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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

(*Director, R.H.Stoy, C.B.E., H.M. Astronomer until 1968 November 20*)
(*Officer-in-Charge, A.W.J.Cousins from 1968 November 21*)

(Report for the year ending 1968 December 31)

ISAAC NEWTON TELESCOPE

Regular observing with the Isaac Newton Telescope started in March. For the greater part of the time, which has been marred by particularly unfavourable weather, the telescope has been used for spectroscopy at the Cassegrain focus, first with the Yapp spectrograph and, since August, with the new spectrograph which has been designed and built at Herstmonceux. Direct photography at the prime focus has also been carried out regularly, around new moon.

Reference to particular observing programmes will be found in various sections of this report.

STELLAR KINEMATICS AND DYNAMICS

Nearby stars

An extension and revision to Gliese's catalogue of nearby stars has been carried out. The new catalogue now in preparation includes stars within 25 parsecs of the Sun, in most cases with trigonometric parallaxes. The addition of 848 stars now brings the new catalogue to a total of 1763 stars. Analysis of the motions of the stars in the new catalogue has been made, employing parameters of 'box orbits' to describe the motions. A good correlation of box inclination and orbit eccentricities with age was found, as judged from the colour-magnitude diagrams for various groups.

Radial velocities

About 500 spectra were obtained with the Cassegrain spectrograph in Pretoria for the Cape general radial velocity programme. About half of these have been measured and 180 stars are now awaiting

publication. An investigation into the *d*-camera errors was carried out and published (**39**).

Most of the material for the supplement to the General Catalogue of Radial Velocities is now on cards and first proofs have been prepared up to 8^h of R.A.

Programmes to improve the quality of the radial velocities in Gliese's catalogue and its extension have been initiated on the Isaac Newton Telescope, using the Cassegrain spectrograph. Initially it has been necessary to establish the line wavelengths to be used for the measurement of radial velocity and to determine the accuracy and stability of the new spectrograph. This has been carried out for the 25 Å mm^{-1} and 60 Å mm^{-1} cameras, and typical values for the errors per plate are $\pm 1{\cdot}5$ km s^{-1} and ± 3 km s^{-1} respectively for the two cameras. Over 400 spectra for this programme were obtained in 1968.

The radial velocities and MKK spectral types obtained at Pretoria for 125 stars classified as A0 in the Henry Draper Catalogue, and appearing in the South Galactic Cap have been analysed. The increase in velocity dispersion with height above the plane was confirmed. A systematic trend in the mean *w*-velocities with height above the plane was found for the stars in the South Galactic Cap, a result not evident in the velocities of A0 stars in the North Galactic Cap.

Proper motions

The repetition of the Radcliffe proper motion plates on the northern Kapteyn Selected Areas, with the 26-in. refractor is now 25 per cent complete. The repetition of the Greenwich photometric series is virtually complete. Preliminary measurements of these latter plates show that relative proper motions with standard errors of between $\pm 0''{\cdot}001$ and $\pm 0''{\cdot}002$ p.a. will be attainable.

The old Radcliffe plates on the areas in the Systematic Plan and the Special Plan have been transferred to Herstmonceux on loan from the University of London Observatory.

Measurements of Oxford Zone astrographic plates in the North Galactic Pole region (project 'Pole Hole') has proceeded.

Stellar orbits

Computations of three dimensional stellar orbits, including perturbations by a gas cloud, have been carried out on the ICL 1909 Computer. It has been found that the change of box angle of the stellar orbit, after an encounter, is small unless the cloud itself moves in an inclined orbit. It is suggested that this mechanism can account for

some of the features of the statistics of the motions of nearby stars (42), (43).

Gould's Belt

An investigation has been carried out on the possible relationship between the structure of Gould's Belt and some characteristics of the local galactic magnetic field (6).

TRIGONOMETRICAL PARALLAXES

Cape

Observations have continued throughout the year, and sufficient plates have accumulated to enable measuring to be re-started. Proper motions in declination have now been measured for all the stars in the programme.

Herstmonceux

Observations with the 26-in. refractor have continued. Six stars which appear to be subluminous according to the data in Gliese's catalogue have been added to the programme.

The computer programme for monitoring the progress of observing has been completed. Data for all plates so far obtained have been transferred to punched cards.

STAR CLUSTERS

(i) *Globular clusters*

Colour–magnitude and two-colour diagrams have been obtained for the globular clusters NGC 6981 and NGC 7099. The horizontal branch of NGC 6981 occurs at $V = 16{\cdot}9$, with an approximately equal population each side of the variable gap. Provisional values of the reddening and ultra-violet excess are $E_{B-V} = 0{\cdot}07$ and $\delta_{U-B} = 0{\cdot}20$. NGC 7099 appears to be a very metal poor cluster. The horizontal branch which occurs at $V = 15{\cdot}5$ mag is heavily populated on the blue side. Using the provisional value of $E_{B-V} = 0{\cdot}10$, the distance of this cluster is about 9 kpc.

