

Proceedings of Observatories

ROYAL GREENWICH OBSERVATORY

(Director, Dr R. v. d. R. 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 year ending 1962 March 31)

INSTRUMENTS

(a) *Herstmonceux*

The 30-inch reflector has been fitted with a new secondary hyperbola and coudé flats to provide an $f/47$ fixed-focus position, in the dome and north of the telescope, for the slit of the new coudé spectrograph. The spectrograph is under construction in the Observatory workshop and the optical parts are being made by Sir Howard Grubb, Parsons & Co. Ltd.

The new Cassegrain grating spectrograph, with 4-inch and 8-inch Schmidt cameras to give dispersions of 80 and 40 Å/mm, has reached the stage of final adjustments and tests of the optical components in the completed casing, and it will shortly be mounted on the 36-inch reflector.

A new blink microscope, to the general design of the Observatory, has been received from Grubb Parsons and satisfactorily tested by comparing plates showing variable stars and stars of large proper motion.

An experimental cathode-ray-tube display system for position measurements of broad lines has been set up and yields an accuracy of ± 1 micron in setting on individual lines. This is a considerable advance over what can be achieved with a conventional measuring microscope, and it is hoped also to reduce measuring fatigue.

A new phase-recording and time-signal receiver for NBA (18kc/s) has been designed and constructed. A similar receiver for GBR (16 kc/s) is under construction as well as a phase shifter to permit one of the local frequency standards to be continuously adjusted to be within 1 part in 10^{10} of a nominal 100 kc/s.

Dr Atkinson's design of the Mirror Transit Circle is now approaching completion, in considerable detail. The Meridian and Electronics Departments have co-operated fully, and the observing procedure will be somewhat simpler than with the Cooke T.C., and will involve less editing and measuring on the following day.

The Lyot birefringent filter, hitherto mounted on the Newbegin equatorial, has been moved into the cellar and is now operated with the 16-inch coelostat and 10½-inch object-glass of 306-inch focal length. This re-arrangement has proved very satisfactory.

(b) *Cape*

The 30-inch Newtonian reflector which was presented to the Observatory by Dr W. H. Steavenson has now been completely overhauled and erected. A suitable secondary mirror has been purchased from Messrs. Cox, Hargreaves and Thomson and the telescope is being provided with a folded Cassegrain focus. When this work has been finished the telescope will be used for photoelectric photometry, probably in the infra-red.

The colour filters in the astrographic photometer have been changed to match those used in the Victoria photometer, and the photometer has been reconstructed to take an E.M.I. cell. It can now be used efficiently for stars at least a magnitude fainter than before. The photometers on both refractors and the one on the 18-inch reflector now have E.M.I. cells and are used for three-colour photometry, giving V magnitudes, $B-V$ and either $(U-B)_C$ or $U-B$ colours.

The infra-red photometer constructed partly at Herstmonceux and partly at the Cape is being used experimentally. When used on the 18-inch reflector with dry ice refrigeration, the photometer is reasonably efficient for measuring red stars down to the eighth magnitude. The resulting colour system is very similar to Kron's I .

POSITIONAL ASTRONOMY

The observations for the Herstmonceux commitment under the AGK3 Reference Star programme were completed. Between 1957 October 22 and 1961 June 30 two observations of each of 13 813 reference stars were secured. Towards the end of the programme, two additional observations of each of 3516 of these stars were undertaken, making in all 34658 observations of right ascension and declination. All FK3 and FK3 (Supp.) stars from the pole to declination -30° were included in the observing list and, with few exceptions, six observations of each were secured. Stars from Blaauw's list of objects requiring improved positions for purposes of galactic research and stars in use with Photographic Zenith Tubes at this and other observatories all received six observations. Including ten members of the solar system, a grand total of 74585 observations of right ascension and declination were secured during the 3½-year observing programme.

The heavy task of programming the electronic computer for the

reduction of this large mass of observational data is proceeding. An appreciable portion of the routine calculations is now performed on the computer, for which some fifteen programmes for various sections of the complete reduction have been written. The problem of computing the atmospheric refraction on a machine with a restricted store received attention during the year. A satisfactory solution now appears to be possible in which the various tabulated functions of zenith distance, temperature and barometric height are represented by Chebyshev polynomials.

