

Q. Jl R. astr. Soc. (1968) **9**, 164–187.

Proceedings of Observatories

ROYAL GREENWICH OBSERVATORY

(Director, *Sir Richard Woolley, Astronomer Royal*)

ROYAL OBSERVATORY, CAPE OF GOOD HOPE

(Director, *R.H.Stoy, H.M. Astronomer*)

(Report for the 18 months ending 1967 December 31)

INAUGURATION OF THE ISAAC NEWTON TELESCOPE

Her Majesty Queen Elizabeth II visited the Royal Greenwich Observatory on 1967 December 1, for the inauguration of the Isaac Newton Telescope. After the ceremony, Her Majesty was entertained at a reception given by the Science Research Council. Distinguished visitors to the Observatory on this occasion included His Grace the Duke of Norfolk, Lord Lieutenant of Sussex; Professor B.H.Flowers, Chairman of the Science Research Council, and Mr Patrick Gordon Walker, Minister of Education and Science.

GENERAL STELLAR KINEMATICS AND DYNAMICS

Radial velocities. A preliminary analysis of the dynamics of K0 stars in four areas centred at $l^{\text{II}}=90^{\circ}$, 180° ; $b^{\text{II}}=\pm 20^{\circ}$, from radial velocities observed at Kottamia, has been carried out, using the general methods developed in *R. Obs. Bull.* No. 97.

The velocity dispersion of A0 stars perpendicular to the galactic plane has been derived from observations made at Kottamia, combined with velocities already published for stars in both galactic caps. An increase in the dispersion with distance from the plane is apparent. In this investigation (II5), data for the southern cap were less complete than for the northern cap, and in order to remedy this, new observations of radial velocities of 126 A0 (HD) stars in the southern cap were obtained at Pretoria. A new discussion will give revised values for the dispersion and its dependence on apparent magnitude.

Observations of a number of spectroscopic binaries have been obtained at Kottamia, and with the Yapp 36-in. reflector.

Work has continued on the Cape general radial velocity programme with the Cassegrain spectrograph of the 74-in. telescope at Pretoria. Observations have also been made on planetary nebulae with the

Newtonian spectrograph. Data for approximately 100 stars are ready for publication in the *Fundamental Data for Southern Stars* series. Progress has been made with the compilation of the supplement to the *General Catalogue of Radial Velocities* (37).

Proper motions. The repetition of the old series of photometric plates, taken with the 26-in. refractor at Greenwich, on the Kapteyn Selected Areas is now well advanced. The measuring programme includes stars contained in the *Bergedorf Spektral-Durchmusterung*, or for which photometry has been published by the Stockholm observers. Measurement of SA 13, 14, 69, 70, and 71 has been completed.

The intercomparison between the Radcliffe 24-in. refractor at Mill Hill and the 26-in. refractor which was mentioned in the last report has been extended to SA 8 and 45. Systematic positional differences at a constant magnitude appear not to exceed 1μ , although there is evidence for relative magnitude equation for stars brighter than $m_{pg} = 11$.

A programme for determining proper motions of some 3500 stars in the Oxford Astrographic Catalogue in an area $8^\circ \times 8^\circ$ near the North Galactic Pole (project 'Pole-Hole') has been started, in collaboration with Professor O.J.Eggen who is undertaking photoelectric photometry for all the programme stars. All the second-epoch plates have been taken with the Oxford lens.

Data on proper motions of faint stars published in the McCormick Catalogues have been reduced to the FK4 system and analysed to give revised values for the corrections to precession, and the Oort constants of galactic rotation.

Gould's Belt. A study of the kinematics of Gould's Belt has been published (16), and theoretical investigations of its structure and its relation to that of the Galaxy are continuing.

Stellar orbits. Theoretical stellar orbits in the galactic plane, using a force law departing slightly from an inverse square, have been computed on the I.C.T. 1909 computer. Perturbations due to a spherical cloud moving in a circular orbit were introduced; these increase the eccentricity of stars moving in circular orbits, but have little effect on eccentricities greater than 0.2. The effects of the perturbations on simulated stellar groups were in many cases catastrophic to the coherence of the group. Calculations in three dimensions are in progress.

