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, Professor R. H. Stoy, C.B.E., H.M. Astronomer*)

(Report for the 15 months ending 1966 June 30)

GENERAL

On 1965 April 1, administrative control of the Royal Greenwich and Cape Observatories passed from the Ministry of Defence (Navy) to the newly established Science Research Council. During the year, arrangements were made for co-operation with the University of Sussex in research and teaching, and certain members of the staff began to give lecture courses at the University for the newly established M.Sc. degree in astronomy. On the instrumental side, much time and effort were devoted to advance planning for two major items of equipment to be installed at Herstmonceux: the ICT 1909 computer which arrived in 1966 May, and the 98 in. Isaac Newton Telescope which is to be completed in the near future.

THE GLOBULAR CLUSTER ω CENTAURI

A detailed account of the work done on this globular cluster has been published in No. 2 of the *Royal Observatory Annals*. This account contains values of B and V for 6666 stars and proper motions for 4525 of these stars, together with their rectangular coordinates in the cluster. Three discussions of the data have already appeared in the *Royal Observatory Bulletins*, namely No. 99 (Radial Velocities of Bright Members), No. 100 (Proper Motions) and No. 101 (Photometry of RR Lyrae Variables). A further Bulletin dealing with the structure of the cluster compared with the theory of its equilibrium will appear shortly.

STELLAR KINEMATICS AND DYNAMICS

1. *Co-operation with Helwan Observatory*

By arrangement with the Director of the Helwan Observatory, Professor A. Samaha, an observational programme of radial-velocity

determinations with the 74 in. telescope at Kottamia has been drawn up for operation by both Greenwich and Helwan personnel. Up to date six expeditions have gone out from Greenwich and more than 1000 spectra secured by Greenwich observers. The programmes included observations of faint stars (9^m to 10^m) chosen for their relevance to the dynamics of the galaxy; observations of RR Lyrae variable stars; and observations of semi-regular variable stars. The first work on RR Lyrae stars is contained in *R. Obs. Bull.* No. 114, which gives mean velocities for 16 stars and mean curves relating velocity to phase. It is confirmed that the velocity amplitude measured from hydrogen lines exceeds that from metal lines (where the amplitude itself is large) and it is found that good agreement between the hydrogen and metal line mean velocities is obtained if Petrie's wavelengths are discarded in favour of Rowland wavelengths.

2. *Velocities of A0 stars in the galactic cap*

As the result of observations of radial velocities of 9th magnitude stars made at Kottamia it is found that the velocity dispersion of A0 stars in the galactic cap does increase with increasing distance from the galactic plane. This result is contrary to earlier analyses but appears to be quite definite. Work is continuing and a detailed analysis will be published later, but a revision of some earlier theoretical work, making use of the new recognition of the increase of dispersion, and making use of the 1909 computer, indicates that the density in the solar neighbourhood is $0{\cdot}10 \pm 0{\cdot}015$ solar masses per cubic parsec (against $0{\cdot}15 \odot\ pc^{-3}$ found earlier). The smaller figure is but little in excess of the estimate of known matter in the solar neighbourhood.

3. *A stars*

Reductions of the determination of radial velocities of 633 A stars with the old 36 in. one-prism Cassegrain spectrograph have been completed and prepared for publication.

4. *Cape radial-velocity programme*

Since the stars included in the Cape programme because of large parallax or proper motion have now mostly been observed, more of the time on the Radcliffe reflector at the disposal of the Cape Observatory has been concentrated on spectroscopic binaries and RR Lyrae stars. New radial velocities, MK types, etc., for 200 stars have been published in *R. Obs. Bull.* No. 110 and a paper giving orbits of 9 spectroscopic binaries awaits publication. The preparation of a supplement to the *General Catalogue of Radial Velocities* has been continued, and the data for nearly 5000 stars entered on cards.

5. *Proper motions in star cluster fields*

Studies of stellar proper motions in the fields of clusters have been continued in the following areas:

(i) *M*67. A region 1°×1° centred 18′ W of the cluster shows a few bright red giants, which are probably members, over 25′ from the centre. Main-sequence members, extending to at least 40′ from the cluster, show the well-known gap of $0^m{\cdot}25$ below the turn-off point.