Light curves in U, B and V have been obtained for 22 variables in the metal-rich globular cluster NGC 6171. Very good correlation between period, amplitude and colour have been obtained. Preliminary analyses has shown quite a sharp separation in colour between variables and non-variable stars in the horizontal branch. There is also a complete separation in colour between *a* and *c* type variables, in marked contrast to variables in metal poor clusters such as ω Cen which show an overlap in colour between the two types of variable. The mean period–amplitude relationship for NGC 6171 occurs at considerably

shorter periods than that for variables in metal-poor clusters. NGC 6171 contains large amplitude variables with periods ~0·4 days and these probably represent the cluster counterparts of the short period large amplitude *a*-type variables previously only known to occur in the field.

A number of direct plates of the globular clusters M3 and M92 were obtained at the Cassegrain focus of the INT, in order to study the detailed structure of the giant branch region of their colour magnitude diagrams. Preliminrary photometry of the plates indicates a useful photometric field of about 15′, with a standard error of about $0^m{\cdot}03$ per plate.

In an attempt to improve the determination of the absolute proper motion of 47 Tuc, about 100 extra field stars have been measured on the four astrometric plates.

Relative proper motions for about 450 stars in NGC 6397, with $B < 15^m$, are being determined from measurement of plates taken with the Yale–Columbia 26-in. refractor.

(ii) *Galactic clusters*

The Thompson 26-in. refractor has been used to obtain improved *B*, *V* photometry in the three old clusters NGC 188, 2420 and 6939. All three clusters have a clump of red giants which appears to be equivalent to the horizontal branch of globular clusters. Comparison with theoretical models by Faulkner and Iben supports this interpretation. The new photometry, taken in conjunction with proper motion measurements, shows that two of these clusters, NGC 2420 and 6939 have a gap near the upper end of the main sequence, similar to the well-known gap in M67 (**5**).

An astrometric investigation of the group of stars near the centre of the LMC, which was first noted by Bok & Bok (*Mon. Not. R. astr. Soc.* (1960) **121,** 531) and which has recently been the subject of a photometric and spectroscopic investigation by Sanduleak & Davis Philip (*Astr. J., N.Y.* (1968) **73,** 566), has been started. This group happens to be very favourably situated on a number of Cape Astrographic plates taken in the years 1898 to 1960. Preliminary results from one plate pair indicate that most of the stars in the suspected group share a common proper motion.

New fundamental proper motions on the FK4 System for 19 stars in Praespe have been determined; the standard error of the results for individual stars range from $\pm 0''{\cdot}002$ to $\pm 0''{\cdot}004$, and the fundamental proper motion of the cluster is:

$$15\mu_a \cos\delta = -0''{\cdot}0355 \qquad \mu_a = -0''{\cdot}0164 \qquad \pm 0''{\cdot}0007 \text{ (s.e.)}.$$

Hyades

A computer programme for selecting possible members of the Hyades cluster and group from the direction of proper motion, has been devised. A list of some 50 possible candidates, brighter than $m_{pg} = 12$ but wihout known radial velocity, in the region of the cluster itself, has been selected from the proper motion surveys of Luyten, Giclas and van Altena. The same programme has been used to search the Radcliffe Catalogue of Proper Motions in the northern Selected Areas; all stars with relative proper motions greater than 0″·05 p.a. were tested and more than 60 possible candidates, whose spectra are given in BSD but without known radial velocity, were found.

VARIABLE STARS

The programme of photometry of RR Lyrae stars with the Cape Elizabeth Telescope has been completed, and light curves have been derived for about fifty stars.

The Cape 18-in. reflector has been used mainly for photoelectric observations of variable stars; others have been made with the 24-in. Victoria refractor. Light curves have been published for the eclipsing variables AU Pup and TZ Men, and for the cepheids V Car, U Car, IT Car and W Sgr (**8**)–(**10**). The eclipsing binaries δ Cir, HR 6283. BL Tel and DV Aqr were also observed, and a search amongst other suspected variables revealed three δ Scuti stars.

Orbits have been computed for the double-lined spectra of the eclipsing binaries TZ (31) Men and RS (9) Cha.

The regular visual observation of long period and irregular variables has been continued at the Cape.

The measurement of plates of variable stars in the Cape Astrographic Zone of the Groningen programme, was completed during the year, for the determination of proper motions. A few RR Lyrae variables were also measured. New proper motions for about 50 southern RR Lyraes have been determined.

Photoelectric photometry of RR Lyrae variables and possible red variables in galactic clusters has been continued, with the 36-in. Yapp reflector. Observations of a number of spectroscopic binaries have also been made with this telescope.