TRIGONOMETRICAL PARALLAXES

Cape. Parallaxes have been determined for 23 stars. All stars for which a complete series of plates has accumulated have been measured except for three stars with very large proper motion and four astrometric binaries.

The current programme on the Victoria refractor consists of 102 stars.

Herstmonceux. Observations with the 26-in. refractor have continued at a reduced rate, due to other demands on the telescope. The plates obtained on 6 red dwarfs in Gliese's catalogue are being measured.

The reductions and the monitoring of the observing programme are being programmed for the I.C.T. 1909 computer.

DOUBLE STARS

Observations of double stars with the 28-in. refractor have continued.

The long series of plates of α UMa obtained with the 26-in. refractor at Greenwich and Herstmonceux have been combined with the Allegheny plates, kindly loaned by Dr N.E. Wagman, to determine the photocentric orbit and trigonometrical parallax of this interesting pair. From a combination of the astrometric data and visual observations the total mass was found to be $3 M_{\odot}$, and the mass ratio to be 0.53, the fainter component being the more massive.

STAR CLUSTERS

(i) *Globular clusters*

ω *Centauri*: photographic B, V photometry has been obtained with plates taken at Pretoria, through a 3.5 magnitude objective grating. These observations indicate that good photometry can be obtained by this method at magnitudes fainter than the faintest available photo-electric standards, thus saving a considerable amount of telescope time.

NGC 6397: photographic B, V photometry of faint stars has been obtained with plates taken at Pretoria through the objective grating.

47 *Tuc*: an objective statistical technique for separating cluster members from field stars, from proper-motion measurements on two independent plate pairs, has been developed and applied to this cluster. The colour-magnitude diagram of cluster members selected in this way, using photographic photometry from Cape plates, agrees reasonably well with that published by Tifft, with the additional feature of a very well defined sequence of stars brighter than and asymptotic to the giant branch. Three or four more possible blue horizontal branch members have been identified. The RR Lyrae star HV 814 is almost certainly not a member.

NGC 6171: a large number of U, B, V plates of this metal-rich cluster have been obtained at the Newtonian focus of the 100-in. telescope at Mount Wilson. The object of this programme is to obtain the relationships between the various light-curve parameters of the RR Lyrae

variables, in order to compare with existing data for metal-poor clusters, and to test current pulsation models. The reddening in the field has been determined from photoelectric U, B, V observations of field stars, observed with the 60-in. telescope.

NGC 5466, 6401, 6981, and 7099: three-colour U, B, V photoelectric and photographic observations of these clusters have been obtained with the Mount Wilson 60-in. and 100-in. telescopes, in order to obtain the colour-magnitude and two-colour diagrams down to the horizontal branches. In the case of NGC 6981 sufficient plates have been obtained to study the light curves of RR Lyrae variables in B and V .

(ii) *Galactic clusters*

Praesepe: in collaboration with R.P.Kraft and W.Krzeminski, the effect of axial rotation on the colours and magnitudes of stars in this cluster has been examined. New photoelectric measurements of V , $B-V$, and $U-B$ were combined with the earlier results of Johnson. It was found that the deviations $\delta(U-B)$ for a fixed $B-V$ were less well correlated with rotation than is the case in the Hyades. The correlation of excess brightness in the colour-magnitude diagram with rotation was also found to be weak; it is thought that these poor correlations may be the result of very slight differential reddening.

NGC 6940: extensive photoelectric observations of some stars which lie near the edge of the Hertzsprung gap have been made in order to investigate possible short-period variability of the δ Sct type. One definite variable, with period about 0^d.2, and one probable variable have been found, but further observations are required to establish the type of variability.

M67: two further papers on the discussion of proper motions in this field have been prepared (70), (71). Five of the suspected outlying red-giant members mentioned in the last report have been observed spectroscopically at Kottamia, and in all cases their observed radial velocity is consistent with cluster membership.

