Geographos was photographed on six nights near its closest approach to the Earth. Observations were also obtained of comets 1969 g (three nights) and 1969 i (two nights).

*Lunar occultations*

Eighteen occultations of stars by the Moon were observed visually

at the Cape. Three of these phenomena were also observed photoelectrically.

*Artificial satellites*

During the year under review 1150 satellite passes were tracked with the kinetheodolite at the Cape. The reduction in numbers compared with last year is mainly the result of the smaller number of predictions received. The observing is done by part-time observers, most of whom are not staff members of the Royal Observatory.

Satellites as faint as magnitude 7 have been successfully photographed. The general standard of accuracy is 0·8 minutes of arc. Careful attention is given to the determination of instrumental errors.

The Apollo 12 spacecraft was photographed with the 24-inch Victoria Telescope at the Cape, and also with the 26-inch refractor at Herstmonceux.

## TIME AND LATITUDE SERVICE

No change was made in the PZT observing programme and 119 plates with an average of 17 stars per plate were obtained. The star count does not include the observations, also contained on the plates, for the determination of the positions of 22 stars which are to be included in the observing programme for the years 1971–77. The results have been communicated weekly to the BIH and monthly to the IPMS.

The first year's observations of the Calgary PZT mentioned in last year's report are now being studied and the preliminary results are very encouraging.

At the beginning of the year, from about the end of January to the middle of March, there was a gradual change of rate of rotation of the Earth, and it appears to have settled down to a losing rate of 2·7 milliseconds per day relative to ephemeris time which is made currently available by atomic standards.

By international agreement the offset of the carrier frequencies of the coordinated radio time signals remained at $-300$ parts in $10^{10}$ (equivalent to a losing rate of 2·6 milliseconds per day).

The Greenwich atomic time scale, GA2, based on caesium standards at Herstmonceux, has been published quarterly in the *Greenwich Time Reports*.

Two travelling clock comparisons were made with the USNO, one in February and one in July, showing a difference of less than one part in $10^{13}$ between the UTC time scales of the RGO and the USNO.

A Loran-C receiver has been installed in the Time Department. Measurements have been made of the pulse from Sylt, one of the slaves

in the Norwegian Sea Chain of which Ejdes is the master station. The results have been published in the Circulars, Series B, from April, in the form UTC (RGO)—Ejdes.

## THE SUN

Photographs were taken, in white light, at Herstmonceux on 281 days and at the Cape on 315 days.

The Lyot Hα heliograph at the Cape was in operation for 2056 hours during the year, and 7000 feet of film were inspected and sent to the University of London Observatory for detailed study. Photographs in Hα were obtained at Herstmonceux on 211 days.

The level of solar activity began to fall in 1969 despite considerable activity in March which resulted in the epoch of maximum phase being retarded until the last quarter of 1968 (previous indications placed it some six months earlier).

Current information was widely distributed by monthly RGO Solar Activity Circulars.

## PHYSICS

The Physics Department was set up at the beginning of the year to develop image tubes for astronomical use. A new building was erected during the year to accommodate it together with the Instrument Development Department and the Drawing Office. The building was ready for occupation in November. The facilities include, in addition to general laboratory and office space, a clean area for the assembly of tubes, ultra-high vacuum pumping equipment for tube processing, a dark laboratory for tube testing and a small workshop.

Initially the Department is concentrating on the development of electronographic tubes. These will be of demountable construction and will incorporate mica windows to isolate the photocathode from the electronographic plate. By incorporating means for protecting the mica from full atmospheric pressure it will be possible to use considerably larger windows than those in existing tubes (e.g. the Spectracon).

The construction of a Kron Electronic Camera is well advanced. Kron's original design has been modified to incorporate a mica window; this will greatly simplify the plate-changing procedure although at the cost of some reduction in recording speed. It is hoped that this Electronic Camera will be useful for the direct photography of star fields.

A method of measuring the integrated density of a stellar image on an electronographic plate is being studied. A scanning digital micro-densitometer is used to measure the image density at points on a rectangular array with step size much less than the diameter of the

stellar image. A computer produces a least-squares fit to the data by varying the parameters of a two-dimensional gaussian function superimposed on a level background. An estimate of stellar intensity is then given by volume of the best-fitting gaussian solid.