Observation of the first pulsar, CP 1919 were made with the Carnegie image tube on the 36-in. reflector. Special equipment to interrupt the light path at a multiple of the known period of variation was constructed. A number of direct plates of the field containing the pulsar were obtained with this equipment. Analysis for suspected variability

of an 18·5 magnitude object was carried out, but no variation greater than the 15 per cent error limit was detected.

A number of spectra at 3 Å mm^{-1}, of the δ Scuti variable HR 1706 were obtained with the Carnegie image tube at the coudé focus of the 30-in. reflector. A variation with an amplitude of 10 km s^{-1} with the known optical period was found. The standard error per plate was about ±1 km s^{-1} but with a more suitable choice of spectral region this could be substantially reduced.

Photographic curves in *B* are being obtained with the Astrographic telescope for the six Mira variables UZ Cem, WX Her, VX UMa, W Cam, AE Cep and U CVn. All these stars have unknown minima. A tentative hump and a flat minimum are suggested for UZ Cam and VX UMa respectively.

Semi-regular and RV Tauri variables

In addition to the meridian observations referred to in the last report, which are continuing, astrometric proper motions for about 160 of these stars are being determined from plates taken with the Astrographic telescope. Only stars which are brighter than $m_{pg} = 11$ at maximum and which appear within 40′ of the appropriate plate centre are being measured. About one-third of the list has already been measured in connection with the Groningen programme in the Greenwich and Oxford zones. First epoch plates for 18 stars in the Vatican zone have been kindly lent by Fr D.J.O'Connell. Proper motions for stars in the other northern zones will be derived by comparing modern plates with coordinates published in the volumes of the Astrographic Catalogue.

STELLAR ATMOSPHERES

Completion of a computerized differential curve-of-growth analysis of spectra of 12 F-type dwarfs taken with the 30-in. coudé at a dispersion of 10 Å mm^{-1} in the blue, gives values for the Fe/H ratio ranging from 1·5 to 0·45 times that of the Sun. Temperatures were determined from multi-colour photometry and shown to be consistent with photoelectric measurements of the strength of Hβ (**30**). Since the ages of these stars are between 0·5 and 2 times that of the Sun, the abundances are consistent with the conclusion of M.E.Dixon that the interstellar medium was fairly well mixed, with an Fe/H ratio of at least 0·5 times that of the Sun, after an initial burst of star formation. The abundances found are well correlated with ultra-violet excess and there is a tendency towards lower metal abundance among high-velocity stars (space motion exceeding 70 km s^{-1}). On the other hand there is no correlation with the weak and strong-line characteristics

found by Miss N.G.Roman in 1950. Comparison with B.Strömgren's Δm_1 index shows a scatter which is reduced by taking into account the effect of micro-turbulence predicted by P.S.Conti and A.J.Deutsch in 1967. Mn and V are found to be overdeficient compared with other metals when iron is deficient.

The strengths of CH lines in the spectrum of the extremely metal-deficient red giant HD 122563 have been re-examined to check the conclusion previously arrived at that carbon is overdeficient compared to metals. The results are rather ambiguous when interpreted by a simple curve-of-growth theory and they are being reinterpreted with the aid of model atmospheres. An analysis of the red giant HD 71377, identified by O.J.Eggen as a member of the ζ Herculis moving group, using plates taken at Mount Wilson, shows that the composition is the same as that of the Sun, within the uncertainties, and hence the same as that of ζ Her. However, in the light of present knowledge of abundances in stars of Population I, this cannot be regarded as a very sensitive test of group membership. To elucidate further the variations in metal abundance among Population I giants, a series of low-dispersion (62 Å mm^{-1}) spectrograms of stars in galactic clusters is being taken with the INT, using methods of analysis of the intensities of strong spectral lines developed by F.Spite and J.B.Alexander. This should enable an independent test to be made in particular, of the conclusion of H.Spinrad that the stars in M67 (among other old galactic clusters) are super-metal-rich.

The effect of metal-abundance on H and K emission widths is being examined, mainly on the basis of observational data. It is becoming clear that the use of the Wilson–Bappu relation underestimates the luminosities of mildly metal-deficient stars by about a magnitude, leading to serious underestimates of the mass when this is deduced either from visual binary orbits (as has been done for γ Leonis by O.C.Wilson) or from spectroscopic gravity determinations (as has been done for a group of red giants by H.L.Helfer and G.Wallerstein).