Using the members selected by the proper-motion criteria, projected star densities have been obtained out to a radius of 30'. The total projected density can be well represented by a truncated isothermal distribution of the type discussed in *R. Obs. Bull.* No. 42. A significant mass segregation is found in the central parts, consistent with an isothermal model assuming the usual mass-luminosity relation.

Old and intermediate-age clusters: a proper-motion study of several of these clusters has been carried out with the principal aim of determining colour-magnitude diagrams free from the effects of field stars. The clusters investigated were NGC 752, 2420, 6939, and 7789 using Mount Wilson 60-in. plates, and NGC 188 using 13-in. astrographic

plates taken at Greenwich and Herstmonceux. The limiting magnitude on the 60-in. plates is about $B=16^m$, but is only 15^m on the astrographic plates. Some 2000 stars in NGC 7789 and about 300 in each of the other clusters have been measured. New photographic photometry, using plates taken with the 26-in. refractor, has been obtained for NGC 188, 752, and 2420.

Three clusters, NGC 752, 6939, and 7789, were found to have very similar colour-magnitude diagrams. In each case there is a concentration of red giants at $(B-V)_0 \sim 1.0$, $M_v \sim 1.0$, with no bluer stars between this group and the top of the main sequence, and only a few redder stars extending the giant branch to brighter magnitudes. An attempt to determine whether or not these clusters have a gap near the top of the evolving main sequence, similar to that in M67, was largely frustrated by inaccuracies in the available photometry. One notable feature is that, in each of these clusters a few anomalously bright stars are found in the neighbourhood of the main sequence, lying above the evolutionary turn-off point. The detailed distribution of these stars strongly supports the theory of McCrea and others that they are binary systems which have undergone mass exchange, rather than that they are analogous to the horizontal branch stars of globular clusters.

NGC 188 is believed to be much older than the other clusters. The proper motions reveal a fairly well defined giant branch, and also a comparable number of much bluer stars in about the same magnitude range. The membership of these blue stars is confirmed by their distribution in the cluster, and they are probably similar to the blue stars found in the younger clusters.

Work on NGC 2420 is in progress.

IC 2944: a proper-motion investigation of this cluster is being undertaken at the Cape.

VARIABLE STARS

Radial velocities of RR Lyraes, semi-regulars, cepheids and eclipsing binaries have been obtained at Kottamia. Light curves (in blue light only) for these stars have been obtained with the 13-in. astrographic refractor at Herstmonceux.

Photoelectric observations of eclipsing binaries and other variable stars are being made with the 18-in. reflector at the Cape.

RR Lyrae variables. Proper motions for over 80 southern RR Lyraes have been determined.

A series of astrometric plates centred on some 200 northern RR Lyraes is being obtained with the Herstmonceux astrographic telescope. An objective grating is being used, and it is intended to obtain four

plates on each variable at the present epoch, to provide homogeneous material for future improvement of the proper motions of these stars.

A programme of photometric observations with the Cape Elizabeth telescope, combined with spectroscopic observations made at Pretoria, on about 50 RR Lyrae variables is nearly complete.

A programme of four-colour narrow-band photometry of RR Lyrae variables and their Population I analogues is in progress at Pretoria.

Semi-regular and RV Tauri variables. Fundamental observations of the positions of 167 of these stars are currently being obtained with the transit circle at Herstmonceux to provide good modern places for the improvement of proper motions.

Revision, within the FK4 system, of the proper motions of 182 variables, referred to in the last report, has been completed.

A programme of photoelectric observation of red giants in clusters in order to detect possible semi-regular variables is in progress with a U, B, V single-channel photometer at the Cassegrain focus of the 36-in. reflector at Herstmonceux. The photometer, which is easily transportable, was built at Herstmonceux.

NML Taurus. This object has been observed with the 26-in. refractor. The light variations suggest that it is probably a Mira-type variable (II), (I2).

Short-period variables. Photoelectric U, B, V observations, made at Mount Wilson, of about 80 bright, mostly F-type stars have revealed that some 10 per cent of the stars show short period, small amplitude light fluctuations. They are assumed to be mostly variables of the δ Sct type. Effective temperatures and surface gravities of these stars have been derived from photoelectric spectrum scans obtained with the 60-in., and coudé spectra obtained with the 100-in. (28). The temperatures and gravities were used to derive pulsation constants (Q) which, for some of the stars, are anomalously small and could indicate a high harmonic mode of pulsation.