Work on the First Greenwich Catalogue for 1950.0 (fundamental stars and stars in the zone $+0^\circ$ to $+24^\circ$ declination) was re-started during the year, after being largely in abeyance since 1957. Punched cards for production of copy by the card-controlled typewriter have been prepared. Proper motions of 2500 G.C. stars in the catalogue have been obtained. For these stars published post-G.C. observations of each star have been included with the G.C. data in a least-squares solution on the computer, and the proper motions have been corrected to the N30 proper-motion system. A decrease by a factor of 2 in the probable error of a proper motion, in comparison with that of the G.C., has resulted for many of these stars. Proper motions of the non-G.C. stars in the catalogue, derived in earlier years by graphical methods, are also available on punched cards and probable errors for these proper motions are currently being derived.

Proper motions of stars in the region of the Hyades cluster have been analysed. A new determination of the vertex of the motion has been obtained, and by consideration of the accuracies of the proper motions an upper limit to the intrinsic velocity-dispersion within the cluster of about 0.3 km/sec has been inferred. Using radial velocities, magnitudes, colours and spectral types, in conjunction with newly determined proper motions, a search for additional stars in the vicinity of the cluster, which are likely to share the Hyades space-motion in all three components, has yielded about ten possible members of magnitude 8.0 to 10.0.

During the year a new observing catalogue for the Cooke transit circle has been prepared. The catalogue includes FK3 and FK3 (Supp.) stars and about 6000 stars selected from the Mt. Wilson *General Catalogue of Radial Velocities*. The selection is intended to ensure that good positions are available for determining improved proper motions of all stars north of -30° declination and brighter than $9^m.5$ which have known radial velocities.

The N.A.O. programme for lunar occultations has continued unchanged. Predictions for 1964 have been completed. The observations made during 1960 have been reduced. Microfilms have been received or

the charts of the profile of the Moon's limb prepared by C. B. Watts of U.S. Naval Observatory, and limb corrections for the 1959 and 1960 observations are being derived. A second reduction of the observations for 1958 has been made using the improved lunar ephemeris, and a start has been made on preparing all the observations received from 1943 onwards for reduction with the improved lunar ephemeris and the application of limb corrections.

Observations for the "Third Cape Catalogue for 1950.0" have been continued, and observations begun for the -40° to -52° zone of the "Faint Star Catalogue". Both of these catalogues, while being observed completely independently, are intended for integration in an international scheme analogous to the AGK3R project in the northern hemisphere. The meridian places of the zone stars will be strengthened by measures made on a series of photographs taken with the new astrometric lens. During the past year 5826 transit observations were made for this programme and 628 plates were taken with the astrometric lens.

The 26-inch Thompson refractor has been used almost exclusively on the trigonometrical parallax programme, for which 2072 plates were obtained on 121 nights. In addition to these, 26 plates have been taken on pre-war parallax fields for proper-motion purposes.

Between April 1 and June 26 the Herstmonceux 13-inch astrographic refractor was used to obtain 157 plates on 25 nights on fields covering about a third of the Oxford astrographic zone; in addition, plates on 6 stars in the Groningen variable star list have been obtained. The lens was then replaced by that from the Oxford astrographic refractor, which has been lent by the University Observatory, and, since June 28, 330 plates on 53 nights have been obtained. The Oxford lens has been found to be of different design from the Greenwich lens, in that it has a negative meniscus flint ahead of a plano-convex crown. Although the effective focal length is only 2.5 cm longer than that of the Greenwich lens, the focal distance as measured from the flange of the cell is about 10.5 cm longer. An adaptor to extend the tube by this amount has been made in the Observatory workshop. In principle, the Oxford design can result in a scale which varies with colour; a test field has been observed with both lenses to investigate this and other possible systematic differences.

During October and November, the Astronomer Royal and Mr Murray, working at the Cassegrain focus of the Mt. Wilson 60-inch reflector, obtained 68 plates on 15 cluster fields which had been observed previously by van Maanen. These plates, together with 40 corresponding early-epoch plates, are now at Herstmonceux for measurement.

Proper motions of 669 stars in the field of M67, down to photographic magnitude 17.0, have been determined from two plates taken with the

26-inch refractor with an epoch difference of 62 years. The plate constants were derived from about 450 supposed members of the cluster. The separation of the proper-motion vectors of the field stars from those of the cluster members indicates that membership can be assigned with at least a 90 per cent certainty. The results from individual stars have been compared with those obtained by van Maanen from plates taken with the Mt. Wilson 60-inch reflector, and the correlation between the two independent sets of observations is good.