Published observations of the spectrum of η Carinae are being rediscussed in some detail, with a view to understanding some of the physical effects involved and obtaining data on the abundances of N, S, O and Fe. A comparison of relative intensities of [Fe II] lines at different wavelengths shows that the spectrum is heavily reddened with a colour excess $E_{B-V} = 1^{m}{\cdot}2$, about half of which is intrinsic and is presumably caused by a local dust cloud that is also responsible for the strong infra-red emission. When this reddening is allowed for, several observations that previously seemed anomalous appear to become more reasonable. The continuum no longer shows any resemblance to synchrotron radiation and can be satisfactorily accounted for by two-photon emission from hydrogen in the Zs state. The Balmer

decrement, and the ratios of corresponding Balmer and Paschen lines, are consistent with recombination theory for an optical depth of about 25 in Hα. The [N II] and [S II] lines yield nearly consistent estimates of electron density and abundance of N and S relative to H that are close to solar values, oxygen, however, still appears to be under-abundant. For iron a high degree of uncertainty exists because of the difficulty in calculating relative populations of the energy levels of such a complex atom as Fe II. The intrinsic nature of this remarkable object remains uncertain, but the ideas of intrinsic reddening and two-photon emission may have applications to other objects such as quasars and the nuclei of Seyfert galaxies.

Work is continuing on the derivation of hydrogen line profiles and line blanketing corrections for A and F type stars, using coudé spectra at 10 Å mm^{-1}, obtained with the 30-in. reflector.

EXTRA-GALACTIC STUDIES

Optical monitoring of quasars has continued, with the 26-in. refractor.

Proper motions have been measured in the fields of the two bright N galaxies, 3C 371 and 3C 390·3. These were both recorded on plates taken for the Greenwich Astrographic chart, and new plates were obtained during the year. Neither galaxy showed any significant proper motion; any short-term changes in position are less than 0″·3.

A programme of deep ultra-violet plates on radio sources in the Ryle–Neville north polar catalogue has been started on the Isaac Newton Telescope, at the prime focus.

The programme for measuring accurate astrometric positions of selected calibration sources for radio astronomy has continued. Plates on five objects which were difficult or impossible to observe with the 26-in. refractor were obtained with the Isaac Newton Telescope, at the prime focus. For this purpose the aperture was diaphragmed to 80-in. From comparison between different plates on the same fields it appears that the final position from the INT plates are good to an accuracy of about 0″·1, which is similar to that from the 26-in. plates.

THEORETICAL STUDIES

Theoretical work on galaxy and star formation led to the discovery of similarity solutions for spherical collapse in both the isothermal and pressureless cases, and confirmation of the runaway densities developed in condensation nuclei during gravitational collapse (**24**). It is hoped that these may help to explain star formation and galactic nuclei.

A general purpose Poisson solver for determining gravitational potential of axially symmetric matter distributions has been developed

and will be applied in a number of fields including model galaxy building.

A general method for analysing the stability of model galaxies has been developed. This will also be applicable to electrostatic instabilities of inhomogeneous plasmas.

A possible acceleration mechanism for the fast particles in radio sources was shown to give quite promising results.

PHOTOMETRY

The Elizabeth 40-in. telescope at the Cape was used exclusively for photoelectric photometry. In addition to the RR Lyrae programme, it was used to obtain *UBV* observations of 166 A-type stars in the south galactic cap and to continue with the general programme that includes a variety of stars, mainly between the seventh and twelfth magnitudes, for which photometric data are desired. A number of sub-dwarfs have been identified by *UBV* photometry. Some progress has also been made in setting up standards for the photometry of selected stars in a four-colour system similar to that of Strömgren and his associates.

The programme for obtaining V, $B-V$ and $(U-B)_c$ for all HR stars south of $-4°$ declination has been continued with the Cape Astrographic telescope and two further lists, containing 498 stars, have been published. Large parts of the sky have now been completely observed.

The photography of the $-40°$ to $-52°$ zone has been completed. Initial difficulties with the Askania iris photometer have been overcome and the measurement of the plates has started. The photometric quality of the photovisual plates is disappointing and a certain number may have to be repeated.

A computer programme has been used to investigate problems connected with atmospheric extinction, mirror tarnishing and the colour equations of various photometric systems that have been used at the Cape and elsewhere.

A number of guest astronomers have used the Cape telescopes, especially the Elizabeth reflector, for photoelectric photometry.

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.

Comparison between observations in Right Ascension made with and without the objective screen has indicated that the instrument is virtually free from coma. Declination observations on the other hand suggest a very small change in coma when the instrument is reversed, which may arise from flexure of the objective.

Mechanization of the differential and fundamental reduction processes has continued.

Cape. Observations for the Southern Reference Star (SRS) and Bright Star (BS) programmes have continued, but it has not been possible to complete the $-30°$ to $-40°$ zone as had been hoped, due to abnormal observing conditions. With the continued assistance of the U.S. Naval Observatory the reduction of the observations has been kept up to date.

Plans are being prepared for making the computational procedures of the Meridian Department at Herstmonceux, available for the reduction of the Cape Meridian observations.

Astrolabe observations

Cape. The programme has been extended beyond the original closing date of 1968 December 31 as there are still a number of stars requiring further observations; this is partly due to poor observing weather in 1968. Of the 1880 stars on the programme 86 per cent have received at least five observations each, and 60 per cent have received ten or more.