Spectrum scans have been obtained for a number of A and F stars in order to investigate further the changes of gravity and temperature in the region of the colour-magnitude diagram occupied by δ Sct stars. These have been supplemented with spectra at 40 Å/mm obtained with the 60-in., and further coudé spectra currently being obtained at Herstmonceux with the 30-in. reflector. These will be used to determine axial rotations, hydrogen line profiles and line blanketing corrections.

Long-period variables. The regular visual observation at five-day intervals of 173 of these stars has continued at the Cape.

SPECTRAL CLASSIFICATION

All spectra observed for the Ao and Ko star radial-velocity programmes have been reclassified on the MK system.

Of the Ao (HD classification) stars, almost 20 per cent were reclassified as metallic-line stars, and the remainder are heavily concentrated around AoV.

75 per cent of the Ko (HD) stars were reclassified as luminosity class III, with types between G7 and K5.

STELLAR ABUNDANCE STUDIES

Helium abundance in nearby stars. The possibility that most of the helium in the Universe was synthesized during a 'Big Bang' phase (whose existence now seems very likely in view of the observation of the 3°K background microwave radiation) makes it particularly interesting to try to determine the helium content of young and old stars that have undergone little evolutionary change since their formation. Since, except in the case of the youngest objects, such stars are invariably rather cool, their helium abundance cannot be determined spectroscopically, so that one has to rely on masses, luminosities and effective temperatures, interpreted in the light of internal structure models.

Studies of the colour and luminosity of the old, metal-deficient subdwarf Groombridge 1830 and of the masses and luminosities of much younger stars belonging to the Hyades and Ursa Major clusters have enabled a preliminary sketch of the evolution of helium abundance in the Galaxy to be outlined. For Groombridge 1830 (4), representing star formation at some epoch during the 'halo' phase corresponding to the first 2×10^8 years or so of the history of the Galaxy, and also for the milder subdwarfs 85 Pegasi and μ Cassiopeiae (14), the helium abundance is similar to that of the Sun (about 0.2 by mass), whereas for younger stars in the Hyades and Ursa Major clusters the helium abundance is perhaps about 50 per cent greater. These results are not incompatible with the expected rate of enrichment in helium of the interstellar medium in the last 5×10^9 years as a result of the evolution of normal stars. O.J.Eggen's suggestion that the Hyades have a higher helium content than equally young stars in the Ursa Major cluster is not confirmed, but there is still a considerable degree of uncertainty in the mass-luminosity data on which these conclusions are based.

Spectroscopic studies of metal-deficient stars of the galactic halo. Studies of the solar curves of growth for different elements have been continued, with a view to improving differential abundance determinations relative to the Sun by making proper allowance for differences in the amount of collision broadening and eliminating errors due to blends.

A computer programme for automatic differential curve-of-growth analysis has been developed, and a series of model atmospheres is being computed in the hope of improving the abundance determinations still further.

Some problems in the application of the theory of element synthesis in stars (as described by E.M.Burbidge, G.R.Burbidge, W.A.Fowler, and F.Hoyle in 1957) have led to investigations of element synthesis in exploding models of the Universe and of supermassive stars, notably by R.V.Wagoner, Fowler, and Hoyle in 1967 (WFH). These authors have suggested that the synthesis processes predicted in certain types of massive objects with a trace of He^3 initially present may be relevant to the composition of some extremely metal-deficient stars such as the red giant HD 122563. Since the WFH process leads to the prediction that carbon-13 should be as abundant as carbon-12, it has proved possible to test this hypothesis by searching for C^{13}H lines in the G-band of the spectrum of this star, using two coudé plates at a dispersion of 6.7 \AA/mm from the Radcliffe Observatory, Pretoria. Examination of the plates shows that the C^{13}H lines, if present, are weaker than the C^{12}H lines by at least a factor of 2, so that the WFH type of synthesis does not seem to be applicable in this case. Even the C^{12}H lines are extremely weak, suggesting that carbon may be deficient in HD 122563 by a still larger factor than the metals, and CN bands are completely invisible, implying that nitrogen is also very deficient (though not necessarily by a larger factor than the metals) (7). The exceptionally low abundance of carbon, as well as of barium, confirms the suggestion that HD 122563 presents a 'mirror image' of the overabundances found in CH stars.