Towards the end of the year a collaboration was started with Dr M.E.Barnett of the Applied Optics Section, Physics Department, The Imperial College of Science and Technology, aimed at applying computer techniques to the design of electron optical systems for image tubes. In particular it is hoped that this will lead to a better understanding of the factors influencing geometrical distortion and will enable tubes to be designed which will be better in this respect than existing ones.

## INSTRUMENTATION

### *Isaac Newton Telescope*

(a) *Prime focus.* A four-element field corrector made by Grubb Parsons was fitted in July. The optics were designed (by Professor C.G.Wynne of Imperial College, London) to give images less than 0·5 arc sec in diameter over a field diameter of 40′ for wavelengths extending from 3650 Å to 10 140 Å. Direct photographs have shown that images within this field are better than 1 arc sec in diameter; preliminary reduction of Hartmann tests has confirmed the theoretical performance.

Tests on the performance of the corrector for photographic photometry have been carried out on *UBV* plates taken on NGC 188 using Sandage's photoelectric standards for comparison. Preliminary results indicate that the s.e. of a single magnitude from one plate is about $\pm 0^m.03$ in *V* and $\pm 0^m.04$ in *U* and *B*. There is no evidence for a decrease in accuracy at least as far as 15′ from the field centre, nor for the presence of systematic errors depending on position in the field.

The astrometric performance of the corrector is being tested from plates taken on the North Celestial Pole and on the Pleiades. Although the field distortion is large, reaching about 1·6 per cent at the edge of the corrected field of 40′, it appears that the corrector system can be used satisfactorily for high-precision astrometric work.

A study for the redesign of the prime focus direct photographic camera has begun; this will incorporate automatic guiding and will, as far as possible, be remotely controlled.

(b) *Cassegrain spectrograph.* The spectrograph has now been completed by the introduction of a third low-dispersion camera system. This comprises a mirror collimator of 55-mm beam diameter, a grating blazed at 5000 Å giving a linear dispersion of about 360 Å $mm^{-1}$ at the focus of a semi-solid Schmidt camera, *f*/0·8 (effective). The camera

was designed and manufactured by Grubb Parsons. Problems of plate location having been solved, the system has been brought into observational use.

(c) *Coudé spectrograph.* Further work has gone on throughout the year on this instrument. The access stairway and most of the intermediate flooring has now been installed and the slit area enclosed. Manufacture of mountings for the optical components has progressed. Assessments of diffraction grating performance, including photoelectric tests of efficiency, were carried out during the year. As a result, the original grating blazed at 8000 Å was found not to be satisfactory and has been replaced by the second-choice grating of 1200 l/mm, blazed at 4100 Å.

(d) *Television field relay.* The Image Isocon television camera, made by Marconi Instruments Ltd, has been used since 1969 January to relay the field of an 8-in finder on the main telescope. The sensitivity has proved to be good (giving a star threshold of about $13^{m}\cdot5$). Maintenance time, however, has proved greater than originally expected in the first year of operation.

(e) *Polar axis.* Investigations are being carried out on the flexure of the polar axis. From analysis of plates taken at the prime focus, on the North Celestial Pole, it appears that the main component is a simple flexure with half amplitude $0'\cdot3$, which is nearly symmetrical about the meridian.

*Image intensifiers*

The unit construction spectrograph for image intensifiers has now reached the stage of laboratory testing prior to telescope tests.

A redesign of the 30″ reflector image tube camera has been completed, the existing lens camera is to be replaced by a mirror system producing a linear dispersion of about 5 Å $mm^{-1}$. The optical components are on order and the change should be completed in 1970. The resolution and wavelength coverage of the system will be much improved.

An exposure meter, panel supplies and control units for the unit spectrograph, are being built for use at Pretoria.

*Photometers*

The electronics for the two-channel, pulse-counting, integrated circuit photometer have been built, and an order for the mechanical work has been placed.

Basic design work has been carried out on a general purpose photometer, which incorporates two photo-multipliers.

A D.C. amplifier system for photometry has been built for the Cartuja Observatory in the Sierra Nevada.

A D.C. amplifier system to replace the existing valve amplifiers used for photometry at the Cape, has been provided.

Work is proceeding in cooperation with Dr van Breda, on digital clocks and pulse-counting equipment for use in the photometric work at St Andrews University Observatory.

*Time service*

The installation of new transmitting clock systems in the Time Department has been completed and work is under way on an automatic digital comparator for clock intercomparisons.