Photographic star positions

Cape. The photography of the sky from the equator to $-30°$ declination with the 'new' Taylor Hobson astrometric camera was started early in the year, in a programme of overlapping plates. About 1600 of the 2700 plates required have so far been obtained.

Measurements of the plates in the zone $-40°$ to $-52°$ has proceeded steadily. Only SRS stars are being measured for the preliminary investigations. The analysis is being carried out on the ICL 1909 computer at Herstmonceux and it is already apparent that a relative positional accuracy of better than $0''{\cdot}1$ (s.e.) for each star will be attainable.

Planets

At the Cape, the minor planet 433 Eros was photographed several times during its 1968 opposition, and 1566 Icarus was observed during June and July. The results of these observations have been published **(22)**, **(23)**.

At Herstmonceux, astrometric positions of Neptune and BD -17° 4388 were obtained in order to assist the Nautical Almanac Office in the prediction of the occultation on 1968 April 7.

Lunar occultations

49 observations of lunar occultation were made at the Cape, 6 of them photoelectrically.

Artificial satellites

Regular satellite tracking has been carried out at the Cape with the modified Askania Kinetheodolite, and the results have been sent to the World Data Centre at Slough. With a new film, Kodak 2475 satellites down to magnitude 7 can be recorded. During the year about 1500 satellite passes were tracked.

TIME AND LATITUDE SERVICE

The PZT continued in regular service throughout the year, and 101 plates with an average of 15 stars per plate were obtained. The decrease in the number of plates in comparison with the previous year is indicative of the exceptionally cloudy weather in 1968.

The PZT observations made in the years 1958–67 have been analysed to evaluate the errors in the relative positions adopted for the stars in 1957, using a chain-method. The results were found to be in close agreement with those obtained by comparisons between the Herstmonceux time and latitude results, and the 'Heure définitive' and the x coordinates of the pole, respectively, computed for the epoch of observation from the published results of the Bureau International de l'Heure. In addition, a correction of $+0''{\cdot}40$, deduced from transit circle observations and from comparisons between the PZT and astrolabe results, has been applied to the adopted declinations of all the stars.

Proper motions of 22 potential PZT stars have been computed by the Meridian Department.

The observations have been communicated weekly to the BIH and monthly to the IPMS.

The published results from 1968 January are based on the revised constant of aberration ($20''{\cdot}496$) and on the corrected star positions. Commencing with this year, the coordinates of the instantaneous pole are referred to the Mean Pole of 1900–05, now designated the Conventional International Origin (CIO). On 1968 January 1 the adopted longitude of the instrument was changed from $1^{m}21^{s}{\cdot}102$ E to $1^{m}21^{s}{\cdot}0785$ E following comparisons made by the BIH. Arising from these changes

there was a discontinuity in the time system such that UT2 (Herstmonceux) becomes earlier by 7 milli-seconds.

In 1968 a PZT was inaugurated near Calgary in Western Canada by the Dominion Observatory. This instrument is on the same latitude as the Herstmonceux PZT; the two instruments use the same observing programme, and the observatories work in close co-operation.

The rate of rotation of the Earth has remained at 2·4 ms day^{-1} losing relative to ephemeris time which is made currently available by atomic standards: there was, however, a rather sudden change towards the end of August which resulted in a loss of time of approximately 20 msecs, followed by a resumption of the former rate.

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 ms day^{-1}). The signals were advanced by 100 ms on 1968 Febreuary 1 and remained within 100 ms of UT2 throughout the period. The HF signals associated with GBR were discontinued from December 31, as their usefulness had decreased and many standard frequency emissions are now available as alternatives.

A third caesium beam atomic standard was installed in August and brought into operational use in November. The Greenwich atomic time scale, which commenced in 1955, is now based entirely on standards at Herstmonceux.

A new series of Circulars was inaugurated containing the daily readings of the relative phase difference between the Herstmonceux atomic standards and the received carriers of selected LF and VLF radio emissions. By using similar results published elsewhere, the atomic time scales of different establishments are compared. Using the additional information provided by travelling clock comparisons, coordination to an accuracy of about 10 μs has been maintained over a period of several months.

In addition to the comparisons made by means of the travelling clocks of the USNO, other organizations have utilized the facilities provided by the RGO to obtain a link with the USNO time system.

Progress in the replacement of obsolete equipment in the Herstmonceux Time Service has been slow but is continuing.

At the Cape, a 50-ft aerial has been erected, for receiving the 10 MHz time signals from Johannesburg. Good signals can now be obtained at any time of day.

THE SUN

At both Herstmonceux and the Cape, photographs of the Sun in white light have been taken on every possible day. At Herstmonceux this was possible on only 259 days owing to adverse weather conditions.

This is the poorest record obtained since the photoheliograph was moved from Greenwich in 1949.