Luminosity and population characteristics of the field stars have been deduced from proper-motion dispersions. A kinematic frame of reference, independent of assumed solar apex or parallactic motion, has been set up. Referred to this, the cluster proper motion is

$$\mu_\alpha = -0''{\cdot}0094 \pm 0''{\cdot}0008 \text{ (s.e.)}$$
$$\mu_\delta = -0''{\cdot}0070 \pm 0''{\cdot}0023.$$

(ii) *Other clusters:* 47 *Tucanae*, *NGC* 2168, *NGC* 752, *NGC* 7789, *NGC* 6522. Proper motions in the fields of NGC 752 and 7789 have been measured on Mount Wilson 60 in. plates and of 6522 on 100 in. plates. Analyses of 752 and 6522 have been completed. In NGC 752, the main sequence cuts off at $m_v = 14$, two magnitudes above the plate limit; the membership of the blue 'upper main sequence' star is confirmed. In the NGC 6522 field it has proved possible to identify red giants in the galactic nucleus which have been used to define the origin of the proper motion system in the field.

6. *Gould Belt*

A simple model of the Gould Belt has been developed and the radial velocities of B stars therein have been analysed to reveal a motion equivalent to that of the Pleiades group, together with an overall expansion in the direction of the galactic centre.

7. *RR Lyrae stars*

Measurement, and reduction to an absolute system, of the proper motions of RR Lyrae variables have continued, and about 110 northern stars have now had absolute motions determined. This work is being extended to the southern hemisphere either by comparing second-epoch plates from the Cape with published positions in the *Astrographic Catalogue* or (in a few cases) by the use of plate pairs kindly lent by the Director of Sydney Observatory.

8. *Selected Areas*

Plates taken with the 26 in. refractor before 1920 for photometric studies, chiefly in Kapteyn Selected Areas, are being repeated now in order to derive proper motions down to $B \simeq 14^m$.

Investigations are being carried out to see whether it will be possible to obtain good proper motions by comparing new plates taken with the 26 in. refractor with old plates taken with the Radcliffe refractor, now at Mill Hill. The old Radcliffe plates, together with some new ones in S.A. 57, taken by courtesy of Professor C. W. Allen, are being compared at Herstmonceux with recent plates from the 26 in. refractor.

TRIGONOMETRIC PARALLAXES

1. *Cape*

Just over 400 plates were taken with the Victoria refractor for the stellar parallax programme which is now confined to stars thought to be within 20 parsecs and which have no, or only one, previous parallax determination and to stars on Parenago's list south of $-20°$. Over 1000 plates were measured, or remeasured, and parallaxes were deduced for 25 stars, the reductions being done on the ICT 1301 computer of the University of Cape Town.

2. *Herstmonceux*

The stellar parallax programme has been shortened by the exclusion of stars for which spectroscopic or other evidence suggests that the values will be small.

First-epoch plates of faint stars with annual proper motion exceeding 1″ which appear from time to time in the lists of Luyten and Giclas are being secured with the 26 in. refractor; it is hoped to measure parallaxes for these stars using the prime focus of the Isaac Newton Telescope.

ABUNDANCES IN STELLAR ATMOSPHERES

1. *Ageing effects in stars of the galactic halo*

The possibility that different elements were supplied to the interstellar medium at different rates during the early history of the Galaxy leads one to expect that some stars of the halo population may have differences in detailed composition superimposed on a general shortage of heavy elements in comparison with the Sun. As was pointed out earlier in connection with the red giant HD 122563, which is the most metal-deficient star known, such 'ageing effects' can only be measured by the differential curve-of-growth method if one takes into account the multiple character of the solar curve of growth for Fe I which arises from the parity-dependence of solar collisional damping parameters originally discovered by W. W. Carter in 1949. The re-analysis of 122563, taking this and other effects into account, has been completed and similar re-

analyses have been carried out for the red giant Barnard III-13 in the globular cluster M92 and for a field red giant with retrograde galactic orbit HDE 232078 using observations published by Helfer, Wallerstein & Greenstein in 1959. The cool subdwarf HD 25329 has been analysed on the basis of original plates kindly supplied by E. M. Burbidge and J. L. Greenstein.