## H.M. NAUTICAL ALMANAC OFFICE

The Office has continued its three principal activities in the preparation of ephemerides for astronomers, navigators and surveyors, research in the dynamics of the solar system, and the provision of a computer service for the Observatory as a whole.

*Ephemerides*

The following almanacs have been published during the period under review: *The Astronomical Ephemeris* for 1970; *The Nautical Almanac* for 1970; *The Air Almanac* for 1969 May to 1970 April (in three parts); *The Star Almanac for Land Surveyors* for 1970. The advanced proofs of the first part of *The Astronomical Ephemeris* for 1972 were distributed in June. The corresponding data for 1973 were distributed in the form of reduced size Xerox copies of computer listings in November. In addition the Office has prepared and distributed special predictions and ephemerides including: world-wide predictions of lunar occultations of stars and radio sources; topocentric ephemerides of the Moon for radio observatories; transit ephemerides of planets for Herstmonceux and the Cape; co-ordinates of the Earth with respect to the centre of mass of the solar system for use in the reduction of pulsar observations; and rising and setting times, etc., for particular places to meet civil requests.

Progress on the production of the new *Sight Reduction Tables for Marine Navigation* has again been slower than anticipated; proofs of all the tabular matter and of the explanation for volume 6 have been received from the U.S. Naval Oceanographic Office and most of them have been examined. Star recognition diagrams for use with periscopic sextants were prepared for inclusion in *The Air Almanac* for 1970 onwards. A further reprint of *Interpolation and Allied Tables* (last revised in 1956) was issued by H.M. Stationery Office in March.

*Research activities*

The research effort of the Office has again been largely devoted to the study of the motion of the Moon, through the analysis of the observations of occultations and the attempt to improve the theoretical basis of the ephemeris.

The digitization of Watts' charts of the marginal zone of the Moon is almost complete; the paper tapes prepared on the D-mac pencil follower have been processed and nearly all the data are now available on exchangeable-discs. The system is in use for the automatic reduction of currently received observations and will be used to extend to earlier years the preliminary analysis for 1960–66 that was made last year (**30**). A study of the residuals in the preliminary analysis suggested that some of the adopted positions of the telescopes were in error; corrected positions have now been obtained for many places. Observations of grazing occultations have been analysed in order to allow a better determination of the latitude of the Moon and to detect errors in the declination of stars, but it has also been shown that the origin of position angle for Watts' charts requires a correction of 0°·25. Programs for the prediction of the tracks of grazing occultations have been written; the tracks are plotted automatically and then detailed predictions are prepared for suitably placed observing groups.

The testing of a new program for the evaluation of Brown's lunar theory to give the lunar ephemeris $j = 2$ revealed (**62**) the presence of an error in Eckert's series for the differential correction of the lunar ephemeris ($j = 0$). The new program is being used to prepare the ephemeris for use in comparison with past occultation observations, as well as for publication in *The Astronomical Ephemeris*.

Programs for the integration of the motions of the Sun and Moon have been written but so far the nature and origin of the discrepancies between the results of the integrations and of the lunar ephemeris ($j = 2$) have not yet been established. It has not proved possible to find a direct way of improving the precision of Brown's theory of the planetary perturbations.

An analysis of recent observational data received from the U.S.S.R. and U.S.A. has confirmed (**61**) that the secular acceleration of Phobos, the inner satellite of Mars is very much less than that originally reported by Sharpless.

A definitive analysis of the observations of the occultation of a star by Neptune on 1968 April 7 has been completed (**55**) and has led to the value of 50 940 $\pm$ 140 km for the diameter of the planet, including its atmosphere.

Numerical confirmation of the existence of certain periodic solutions

of the three-body problem has been obtained and all the material has now been prepared for publication.

Some further work has been done in collaboration with Dr Thackeray of Radcliffe Observatory on the determination of the elements of orbits of some spectroscopic binaries (17).

A review of the uses of observations of the positions of the Moon and planets was prepared.

*Computer service*

Two exchangeable-disc store drive-units were added to the ICL 1909 computer in March. These have considerably reduced the amount of time spent on program compilations and on magnetic-tape searches. The computer has continued to be reliable with an average serviceability ratio of 0·95. The average amount of useful computer time (i.e. excluding time lost for faults and all hardware and software maintenance) has increased to 34 hours per week; of this 37 per cent has been for N.A.O. work, 40 per cent for the rest of the Observatory and 23 per cent for external users (Natural Environment Research Council and Ministry of Defence).