The flare patrol with the Lyot Hα heliograph was continued at the Cape, and the films sent to Professor C.W.Allen at the University of London. Photographs of the disk and limb features, in Hα, were also obtained at Herstmonceux.

Current information is widely distributed by monthly Circulars.

Unless unexpected activity occurs in the near future, it would appear that the maximum phase of the present solar cycle fell in the first half of 1968, and that the level of activity did not exceed 60 per cent of that recorded during the previous maximum.

INSTRUMENTATION

Isaac Newton Telescope

Hartmann diaphragm tests of the figure of the telescope primary mirror have been taken on the telescope at a time when the glass should have been in good thermal equilibrium. Results show that 80 per cent of the light falls within a circle of 1 arc sec diameter. The primary mirror was re-aluminized in early October.

Cassegrain spectrograph

The spectrograph was mounted on the telescope in August and has been in use during each Cassegrain period of observing since that date. The 10-cm diameter collimator is used with two cameras of 31·6 and 13·3 cm focal length. The linear dispersions available are 12·5, 25, 60 and 180 Å mm^{-1} in spectral region 3200–5000 Å and 25 and 60 Å mm^{-1} in the red region.

Optics for the 360Å mm^{-1} camera have been received.

An integrating exposure meter and stabilized power supply for a spectral source have been constructed for use with this instrument.

A provisional spectrograph of Fastie–Ebert form has been set up to provide photographic calibration when the Cassegrain instrument is used for photometry.

Coudé spectrograph

Thermograph recording has been installed in the INT dome with the primary object of monitoring the conditions in the coudé instrument room. The essential optical components for the coudé spectrograph have been received from the manufacturers and are under test. These comprise the 340 cm focal length *f*/2·6 spherical mirror, the 20 cm aperture collimator and flat, also the 1200 lines/mm grating blazed in the first order for 8000 Å.

Construction work on the camera frame and coudé laboratory is about to start.

Television field relay

An experiment using a television system incorporating the English Electric Image Isocon camera tube to relay the field of the finder telescope to the control console proved so successful that an order has been placed with Marconi Instrument Ltd for this equipment which is expected to be in use in January 1969.

Image intensifiers

Further tests with the McGee Spectracon tube show improved resolution now at 80 l.p. and higher sensitivity with the S.11. photocathode. The first S.20. photocathode tube was tested and found to have good background. At present residual field distortion remains to be improved.

Parts of the unit construction spectrograph for image tubes are in manufacture in the R.G.O. engineering department. The optical components of two *f*/2·2 cameras have been received and tests are nearing completion. Results to date show good agreement with the optical design.

Light sensitive charge storage device

A small four turret vacuum plant is now in use to coat experimental surfaces for this project. A single coordinate measuring machine has been mounted in a cooled air conditioned chamber. Tests have commenced on surfaces which can be exposed and read without removal from the chamber.

A preliminary investigation into the possible application of grain counting techniques for electronography suggest that for the particular combination of the Spectracon and G5 nuclear emulsion the method shows little advantage over that obtained from a conventional null balance microphotometer with a good performance in the low density region.

Photometers

A single channel pulse counting photometer has been constructed and is in use with the Yapp 36-in. reflector.

A general design study and specification contract for the photometer heads and their mechanical mounting, for a two channel photometer has been completed. Detailed manufacturing drawings are now in preparation. The electronic parts of this instrument are nearing completion.

NERC

An experimental rubidium vector magnetometer was assembled and installed at Hartland, under an agreement with NERC for continued technical support to the Magnetic Department.

H.M. NAUTICAL ALMANAC OFFICE

The Office has continued its three principal activities in the preparation of ephemerides for astronomical and surveying use, 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 1969; *The Nautical Almanac* for 1969; *The Air Almanac* for May 1968 to April 1969 (three parts); *The Star Almanac for Land Surveyors* for 1969. The advanced proofs of the first part of *The Astronomical Ephemeris* for 1972 are still not in a form suitable for distribution (normally about 80 copies are sent to most countries), but copies of the data have been made available to meet all urgent requirements.

Some 'teething' troubles, mainly due to faults in conversion equipment not under the control of the Office, have seriously delayed the completion of the automatic film-setting of the ephemerides for 1972; it is disappointing that the considerable, and fully successful effort devoted to writing the many complicated and detailed programmes for the ICL 1909 computer should have been so frustrated. However, the results demonstrate the practicability, versatility and accuracy of the method; and improved conversion equipment should enable full use to be made of it in the future.

In addition, many special predictions and ephemerides have been prepared and distributed. The major service has been the continuously expanding programme of occultation predictions for both optical (stars) and radio sources; there is ample evidence of the increasing use made of these predictions. However, the weekly service of look-data predictions for visual and kinetheodolite observations of artificial satellites has been discontinued, and handed over to Radio and Space Research Station early in the year. A special ephemeris giving the coordinates of the Earth with respect to the centre of mass of the solar system was supplied to Jodrell Bank for use in connection with determination of the changes in period of pulsars.