The results for the four stars provide a preliminary picture of the trend in [M/Fe] with [Fe/H], where M represents some metal or C or N and square brackets denote the logarithm of any quantity in the star minus the logarithm of the same quantity in the Sun. The greatest peculiarities in [M/Fe] are shown by 122563 with [Fe/H] $\simeq -2{\cdot}6$, for which vanadium, barium and cerium are deficient relative to iron by factors between 4 and 10, although other metals (except perhaps Mn) are normal. M92, with [Fe/H] $\simeq -2{\cdot}3$, shows the Ba–Ce deficiency to a smaller extent, whereas HDE 232078 and HD 25329, with [Fe/H] $\simeq -1{\cdot}8$ and $-1{\cdot}3$ respectively, have roughly normal ratios relative to iron of all metals measurable except Mn. Furthermore, C and N are nearly normal relative to Fe in the last two stars.

These results suggest the following conclusions:

1. The halo stars with the lowest metal abundances are the oldest, in accordance with the suggestion by M. E. Dixon that the interstellar medium was well mixed during the halo phase at the beginning of the history of the Galaxy (though not during the subsequent disk phase).

2. All elements were supplied to the medium by stars or other objects having masses of at least 10 $\odot$, so that their abundances were able to 'catch up' with that of iron in the brief period of a few times 10^8 years during which the halo phase is believed to have lasted.

3. Elements up to Zr (on the first 'magic-number' peak of the cosmic abundance curve, corresponding to synthesis by slow neutron captures) were formed very rapidly in still more massive objects, whereas Ba and Ce (on the second magic-number peak) made their appearance more slowly through the activity of objects resembling the CH stars, but having a larger mass in accordance with 2. The underabundances of Ba and Ce in 122563 and M92 form a 'mirror image' of the overabundances of the same metals found by Wallerstein and Greenstein in two CH stars.

4. The behaviour of V and Mn reflects variations in the conditions of equilibrium under which elements of the iron group were synthesized, presumably as a result of variations in the mass distribution of supernovae. The almost universal shortage of Mn in metal-deficient stars could be due to variations in R, the total proton : neutron ratio, resulting from different time scales for neutrino emission. However, [Mn/Fe] does not go on decreasing steadily as [Fe/H] decreases.

2. *Detailed analyses of nearby stars*

Abundances have been determined for α Centauri A and the mild subdwarf μ Cas, using material supplied by T. Dunham, Jr from Mount Stromlo and by J. L. Greenstein from Palomar Mountain, respectively. The resulting metal abundances are [Fe/H] = +0·15 for α Cen A and −0·60 for μ Cas, with an estimated uncertainty of ±0·10. μ Cas, which belongs to the 'α-rich' group discovered by Wallerstein, is of particular interest because it is a visual and astrometric binary for which it may be possible to derive the helium abundance when the orbit is sufficiently improved.

An abundance analysis of Arcturus has been carried out by Miss R. E. M. Gasson, using material secured by Dr R. F. Griffin, under the supervision of B. E. J. Pagel. Metals are deficient by a factor of 2 or 3, but a study of forbidden lines of [OI] and [Fe II] indicates that O/H is about the same as in the Sun and that the discrepancy found by J. P. Swings between the solar abundances of iron derived from Fe I and [Fe II] is reproduced in the spectrum of Arcturus.

Twelve F stars (including several of Miss Roman's 'weak' and 'strong' line groups) are being observed at 10 Å/mm in the blue, using the 30 in. coudé spectrograph, with a view to curve-of-growth analysis which will be carried out using the new ICT 1909 computer.

Equivalent widths are also being measured in the spectra of stars of various types at the request of Dr G. Cayrel-de Strobel with a view to investigating systematic differences between observers.

3. *Low-dispersion abundance studies*

Abundance studies using 80 Å/mm spectra from the 36 in. Cassegrain spectrograph have been calibrated by a careful re-analysis of the data for 18 G dwarfs published by Wallerstein. The agreement with Wallerstein's values of [Fe/H] is good except in the case of his three stars in the Hyades, which now turn out to have [Fe/H] between +0·2 and +0·3. It appears that, for most G dwarfs in the solar neighbourhood, the ultra-violet excess does not depend to any large extent on factors other than chemical composition, effective temperature and surface gravity.

The 80 Å/mm plates have been used to derive a parameter x which measures the strength of Hδ relative to Fe I λ4045 and λ4143. For G dwarfs, x is well correlated with $B-V$ (uncorrected for line-blanketing effects). Observations of solar-system objects thus lead to a value of $B-V$ for the Sun, which is $0^m{\cdot}663 \pm 0^m{\cdot}008$. The small scatter in the relationship between x and $B-V$ confirms the conclusion derived from the ultra-violet excess that the degree of line-blanketing is fixed by composition, temperature and gravity.