Analyses of nearby stars. The computer programme for curve-of-growth analysis is being applied to coudé spectra from Mount Stromlo of α Centauri A and B, to investigate whether there are differences in composition as suggested by six-colour photometry. An analysis of 12 F-type dwarfs, using coudé spectra taken with the 30-in. telescope at Herstmonceux, indicates that these are all metal-deficient relative to the Sun by factors less than or equal to 4 and that there is little correlation with space velocity in the range covered.

STAR FORMATION AND INTERSTELLAR CLOUDS

Orion Nebula. Plates on the Orion Nebula, in red light, were obtained with the 26-in. refractor. Analysis of microphotometer tracings of the dark blobs projected against the nebula gave estimates of their temperatures and masses, in agreement with the suggestion that these form an early stage in the development of proto-stars.

Theoretical work. Grain opacity and molecular dissociation was found to shift the Hayashi tracks of red stars only slightly further into the red.

Work continued on proto-stars and their dynamic formation from interstellar clouds (81)–(83). A method of solving the Oort model for the velocity and mass distribution of these clouds was devised.

EXTRA-GALACTIC STUDIES

Extra-galactic nebulae. Spectra of extra-galactic nebulae have been obtained with the 74-in. reflector at Pretoria.

Quasars. About 30 of the brightest quasars have been observed with the 26-in. refractor, in order to detect possible light variations. Only quasars with flat radio spectra are currently violently variable at optical wavelengths; 3C 446 (13), 345 (84), 454.3, 371, 390.3, and possibly PHL 658 were found to vary during the period of this report. The observations do not conflict with the idea that all quasars vary, but in any one year only about 20 per cent are violently variable.

Attempts to detect the variability of N galaxies were successful only after the discovery had been made elsewhere.

An attempt to check the validity of Arp's claim that quasars are associated with relatively nearby galaxies showed that, whereas some galaxies might be associated with widely spaced pairs of radio sources, there was no good evidence for an association with quasars (57). It was suggested that the anisotropy of quasars with large red-shifts might be due to observational selection (85).

At the request of Professor Ryle, accurate astrometric positions of some quasars and optically identified small-diameter radio sources are being determined. Some six to eight reference stars have been specially observed, in the FK4 system, with the Herstmonceux transit circle, in each of 17 fields. These have been used to obtain positions of faint reference stars ($m_{pg} \sim 13$) from astrographic plates, which have in turn been used to derive positions of fainter reference stars ($m_{pg} \sim 16$) or, where possible, the source itself on 26-in. plates. The magnitude interval covered in each step is thus kept below 4^m, in order to reduce the effect of possible magnitude errors. Provisional positions with an accuracy of $\pm 0''.1$ (s.e.) for 10 sources have so far been communicated to Professor Ryle.

Theoretical work. Work continued on the theory of galaxy formation (63), (64). The mechanism by which a galaxy achieves an unrelaxed but smooth equilibrium state as a result of violent relaxation during its birth stages, was studied in order to predict the surface brightness–radius relationship observed in elliptical nebulae (61). Computer experiments

carried out elsewhere show an encouraging degree of agreement with theory.

Further studies in the statistical mechanics of gravitating assemblies emphasize the importance of entropy in determining the sense of evolution of star clusters and of galaxies.

Work continued on the stability of rotating and differentially rotating bodies (58), (59), (62), (72).

COSMOLOGY

A theory of Mach's Principle was proposed, which is in full conformity with General Relativity, and reduces the boundary conditions on Einstein's equations (60). Probably none of the Friedmann universes satisfies the boundary conditions at its singularity.