Proper motions of 647 stars in LMC Field 1, down to photographic magnitude 16.0, have been determined at Herstmonceux from two plates taken with the Cape 13-inch astrographic refractor with an epoch difference of 49 years. The plate constants were derived from about 180 blue stars which are believed to be Cloud members. The separation between the proper-motion vectors of field stars and Cloud members is not so good as in the case of M67 on account of the smaller scale, but a preliminary statistical study of the proper motions indicates that there cannot be many more than 200 Cloud members in the field.

Proper motions of some 1800 stars in the field of ω Centauri, down to visual magnitude 15.0, have so far been determined at Herstmonceux, from two plates taken with the Cape 24-inch refractor with an epoch difference of 56 years. The plate limit is considerably fainter than this, and measurement down to the limit is being carried out.

All Hyades plates obtained in 1959–60 with the Mt. Wilson 60-inch and 100-inch reflectors have been examined, and stars with apparent large proper motion in the direction of the Hyades convergent point were selected for measurement. Of the total of 69 fields, 27 60-inch and 29 100-inch fields were measured. From this examination about 15 stars fainter than photographic magnitude 11.0 are suspected of being members of the cluster.

The last astrometric plate for the "Cape Photographic Catalogue for 1950.0" was measured in 1961 December, just a little over 27 years after the first. The computation of the proper motions for the stars between -68° and -76° was completed during the year and also the derivation of the 1950.0 positions and precessions for the stars in the -76° to -80° zone. The calculations of the proper motions for this zone and of the 1950.0 positions for the zones between -80° and -90° are in hand.

During the year, 60 modern-epoch plates were obtained with the Cape astrographic refractor, for the Groningen Carte du Ciel programme for obtaining the proper motions of selected variable stars. With the Victoria refractor, 52 pairs of blue and yellow plates were taken; these were either of star clusters or of regions in the Magellanic Clouds.

The derivation of proper motions for stars previously observed for

parallax with the Victoria refractor has continued and 366 plates were measured for this purpose.

The 28-inch refractor was used for the observation of double stars on 126 nights. 565 measures of separation and position angle were secured, distributed according to separation as follows:

$$\begin{array}{cccc} d < 0''.5 & 0''.5 \leq d < 1''.0 & 1''.0 \leq d < 2''.0 & d \geq 2''.0 \\ 131 & 189 & 185 & 60 \end{array}$$

RADIAL VELOCITIES

Observations on the bright A-star programme down to $6^m.35$ with the Yapp 36-inch reflector and 1-prism spectrograph are nearly complete. Five spectra of each of some 480 stars have been obtained, and about one third of these have so far been measured. The results have been compared with those in Wilson's catalogue, which has entries in quality class "c" or worse for about 50 per cent of the stars on the programme; the standard deviation of the difference R.G.O. *minus* Wilson is about 5 km/sec and is consistent with the estimated combined errors, but in individual cases deviations up to about 20 km/sec have been found.

With the 74-inch Radcliffe reflector, increasing use has been made of the new coude spectrograph and rather less emphasis placed on the routine radial velocity programme. Nevertheless, 863 Cassegrain spectra were obtained which were mainly for this programme. In addition, 55 spectra of selected stars were taken with the coude spectrograph and 10 of extragalactic nebulae with the Newtonian spectrograph. Other observations made include 100 direct photographs and 102 photoelectric observations, mainly of stars in the Magellanic Cloud sequences.

During the year, 870 Cassegrain spectra were measured and also 29 coude spectra and 5 Newtonian spectra. A start was made with compiling a fifth list of "Fundamental Data for Southern Stars". New radial velocities and MK spectral types are available for 227 stars but the corresponding photometric data are not yet complete. This list includes several high-velocity sub-dwarfs and also numerous nearby stars.

Selected standard stars, including accessible northern ones, have been observed with the coude spectrograph to check on the uniformity of the northern and southern radial-velocity systems. This same spectrograph has also been used to observe double-lined spectroscopic binaries and has permitted the identification of the second component in several stars previously classified as single-lined.

The Astronomer Royal has continued his observations of radial velocity using high-dispersion spectrograms. Spectra of a number of stars were secured last year with the spectrograph at the coude focus of the Radcliffe

74-inch reflector and, through the courtesy of the Mt. Wilson Observatory, with the spectrograph at the coudé focus of the 100-inch reflector. These spectrograms were all measured for radial velocity during the course of the year.