Measurements of the λ3800 CN feature in G and K dwarfs indicate that, although its strength is correlated with [Fe/H], the product of the C and N abundances is not uniquely fixed by iron abundance. In particular, CN has about the same strength in the Sun and in Hyades stars of the same colour. CN strengths have been observed in some visual binaries for which masses have been determined; preliminary results show little correlation with the position of the star in the mass–luminosity diagram. If present-day models of stars are correct, this would imply that stars of moderate metal deficiency have about the same helium content as the Sun.

STELLAR CLASSIFICATION

In the course of the A-star radial-velocity programme, 25 stars were newly classified as metallic-line stars.

The hypothesis that peculiar A stars are rapidly rotating stars seen pole-on has been tested quantitatively and found to be in conflict with observation. Some 500 plates of 12 Ap stars have been taken using the 36 in. Cassegrain grating spectrograph with a view to looking for variations in radial velocity. While variations are suspected in many cases, no periodicity has been found.

Spectra have been secured at 40 Å/mm for all northern A-stars brighter than 6^m that are known to be spectroscopic binaries with period under 10 days. Each star in this sample having spectral type later than A3 appears to be a metallic-line star, but among the stars earlier than A3 all varieties of normal and peculiar stars are represented.

Following a suggestion by Professor O. J. Eggen, a few F stars which appeared likely to be δ Scuti variables were observed for possible radial-velocity variation. Positive results were obtained at Herstmonceux for HR 4715, with period $0^d{\cdot}1707$, and at Pretoria for HR 1653, period $0^d{\cdot}141717$.

PHOTOMETRY

1. *Cape*

The general programme of photoelectric photometry of stars of astrophysical interest has been transferred from the Victoria to the 40 in. Elizabeth telescope. The three-colour observations of all HR stars between $-4°$ and $-64°$ have been continued with the Astrographic refractor, while similar observations of the HR stars between $\pm 10°$ with the 18 in. reflector have been completed. As is usual, provisional results

have been published in *Mon. Notes astr. Soc. Sth Afr.* (1965) **24,** 29, 41, 120, 122; (1966) **25,** 44. Much time and effort has been devoted to a critical examination of various series of published and unpublished magnitudes prior to incorporating them into a standard catalogue. (*Observatory* (1966) **86,** 69; *Mon. Notes astr. Soc. Sth Afr.* (1965) **24,** 160.) The results of the First (Fabry) Bright Star Programme giving magnitudes for over 900 of the brightest southern stars have been written up for publication as a *Royal Observatory Bulletin.* A mimeogram edition has been circulated to those likely to be interested. An appendix gives all precision observations of bright variable stars made at the Cape prior to 1966.

There has been steady progress with the photography of the zone between $-40°$ and $-52°$ with the photometric cameras. The aim of this programme is to produce photographic and photovisual magnitudes for the 40 000 stars for which proper motions are given in the *Cape Astrographic Catalogues.* These magnitudes should be comparable with those given in the *Cape Photographic Catalogue* for 1950·0. Comparisons with photoelectric observations indicate that these are reliable and of a gratifyingly consistent standard. The photometric plates will be measured with the new Becker iris-diaphragm photometer which, after many delays, arrived at the Cape in 1966 June.

A four-colour narrow-band photometer has been tried experimentally with the Radcliffe reflector. Its object is to find a sensitive method for sorting RR Lyrae stars, δ Scuti stars and dwarf cepheids into homogeneous population groups.

The regular visual observation at five-day intervals of 173 long-period variables and 2 flare stars has continued. Photoelectric observations of selected RR Lyrae stars have been made with the Elizabeth telescope. δ Pic, BL Tel, 31 Men, 9 Cha and HR 8024 have been observed with the 18 in. reflector and a number of eclipsing variables with the Victoria telescope. A paper on δ Pictoris was communicated to the Society (*Mon. Not. R. astr. Soc.* (1966) **131,** 443) and preliminary notes on some of the others have appeared in *Mon. Notes astr. Soc. Sth Afr.* (1965) **24,** 27, 72; (1966) **25,** 40.