PHOTOMETRY

Observations of variable stars and clusters have been reported above.

Photoelectric observations have been carried out with the Cape Elizabeth telescope, on the general programme including stars in the Cape radial velocity programme. Additions to the observing list which have received special priority include 165 A0 stars in the southern galactic cap to assist the Herstmonceux investigations, and 144 O, B, A stars for Dr Thackeray.

Four-colour observations using filters with narrow pass bands similar to those used by Strömgren and his associates, have been started.

The 18-in. reflector at the Cape has been used on a programme designed to establish a consistent photometric system all over the sky. Although the standardization of B and V observations has been relatively satisfactory for some years, that for U leaves much to be desired. The sensitivity of this band to small changes in the aluminium coating of the mirror, to temperature and other meteorological conditions makes it extremely difficult to reproduce precision observations with any degree of consistency. The abandonment of this band for general photometry and its replacement by another more precisely defined band is under very active consideration.

At the beginning of 1967 the Cape Astrographic refractor was used exclusively by Dr Willstrop of the Cambridge Observatories to support his ten-colour photometer with which he observed a number of the brighter southern stars. Thereafter the telescope was used on the programme of three-colour (U_c , B , V) observations of HR stars between -4° and -64° .

Photography of the -40° to -52° zone with the Taylor Hobson photometric cameras is nearing completion. Each plate contains four

equal exposures, two being on a zone area and two on one of the standard E regions.

POSITIONAL ASTRONOMY

Meridian observations

Herstmonceux. In addition to the special observations of variable stars and reference stars near quasars already reported, the Cooke transit circle has been used to observe stars with good radial velocities but poor proper motions; this programme is nearly completed.

Computer programming for the current reductions is now nearly complete, and rapid progress is being made in reducing the observations from 1961 to date.

The use of a line-scanning machine for measuring circle films has been investigated, and the method has proved to offer considerable advantages in speed and accuracy over direct visual measurement.

Investigation of the Herstmonceux instrumental system 1957–61, in declination, is progressing satisfactorily. Comparison of observations in the two clamp positions of the instrument has revealed a small difference in apparent latitude, a very small circle flexure effect, and a negligible cosine term in the flexure of the tube.

The planetary observations are now being reduced.

Cape. Observations for the Southern Reference Star (SRS) and Bright Star (BS) programmes have continued. It is hoped that the -30° to -40° zone will be finished in 1968. Thanks to computing assistance from the U.S. Naval Observatory, the reductions are being kept completely up to date.

The reductions of the Sun, Moon, and Planet observations from 1936 to 1959 have been re-examined and corrected for the E.T.–U.T. difference. This material has been analysed for equator point, equinox, and obliquity corrections, and has been prepared for publication in the second Cape catalogue for 1950.0.

Cape astrolabe. In addition to the observing programme mentioned in the last report, observations have been secured on Mars and Vesta.

Preliminary results from an analysis of the first year's observations (95) indicate that the right ascensions of FK4 require an increasing negative correction at declinations south of -40° . This conclusion is supported by recent observations at other observatories.

Time and latitude results which are determined as by-products of the main programme have been communicated monthly to the Bureau International de l'Heure and the International Polar Motion Service.

Photographic star positions. Following a resolution of the International Astronomical Union and as a part of the SRS project, it has

been decided to photograph the whole of the southern sky with the 'new' Taylor Hobson astrometric camera. Previously only coverage of the sky south of -30° had been contemplated. About 10 000 plates will be needed for the whole programme as they are being arranged so that every star will appear on four plates, once in each quadrant. During 1967 the necessary working lists for the zones between the equator and -30° were prepared and the photography of the zone between -30° and -40° completed. The zone between -40° and -52° was photographed in 1962. It is hoped that the photography of the whole southern sky can be completed in the next three years.

The complete exploitation of the vast amount of precision data contained on these plates will eventually require the use of an automatic measuring machine and computerized reductions. Meanwhile a number of preparatory investigations are being carried out. The plates are ideally suited for reduction by the overlap technique, and schemes of measurement together with corresponding reduction programmes for running on the I.C.T. 1909 computer have been developed. Two preliminary series of measurements are being made. The first is to test for the size and constancy of the effects on the relative star positions produced by the telescope-filter combination, by star colours and magnitudes, and by plate emulsion irregularities. The second series is to test the proposed methods of reduction.