Volume 1 (for epoch 1970.0) of *Sight Reduction Tables for Air Navigation*, AP 3270, containing the tabulations for selected stars, was published during the year. However, progress with the new *Sight*

Reduction Tables for Marine Navigation has been disappointingly slow; the Office spent a considerable amount of time and effort on the introduction of Volume 6, with detailed analyses of methods of interpolation and their associated accuracies, but no proofs are yet available from the U.S. Government Printing Office. Several minor investigations have been made into navigational techniques, particularly in respect of star identification with periscopic sextants.

The booklet *Man is Not Lost* (**35**), originally written hurriedly in November 1966 for association with the exhibition of the same name, was eventually published by H.M. Stationery Office for the National Maritime Museum towards the end of the year. The exhibition itself, already extended by one year, is being kept open, in a slightly modified form, more or less indefinitely.

Astronomical research activities

The most encouraging event during the year has been the completion, in final form, of the reduction of the 10 000 occultations of stars by the Moon in the years 1960–66, and of the preliminary analysis of the results. Although only a small portion of the total material has thus been discussed, the results indicate that the observations themselves are of a high standard and that they are capable of providing accurate information about Ephemeris Time, the elements of the Moon's orbit and of indicating small discrepancies in the adopted theory of the motion of the Moon: in fact, the presence of a small error in latitude (of amplitude 0″·035, recently found in the *Improved Lunar Ephemeris*) was confirmed by the analysis. The most important result is to rule out the possibility of large errors in the adopted values of the motions of the node and perigee.

A new catalogue of the positions of 512 discrete radio sources, to be used in the prediction of occultations, has been compiled from the recent extensive literature on the subject. The Office continues to aid radio astronomers by calculating precise positions of radio sources from their times of occultation.

The main obstacle to a more rapid handling of the occultation observations is the accurate determination of limb corrections from Watts' charts, at present a tricky and time-consuming process. Some progress has been made towards mechanizing the process by representing the charts in digital form, and programming the ICL 1909 computer to do all the necessary interpolations. All the programmes are written and 350 of the 1800 charts have been successfully digitized with the help and co-operation of the staff of the Royal Armament Research and Development Establishment at Sevenoaks, which possesses a curve-following machine. However, the curve-following (done by hand) is held up at present by shortage of staff.

The preliminary work on the revision of the planetary perturbations of the Moon has been continued; the basic reference orbits of the Sun, Moon and planets are now available, and the high-accuracy numerical integrations of the orbits of the Earth and Moon are about to be started. No further progress has been made with the analytical developments.

A review of the theories of the origin and evolution of the satellites of Mars was prepared (**41**) and numerical investigations of the effects of tidal friction on satellite systems was started, but has had to be left in abeyance owing to the shortage of staff.

Investigations into the orbits of several spectroscopic binaries has been carried out, in co-operation with Dr Thackeray, and a series of comprehensive computer programmes for the analysis of the observed radial velocities and the determination of the period and orbital elements are now available.

Arising from the routine predictions of planetary occultations, special predictions for an occultation of a star by Neptune on 1968 April 7 were distributed, resulting in a series of photoelectric observations from Australia, New Zealand and Japan. A preliminary analysis of the observations has given an improved determination of the diameter of Neptune (**37**).

Although hardly 'research', much effort has been devoted to a series of studies connected with the specification of UTC (Coordinated Universal Time); the Office has a responsibility for ensuring that the requirements of astronomers, navigators and surveyors are considered together with those—often contradictory—of the physicists and technologists.

Computer service

The ICL 1909 computer has continued to be used for the reduction of observations, for calculations required to produce *The Astronomical Ephemeris* and other publications, and by the research departments of the Observatory. No enhancements were made to the computer during 1968, but the multi-programming facilities were much more fully used. It has continued to be reliable with an average serviceability ratio of 0·96. With single-shift working the amount of useful computing time (i.e. excluding time lost for faults and all hardware and software maintenance) has been 31 hours a week, of which about 27 per cent has been for N.A.O. work, 49 per cent for the rest of the Observatory and about 24 per cent for external users (Ministry of Defence and National Environment Research Council). The Computer Section has continued to provide a programming advisory service and a data preparation and punching service for all users.

SITE-TESTING

The University of Riyadh has sought advice from the Science Research Council on the practicability of building a large optical telescope in Saudi Arabia. A small international advisory panel chaired by the Astronomer Royal met at Herstmonceux in February and at Riyadh in April. On its advice an expedition led by the Astronomer Royal set up in November a portable 12-in. Cassegrain reflector in the mountains some 25 miles west of Riyadh to test the seeing at the site by observing double stars. Encouraging results were obtained, and it is proposed to repeat the tests to cover other seasons of the year.