2. *Herstmonceux*

The 26 in. and 13 in. refractors have been used in conjunction with the spectrographs at Herstmonceux to derive simultaneous light and velocity curves for long-period variables, using photographic photometry.

Selected regions of the northern sky are being searched for new variables by 'blink' comparison of plates taken with the 6 in. Franklin Adams wide-angle camera now installed in Dome C.

POSITIONAL ASTRONOMY

1. *Herstmonceux*

The Cooke transit circle at Herstmonceux has been engaged in a programme of observing stars having good radial velocities in the *General Catalogue of Radial Velocities*, but poor proper motions.

The graduation errors of the 'primary divisions' (0°, 20°, 40°, etc.) of the circle were determined photographically, and the results found to be in good agreement with the values adopted on the basis of visual measurements made in 1936–1940.

The errors of the pivots were determined using the autocollimator method. A new telescope and rigid support were specially constructed for this purpose, and gave very satisfactory results, which agreed well with the values adopted from the previous determination in 1948.

Revised proper motions, in the system of the FK4, for 182 semi-regular and RV Tau variable stars are being prepared for publication in the *Royal Observatory Bulletin* series. The paper includes all the basic data necessary for further revision (by a least-squares method) in the future as new observational material becomes available. From these variable stars, 44 were selected as being in particular need of positional observation at a current epoch, and were made the subject of an experimental programme of differential observations, relating the variable stars directly to groups of six FK4 stars adjacent to them in the sky.

A new computer (ICT. 1909) was brought into service in 1966 May, and the main effort of the meridian department is being directed to the preparation of computer programmes for the routine reductions so that these can be brought up to date.

The definitive investigation of the Herstmonceux instrumental system, 1957–1961, is in progress. This will be based on over 21 700 observations of FK4 stars made here during the AGK3R programme.

2. *Cape*

The Gill transit circle has been used for the international SRS project, the bright star list being observed till the beginning of March and thereafter the faint stars in the zone between $-30°$ and $-40°$. The reductions of the observations of the faint stars in the $-40°$ to $-52°$ zone have been completed and a provisional catalogue giving the places of these stars on the FK4 system has been prepared and circulated in mimeogram form to those known to be interested. It will be used in the reduction of plates that were taken with the astrometric camera concurrently with the meridian observations. A similar set of plates covering the $-30°$ to $-40°$ zone is now being taken with this camera.

The Danjon astrolabe, formerly at Herstmonceux, was transferred to the Cape and brought into operation in 1965 March. Since then it has been used continuously at a rate of five scheduled watches per week. This programme, of which the principal purpose is the improvement of the fundamental system, consists of all suitable FK4 and SRS stars between declinations $-4°$ and $-64°$ and brighter than magnitude 5·9, a little over 1100 stars in all. The observations are being reduced with the Herstmonceux ICT 1909 computer and it is intended to publish monthly the provisional values of the resulting clock and latitude corrections. Those up to the end of 1966 June are given in *Mon. Notes astr. Soc. Sth Afr.* (1966) **25,** 115. The results from the first few months of observing indicate that the longitudes adopted for the Cape transit circles in 1932 need a correction of approximately − 60 ms. (*Mon. Notes astr. Soc. Sth Afr.* (1965) **25,** 147).

Work on the sixth and final volume of the *Cape Photographic Catalogue* for 1950·0, that covering the part of the sky south of $-80°$, has been completed and the manuscript is now being typed out ready for photographic reproduction.

The faint, but important, asteroid 1566 Icarus was photographed with the Radcliffe reflector during the 1965 opposition. These photographs were reduced with the help of secondary plates taken at the Cape and the results were published in *Mon. Notes astr. Soc. Sth Afr.* (1965) **24,** 163. Astrometric plates were also taken of Comet Ikeya-Seki (1965 f) both at Pretoria and the Cape, the resulting positions being given in *Mon. Notes astr. Soc. Sth Afr.* (1966) **25,** 52.

TIME AND LATITUDE SERVICE

1. *Astronomical observations*

A new observing programme with the Photographic Zenith Tube was commenced in 1965 April, details of which are published in *R. Obs. Bull.* No. 113.

During the twelve months up to 1966 March 31, 101 plates with an average of 16 stars per plate were obtained. Reductions were carried out with the aid of the ICT 1201 computer in H.M.N.A.O. until 1965 September, on the IBM 7094 at the IBM Data Centre in London until 1966 May and thereafter using the new ICT 1909 computer in H.M.N.A.O.