The Computer Section has continued to provide a programming advisory service and data preparation and punching service for all users, in addition to operating the computer.

*Other matters*

Members of the Office staff have also taken part in activities connected with: the preparation for the I.A.U. General Assembly and for I.A.U. Colloquium No. 9 on 'The I.A.U. System of Astronomical Constants', both of which are to be held in 1970 August; the organization of the activities of I.A.U. Commission 4, including its Working Group on astronomical ephemerides for space research; the proposals for changes in the basis of the internationally coordinated transmission of Universal Time; and other national and international committees concerned with astronomy and navigation.

## SITE-TESTING

The 12-inch telescope at the Sierra Nevada in Spain was brought into operation in 1969 June. Later adaptations were made to enable observations to be continued through the winter. Since June seven parties have obtained photoelectric observations on a total of 58 nights. As well as the site-testing, extensive work has been done on, amongst other subjects, variables, the setting up of standards, and a survey of nearby

stars. The sky has been photometric for six hours or more on 54 per cent of recorded nights. Site-testing will continue for two years.

The Cape Observatory has assisted with the site-testing programme organized by the Republic Observatory. The meteorological records obtained near Sutherland (site 3) have been studied in detail, and a number of exposures obtained with double-beam instruments at various sites have been measured and reduced at the Cape.

## GENERAL

The Herstmonceux Annual Conference was held at the Castle on 1969 April 9 and 10, on 'The Astronomy of Position, Proper Motion and Occultation'. Overseas visitors included Dr Fricke and Dr Gliese from Astronomisches Rechen-Institut, Heidelberg, Dr T.D.Kinman from Lick Observatory, Professor L.Plaut from Groningen, and Dr A.D.Thackeray from Pretoria.

Dr D.Lynden-Bell has been granted leave of absence to work for a year at the California Institute of Technology.

Dr R.A.Bell of the University of Maryland is working at Herstmonceux for a year as a Principal Research Fellow.

Dr M.V.Penston has been awarded a Carnegie Fellowship at the Mount Wilson and Palomar Observatories.

Microfilm copies of the Royal Observatory records covering the period from Flamsteed to Bradley have been received from the Public Record Office. It is hoped to continue microfilming of the records in the near future.

## PUBLICATIONS

At the beginning of 1969 the division of the *Royal Observatory Bulletins* into five series was discontinued. The magnetic results became the responsibility of the Geomagnetism Unit, Institute of Geological Sciences. The Time and Latitude Service results are now published as *Greenwich Time Report*, and the remainder of the material in a single series starting with *Royal Observatory Bulletin No.* 154.

The following publications have appeared during 1969, or were in an advanced stage of publication at the end of the year, in addition to the routine publications of the Nautical Almanac Office which are referred to in the corresponding section of this Report:

Anonymous publications:

*Royal Observatory Annals* No. 3. First Greenwich Catalogue of Stars for 1950·0.

*Cape Annals* Vol. XXII. Cape Photographic Catalogue for 1950·0 Zones −80° to −90°.

*Cape Annals* Vol. XXIII. Second Cape Catalogue for 1950·0.

*Royal Observatory Bulletins* No. 143. Time and Latitude Service 1966 Oct.–Dec.

*Royal Observatory Bulletins* No. 144. Photoheliographic Results 1961.

*Royal Observatory Bulletins* No. 146. Magnetic Results 1959, 1960, 1961 (Hartland).

*Royal Observatory Bulletins* No. 148. Time and Latitude Service 1967 Jan.–March.

*Royal Observatory Bulletins* No. 149. Time and Latitude Service 1967 Apr.–June.

*Royal Observatory Bulletins* No. 150. Time and Latitude Service 1967 July–Sept.

*Royal Observatory Bulletins* No. 151. Time and Latitude Service 1969 Oct.–Dec.

*Greenwich Time Report* 1968 January–March, April–June, July–September, October–December.

Observations made with the Danjon Astrolabe O.P.L. No. 11 at the Cape. *Mon. Notes astr. Soc. Sth. Afr.*, **28, 30, 42, 62.** 1969.

Other papers which have appeared in *Royal Observatory Bulletins* or elsewhere are listed below:

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