By agreement with the Jesuit authorities in Spain, the Observatory has been allotted time at the new Sierra Nevada outstation of the Cartuja Observatory, Granada, for an initial period of three years. In April a preliminary visit from a small party led by the Astronomer Royal established what needed to be done to bring the 12-in. reflector on site into use, and a further expedition in October began observations. Photometric, double-star and meteorological observations will be made to establish whether the site is suitable for a bigger telescope.

In South Africa, three places near Sutherland in the Cape Karroo have been investigated as possible sites for re-locating the 40-in. reflector and perhaps other telescopes. Photographic seeing tests with a double beam instrument indicate that the mode of the standard deviation of the relative image motion at the zenith is about $0''{\cdot}2$.

GENERAL

A new Physics Department is being set up at Herstmonceux under the direction of Dr D.McMullan to develop more sensitive image sensors than are at present available for astronomical use.

The Herstmonceux Annual Conference was held at the Castle on April 18–19, the main topic being 'The Evolution of Galaxies'.

Ten members of the Herstmonceux staff have been awarded the degree of M.Sc. in astronomy by the University of Sussex during the year.

Dr D.S.Evans, Chief Assistant at the Cape Observatory, resigned his position in September to take up a chair in astronomy in the University of Texas.

Dr R.H.Stoy, H.M. Astronomer at the Cape, resigned his directorship there to become Deputy Director of the Royal Observatory, Edinburgh, in December. Mr G.A.Harding has been appointed officer-in-charge of the Cape Observatory as from the end of the report year.

A start has been made on the microfilming of Royal Greenwich Observatory archives by the Public Record Office. The papers and observation books of the first four Astronomers Royal (1675–1765) have been completed.

PUBLICATIONS

The following publications have appeared during the period under review, or were in an advanced stage of publication at the end of 1968, in addition to the routine publications of the Nautical Almanac Office which are referred to in the corresponding section of this Report:

Royal Observatory Bulletins Nos 142–145, No. 143 (Time and Latitude Service) and No. 144 (Photoheliographic Results 1961) were published anonymously. Other papers, which have appeared in *R. Obs. Bull.* or elsewhere, are listed below:

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(2) Alexander, J.B., 1968. On the helium abundance of young objects in the Galaxy, *Observatory*, **88**, 118.
(3) Blackwell, K.C. & Lowne, C.M., 1968. Proper motions on the system of the FK4, I. 182 Semi-regular and RV Tauri variables, *R. Obs. Bull.*, No. 142.
(4) Cannon, R.D., Penston, M.V. & Penston, M.J., 1968. 3C 390·3, a second variable N-galaxy, *Nature, Lond.*, **217**, 340.
(5) Cannon, R.D., 1968. Intermediate age star clusters, Ph.D. Thesis, Cambridge University.
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(7) Corben, P.M. & Stoy, R.H., 1968. Photoelectric magnitudes and colours for bright southern stars, *Mon. Notes astr. Soc. sth Afr.*, **27**, 11.
(8) Cousins, A.W.J., 1968. Visual observations of V Carinae and T Velorum. *Mon. Notes astr. Soc. sth. Afr.*, **27**, 71.
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(10) Cousins, A.W.J., 1968. *UBV* Photometry of cepheid variables, *Mon. Notes astr. Soc. sth. Afr.*, **27**, 138.
(11) Dickens, R.J., 1968. The observed effects of axial rotation on the pulsation of Delta Scuti variables, *Astrophys. Lett.*, **1**, 213.
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(16) Gough, D.O. & Lynden-Bell, D., 1968. Vorticity expulsion by turbulence: astrophysical implications of an Alka-Seltzer experiment, *J. fluid Mech.*, **32**, 437.
(17) Harding, G.A., Palmer, D.R. & Pope, J.D., 1968. Radial velocity observations of standard stars with the 30-in. coudé spectrograph, *R. Obs. Bull.*, No. 145.
(18) Hewitt, A.V., Milsom, A.S. & Standen, P.R. 1968. The radial velocity curve of VZ Cancri, *Observatory*, **88**, 262.
(19) Lambert, D.L. & Pagel, B.E.J., 1968. The dissociation equilibrium of H^- in stellar atmosphere, *Mon. Not. R. astr. Soc.*, **141**, 299.

(20) Lagerweij, H.C., 1968. Three-colour observations of 31 Mensae (HR 2059), *Mon. Notes, astr. Soc. sth. Afr.*, **27**, 17.
(21) Laurie, P.S. & Leaton, B.R., 1968. Solar activity and geomagnetic storms 1967, *Observatory*, **88**, 235.
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(33) Sadler, D.H., 1968. Presidential Addresses on the Society's Awards, *Q. Jl R. astr. Soc.*, **9**, 271.
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