An attempt was made to correlate variations in observed latitude with recorded variations in the horizontal temperature gradient measured by thermocouples within the tube. The measures showed the existence of significant variations of temperature gradient caused by the operation of the extractor fan employed to prevent stratification of air within the tube,

but attempts to correlate these variations with apparent nightly latitude drift failed to yield satisfactory results.

The observed rate of rotation of the Earth has continued to decrease. The average losing rate relative to ephemeris time, made available by atomic standards, was 2·3 milliseconds per day as compared with 2·0 milliseconds per day in the previous 12 month period.

2. *Time signals*

By international agreement the offset for the carrier frequencies of the coordinated radio time signals was altered to -300 parts in 10^{10} for the calendar year 1966; this is equivalent to a losing rate of 2·6 milliseconds per day. The coordinated signals were retarded by 100 milliseconds on 1965 July 1 and again on 1965 September 1. The signals were emitted within 100 milliseconds of UT2 throughout the year. The UK signals were retarded by 1·0 milliseconds on 1966 March 1 to bring them into closer agreement with other coordinated signals.

As a result of experiments carried out with travelling clocks, and in the light of data derived from tracking observations of the 63031 artificial satellite, a new figure was adopted for the effective surface speed of HF trans-Atlantic radio propagation. From 1966 January 1 the adopted speed was changed from 280 to 285 km/ms.

The GBR 16 kc/s transmitter was taken out of operation for modernization on 1966 January 1. The service of VLF radio time signals is being provided from the reserve transmitter Criggion GBZ on a frequency of 19·6 kc/s.

3. *Equipment*

A third Sulzer quartz crystal oscillator was installed in November. By the end of the year the drift rates of the first two oscillators were less than 1 part in 10^{11} per day and that of the new oscillator was 2 parts in 10^{11} per day.

Two VLF tracking receivers were installed in January for use in the measurement of UK and US radio emissions. A digital counter displays continuously the relative time difference between the phase of the incoming VLF carrier frequency and the phase derived from a local quartz clock to an accuracy of 0·1 microsecond and a recorder gives a continuous record of the phase variations to 0·5 microsecond.

A new frequency comparator has been installed and is capable of measuring to an accuracy of 1 part in 10^{12} over an interval of one second.

4. *Atomic frequency standard*

A caesium beam frequency standard was installed in the Time Department on 1966 May 6. The caesium beam tube resonator uses caesium

133 to obtain an atomic resonance frequency which is compared with a multiplied output frequency from a 5 Mc/s crystal oscillator; any difference in frequency is used to correct automatically the crystal oscillator frequency.

A frequency of 100 kc/s derived from the caesium-controlled crystal oscillator is connected to the beat-counters to give comparisons with the other quartz crystal oscillators of the Time Department.

The caesium beam standard employs solid-state circuits. It is mounted on a standard 19 in. × $8\frac{3}{4}$ in. rack panel and is approximately 17 in. deep. The manufacturer's stated frequency stability (standard deviation) is $\pm 2 \times 10^{-11}$.

GEOMAGNETISM

A rectangular Helmholtz coil of 6 ft side, designed and constructed in the Observatory for the production of vertical magnetic fields up to ± 1·2 oersted, has been installed at Hartland, mainly for calibrating universal vertical-field magnetometers.

Mains interference proved troublesome at Hartland in operating a digitally recording proton vector magnetometer on loan from the Meteorological Office. The instrument has been transferred to Herstmonceux, where its operation proved satisfactory. Field investigations have been started into mains 'noise' and the magnetic effect of electric railways at sites within 20 miles of Herstmonceux.

THE SUN

At both Herstmonceux and the Cape, photographs of the Sun in white light have been taken on every day possible. The flare patrol with the Lyot Hα heliograph at the Cape was continued up to 1965 December 31, the end of the IQSY. This instrument was installed during the IGY and has been operated in co-operation, first with Edinburgh and then with Dunsink. It was completely reconditioned during the first half of 1966 and the flare patrol is to be resumed in co-operation with the University of London Observatory. Dr John Reid, formerly of the Dunsink Observatory and now of the University of Houston, has analysed the Cape films and has produced a definitive list of 2907 flares observed on them during the years from 1958 to 1965.