LARGE MAGELLANIC CLOUD

R.O. Bulletin No. 58 reports the determination of a period-luminosity law for Cepheid variables in Variable Field I of the LMC. The law found differs significantly from that found by Arp in the Small Magellanic Cloud. Special determinations of the magnitudes B and V have been carried out for all the stars whose proper motion was determined. A preliminary study shows a very satisfactory correlation between the division between Cloud members and field stars, as judged by proper motion, and the division as judged by the H.R. diagram.

A start has been made on the determination of the period-luminosity law of Cepheid variables in a second field in the LMC (Constellation III). Plates secured with the Victoria telescope were blinked some time ago by Dr Sandage, and have been further examined with the new blink comparator at Herstmonceux. A number of new variables was discovered at each stage. These, together with known Harvard variables, are now being measured at Herstmonceux on B and V plates taken with the Victoria telescope, with a view to establishing mean magnitudes and periods.

GLOBULAR CLUSTERS

The work on NGC 6397 published in R.O. Bulletin No. 43 stops at visual magnitude 17; during the current year longer exposures than those previously available were obtained by Mr Harding at the Newtonian focus of the Radcliffe 74-inch reflector. These have been measured in B and V at Herstmonceux, but it is felt that the photoelectric sequence used needs further checking. Ultimately it is intended to investigate whether the main sequence in the H.R. diagram of this cluster can be established by measurements going down to visual magnitude 19.

The globular cluster ω Centauri has been the subject of an intensive investigation. About 3 500 B and V magnitudes have already been measured, and the magnitudes of about half of the known variables have been determined on a sufficient number of plates to establish mean magnitudes. In addition, proper motions have been measured and some radial velocities of the brighter stars have been secured by Mr Harding on the Cassegrain spectrograph of the 74-inch reflector at the Radcliffe Observatory. It has already been found that proper motion is a most useful means of distinguishing between cluster members and field stars,

and that the cluster has an appreciable proper motion, from which, together with the radial velocity, some inferences concerning the nature of the galactic orbit of this cluster may be drawn.

PHOTOMETRY

The photometric observations in connection with the Cape Photographic Catalogue were completed in May and the measurement of the resulting plates has been completed for the -76° to -80° zone and about half completed for the -80° to -84° zone.

The general programmes in photoelectric photometry have all been continued. The Victoria refractor is being used to observe stars of astrophysical interest with magnitudes between 6.5 and 12, while the astrographic refractor and the 18-inch reflector are both employed on observing HR stars south of $+10^\circ$ declination. The former is used for stars between -4° and -64° and the latter for the remaining stars. The area south of -64° was completed during the year and the 18-inch aluminized reflector is now being concentrated on the equatorial zone which is particularly important for standardization purposes, as it can be observed equally well from both hemispheres.

The 18-inch reflector has also been used to obtain $U-B$ colour indices for most of the E-region standard stars brighter than the 10th photographic magnitude and is now being used to make a direct comparison between the original "B" filter used by Johnson and the Schott filters used at the Cape. We are very grateful to Dr H. L. Johnson for the loan of this unique filter. Some work has also been done on fixing the zero points of the sequences in the Magellanic Clouds.

Mr R. P. de Kock continued his programme of visual observations with the 6-inch telescope and obtained 6 424 observations of 175 long-period variables and 2 "flare" stars.

STELLAR ATMOSPHERES

The influence of metal abundance on the spectra of cool dwarfs has been studied and the results are used to investigate the interpretation of spectral types on the Mt Wilson and Yerkes systems. If a dwarf and sub-dwarf of the same effective temperature but different metal abundances are compared, the sub-dwarf will have an earlier spectral type and a bluer $B-V$ colour. For MK types, these two effects seem roughly to "compensate" in the sense that the relationship between spectral type and $B-V$ colour is identical for both dwarfs and sub-dwarfs; but for the Mt Wilson types, based on different criteria and mostly on spectra with higher dispersions, a second-order effect seems to exist among K dwarfs in the sense that sub-dwarfs are bluer for a given type than normal dwarfs. The

effect has also been used to identify likely sub-dwarfs among nearby K dwarfs with low-weight parallaxes.

SOLAR PHYSICS

The Sun was photographed at Herstmonceux in white light on 280 days and in $H\alpha$ with the Lyot birefringent filter on 227 days. Solar activity continued to decline during the year, 15 sunspot groups exceeding 500 millionths of the visible hemisphere in area being observed, against 24 for the previous year.

The usual two photographs of the Sun in white light were obtained at the Cape on 344 days and the flare patrol was maintained with the Lyot $H\alpha$ heliograph. This instrument was run on 301 days for a total of 1849 hours. During 1961, 294 flares were detected on the Cape films. Of these, 2 were of Class 3+, 0 of Class 3, 10 of Class 2, 112 of Class 1 and the remainder of Class 1-. These figures, when compared with those for the previous two years, indicate the general decline in flare activity with the approach of solar minimum conditions, which are expected to occur in 1964.

TIME SERVICE

During the year 190 P.Z.T. plates were obtained at Herstmonceux with an average of 11 stars per plate. The time and latitude results are reduced on the I.C.T. 1201 computer and communicated weekly to the Bureau de l'Heure and the Office of the International Latitude Service (now the International Polar Motion Service).

The P.Z.T. working catalogue has been modified for the 7-year period 1965-71 on account of precession. Observations will shortly begin of the additional stars required, in order to determine their places relative to the current groups.

The Danjon astrolabe has been in regular use throughout the year; 244 groups were observed representing 7000 individual observations. Using the I.C.T. 1201 computer the equations of condition for the 11000 observations made since 1959 September have now been obtained. The results of 125 "standard" groups have been computed and preliminary star corrections obtained to refer any individual star to the standard group system. The reduction of all observations with these preliminary corrections will shortly be completed. A preliminary comparison with the results of the Paris astrolabe indicates that the results are of comparable accuracy.

Increasing use has been made of the caesium standard at the National Physical Laboratory in the computation of a clock whose rate may be relied upon to be uniform. The full potentialities of the atomic time scale

have been, however, difficult to realize in practice, owing to the technical and operational difficulties inherent in comparing standards at different sites; the quality of the linkage between the best quartz clocks and the caesium standard has been barely adequate for the stringent requirements of the time service. The difference in the emission-times of the GBR and WWV signals, working in the "co-ordinated" system adopted last year, has been kept below two milliseconds, but in principle this could be improved on.

These signals are emitted on the basis of a rate adopted for the whole year, together with a jump of 50 ms on a pre-arranged date when the accumulated error due to changes in the Earth's rotation makes this seem advisable. The rate for 1961 was set at 150 parts in 10^{10} below that corresponding to the nominal caesium second, and the rate for 1962 is 130 parts in 10^{10} below it. One jump was made in August.

On December 1 the twice-daily time-signal transmissions from GBR were replaced by four transmissions at 0300, 0900, 1500 and 2100 G.M.T. The supplementary short-wave transmissions are still radiated twice daily, but at 0900 and 2100. The increase in the number of signals was originally requested by the survey authorities, but is now essential for the full benefits to be derived from the international co-ordination of radio time signals.

NAUTICAL ALMANAC OFFICE

The routine calculations and proof reading involved in the preparation and printing of the publications for which H.M. Nautical Almanac Office is responsible have been continued. The volumes issued during the year were as follows:

Astronomical Ephemeris 1963—published in November.

Nautical Almanac 1962—published in April.

Nautical Almanac 1963—published in March.

Star Almanac 1962—published in April.

Air Almanac 1961—Part III published in June.

Air Almanac 1962—Parts I and II published in November and January.

The following special publications were issued during the year:

Explanatory Supplement to the Ephemeris—published in January.

Nutation, 1900–1959 (R.O. Annals No. 1)—published in January.

Hourly heights of the tide at Aberdeen have been computed on behalf of the Tidal Branch of the Hydrographic Department in an attempt to determine whether significant improvements in the accuracy of prediction can be obtained by the use of an electronic computer instead of a tidal machine.

The programme for the determination of the effect of irradiation in sextant observations of the Sun's limbs is almost complete, but it has not yet been possible to make sufficient observations at very low altitudes.

The I.C.T. 1201 computer was used in many research problems (216 hours) as well as for the routine calculations of the Office (681 hours) and for the reduction of data from the R.T.C., P.Z.T. and Astrolabe (579 hours). It is clear, however, that it has neither the capacity nor the speed that are required for more extensive investigations; a preliminary submission for a replacement has been made to the Admiralty.

A report is being prepared of an investigation into the optimum form and methods of preparation of ephemerides for use in automatic computation. It has been found that Chebyshev expansions valid over long ranges make efficient use of fast computers, but their full value cannot be utilized on the 1201 computer.