At Herstmonceux, the Lyot filter was used for routine observations on 197 days and photographs of disk and limb features were sent to the Fraunhofer Institut to assist in the compilation of the *Daily Maps*.

INSTRUMENTS AND EQUIPMENT

1. *Isaac Newton telescope*

Work on the building progressed satisfactorily, and at the end of the period the hemispherical framework for the dome was in place on the partially clad drum. Fabrication of the telescope at Newcastle was virtually completed and works tests of the erected instrument nearly finished. A temporary building on the site will house the smaller telescope parts during final erection.

2. *New spectrographs*

Design and construction of the Cassegrain grating spectrograph for the I.N.T. have occupied much of the time of the Engineering Department. Most of the mountings for the optical components have been completed and the welded steel case is being made at Chatham Dockyard. Optical components are being figured by Sir Howard Grubb, Parsons and Company. It is hoped to complete the spectrograph in time for the commissioning of the telescope itself and then to start work on the coudé spectrograph.

An experimental spectrograph was constructed and installed at the coudé focus of the 30 in. reflector to work in conjunction with an image intensifier tube developed by Professor J. D. McGee, of Imperial College. This combination gave spectra at 20 Å/mm in the blue with a gain of about 3^m over baked IIaO emulsion.

3. *Line-scanning device*

A line-scanning device incorporating a rotating glass block and cathode-ray tube display has been fitted to a standard Hilger plate-measuring machine with digitized output, resulting in a considerable improvement in the speed and accuracy of measurement of stellar spectrum plates.

H.M. NAUTICAL ALMANAC OFFICE

The greatest effort during the period was devoted to the installation and commissioning of the new computer. The ICT 1201 computer was removed from service in 1965 September in order that a much larger, air-conditioned area could be prepared ready for the installation of an ICT 1909 computer. In the intervening period computer time was hired on an IBM 7094 in London for regular and urgent jobs. The ICT 1909 computer was delivered, commissioned and accepted (after trials lasting one week) during 1966 May; it has a core store of 16 384 words of 24 bits and cycle time of 2μs, a card reader (900 cards per minute), a line printer

(1 350 lines per minute), a card punch (100 cards per minute), two paper-tape readers (300 characters per second), two paper-tape punches (110 characters per second) and four magnetic tape units ($\frac{1}{2}$ in., 7 track, 20 800 characters per second). The computer is managed and operated by the Computer Section of the Office but it is used for the work of all departments of the Observatory, and, as a temporary measure (until its own computer is installed), by the University of Sussex; time will also be made available to the Ministry of Defence (Navy Department). The principal programming language is Fortran, but Algol and Plan (symbolic machine code) are also used.

The computer is used by the Office for: the preparation of astronomical and navigational ephemerides and tables, theoretical investigations in celestial mechanics; the prediction and reduction of occultations for both optical and radio sources; and for the weekly predictions of 'look data' for some 20 British observers of artificial satellites. Other departments of the Observatory use the computer for the reduction and analysis of observations and for theoretical studies.

The normal production work of the Office was continued. Considerable attention has been given to the content and design of *The Astronomical Ephemeris* to take account of current requirements by users, current methods of computation and data-reading, as well as the techniques of computer-controlled photo-composition; however, it is probable that the main content will be unchanged. The occultation work, particularly in respect of radio sources, has been expanded, and considerable progress has been made towards writing the programs for prediction and reduction on the ICT 1909. Little change has been made in the navigational publications of the Office. The extension of the 'look data' prediction service for selected artificial satellites and stations has resulted in a doubling of useful observations.

In addition to those associated with the production work, the following special investigations have been completed. The effects of the (new) IAU System of Astronomical Constants were thoroughly analysed, and the system was introduced into *The Astronomical Ephemeris* for 1968; this includes a *Supplement* giving a detailed derivation of the corrections to be applied to the ephemerides. A preliminary discussion, by Mr W. Nicholson, of the occultation and meridian observations of the Moon, referred to the IAU system, gave a new determination of the ratio between the rates of Ephemeris and Atomic Times. Dr G. A. Wilkins completed the first stage of his investigations into the motions of the satellites of Mars; he obtained new determinations of the mass and oblateness of Mars, and was able to fit the observations of Phobos without the postulation of a secular acceleration. Much work was done in connection

with the bicentenary of the publication of the *Nautical Almanac*, with additional sections in both *The Astronomical Ephemeris* and *The Nautical Almanac* for 1967; a small exhibit, illustrating the method of lunar distances, was shown at the Royal Society Soirée on 1966 May 11, and a special exhibition is being planned at the Old Greenwich Observatory, in co-operation with the National Maritime Museum. In co-operation with the U.S. Naval Observatory and the U.S. Naval Oceanographic Office, a new set of *Sight Reduction Tables for Marine Navigation* has been designed. Two forms of azimuth diagram have been developed for special air navigational requirements.

With the availability of the new computer several projects in the field of numerical celestial mechanics have just been started; these are primarily concerned with orbits in the solar system.

A series of N.A.O. Technical Notes, describing some of the work done in the Office, was started and the first eleven numbers were prepared; they are in duplicated form and are primarily intended for internal use, but many of them have been given a limited external circulation to those known to be interested in the individual topics concerned.

STAFF, CONFERENCES AND COURSES

Dr R. H. Stoy was awarded the 1965 Gill Medal of the Astronomical Society of Southern Africa. The citation stated that the award was made for 'distinguished contributions to Astronomy, notably in the fields of stellar photometry and positional astronomy and for earnest and selfless devotion over many years which has sustained and amplified the honourable tradition of the Cape Observatory'.

Dr D. S. Evans was awarded a Senior Foreign Scientist Fellowship at the University of Texas, where he is spending the academic year 1965–66.

Dr O. J. Eggen left on 1965 November 1 to take up a position at the Mount Wilson and Palomar Observatories.

New appointments during the period included those of Dr D. Lynden-Bell (P.S.O.), Dr J. S. Griffith (S.S.O.), and Messrs R. Cannon, M. V. Penston and W. B. Wilson (Junior Research Fellows).

The ninth Herstmonceux Conference, held on 1965 April 7–8, was attended by 42 visitors including Professor R. Kippenhahn (Munich) and included discussions on the future of the *Astronomical Ephemeris* and on stellar rotation.

Sixteen students attended the Summer Vacation Course held between 1965 June 21 and August 6.

The tenth Herstmonceux Conference was held on 1966 April 14–15, and was attended by 48 visitors including Professor W. Becker (Basel),

Professors M. V. Migeotte and P. Swings (Liège) and Professor P. A. Wayman (Dunsink).

NATO Summer School

A NATO international Summer School on The Kinematical and Chemical History of the Galaxy, held at Herstmonceux between August 16 and September 3, 1965, was attended by about 60 lecturers and advanced students. The topics discussed included galactic structure, 21 cm observations, stellar kinematics and dynamics, clusters, variable stars, stellar evolution, star formation and the abundances and origin of the elements. The participation of some of the world's leading astronomers made the course outstandingly successful.

PUBLICATIONS

The following publications appeared during the period under review:

Royal Observatory Annals No. 2

Royal Observatory Bulletins 91–115

Third Cape Catalogue for 1950·0 (Preliminary places for stars in the zone $-40°$ to $-52°$)

Astronomical Ephemeris 1967

Astronomical Ephemeris 1970 (Advanced proof of Part I)

Nautical Almanac 1967

Star Almanac 1966

Star Almanac 1967

Air Almanac 1965 Part III

Air Almanac 1966 Parts I, II and III

R. Obs. Ann. No. 2 gives detailed observational data in ω Centauri, while *R. Obs. Bull.* Nos. 94, 96, 102, 105 and 113 are Time and Latitude Service Bulletins, and *R. Obs. Bull.* No. 103 contains Photoheliographic Results for 1959; all these are published anonymously. Other papers that appeared during the period (in *R. Obs. Bull.* or elsewhere) are listed below:

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Clube, S. V. M., 1966. Photometry of the cluster NGC 6522, *R. Obs. Bull.* No. 95.

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Harding, G. A. & Penston, M. J., 1966. Photometric observations of RR Lyrae variables, *R. Obs. Bull.*, No. 115.

H.M. Nautical Almanac Office, 1966. A modern view of lunar distances, *J. Inst. Navig.*, **19,** 131.

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Lake, R., 1965. Photometric magnitudes and colours for bright southern stars (sixth list), *Mon. Notes astr. Soc. Sth Afr.*, **24,** 41.

Laurie, P. S., 1965. Solar activity (1964) (Council Note), *Q. Jl R. astr. Soc.*, **6,** 334.

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