Artificial satellites. Observations of the positions of artificial satellites were made with the kinetheodolite at Herstmonceux until it was dismantled in 1967 January. All Herstmonceux observations have been reduced and the results transmitted to the U.K. Space Data Centre at Slough.

The instrument was overhauled and re-erected at the Cape, where observations have been carried out since 1967 August.

TIME AND LATITUDE SERVICE

Photographic zenith tube. The instrument has been in regular use throughout the period, and 198 plates were obtained. Results are now communicated weekly to the Bureau International de l'Heure and monthly to the International Polar Motion Service.

Astrolabe. An analysis of the Herstmonceux astrolabe observations made at a site adjacent to the PZT in the years 1959–1963 has been prepared for publication. This shows a closing error in latitude of $+0''.25$, which confirms the existence of a local diurnal variation in latitude previously discovered in the PZT observations, and it suggests that the source of the effect is local rather than instrumental.

Rotation of the Earth. During the period covered by this report the observed rate of rotation of the Earth has settled to an approximately

constant losing rate of 2.4 msec/day relative to ephemeris time made available by atomic standards.

Time signals. By international agreement the offset for the carrier frequencies of the coordinated radio time signals remained at -300 parts in 10^{10} for the whole period; this is equivalent to a losing rate of 2.6 msec/day. There were no step adjustments, and the signals remained within 100 msec of UT₂ throughout the period.

The GBR 16 kHz transmitter which had been out of operation for modernization since 1966 January 1 was brought back into use on 1966 December 1; it was again out of operation from 1967 February 1 until 1967 March 6. During these periods the service of VLF radio time signals was provided by the reserve transmitter GBZ on a frequency of 19.6 kHz.

Clocks. A second caesium beam atomic standard was installed in the Time Department in 1967 March. Between 1967 June and 1967 December 31 the divergence between the two atomic standards was two microseconds, corresponding to a frequency difference of 1 part in 10^{13} .

Since 1967 July the time service has been based on these two caesium standards together with the best two of the Sulzer quartz crystal standards. The last and best of the quartz crystal standards designed and built by the Royal Greenwich Observatory, which incorporated an Essen ring crystal, was taken out of service in 1967 May after an oven failure, having been in use from 1954.

Travelling clock comparisons. Comparisons carried out in 1966 November and 1967 March using portable caesium beam atomic standards from the U.S. Naval Observatory showed a change in the difference between the master clocks at the two observatories of 21 microseconds. A visit was also made by a commercial firm in 1967 October in which the U.S.N.O. and R.G.O. standards were compared and fell within the same limits. Use was also made of these visits to check the effective surface speed of HF trans-Atlantic radio propagation. The mean speed was 285 km/ms. The U.S. Coast and Geodetic Survey visited the R.G.O. on seven occasions to check their time standards used in the Western European Triangulation Survey.

Equipment. Considerable progress has been made towards rebuilding obsolete parts of the instrumentation of the Time Department at Herstmonceux.

A complete time-keeping and distribution system, based on commercially available quartz crystal oscillators, was designed and constructed at Herstmonceux, and installed at the Cape during the latter part of 1967.

THE SUN

At both Herstmonceux and the Cape photographs of the Sun in white light have been taken on every possible day. The flare patrol with the Lyot $H\alpha$ heliograph was continued at the Cape, and the films sent to Professor C.W.Allen at the University of London Observatory. Photographs in $H\alpha$ of disk and limb features were also obtained at Herstmonceux.

Current information is widely distributed by monthly circular.

Solar activity has increased considerably but, in spite of this, the general level of activity has remained very much lower than during the corresponding period of the previous cycle.

GEOMAGNETISM

A fluxgate theodolite to permanent observatory standards has been developed. Some parts of the new rubidium magnetometer have been delivered and their performance is being assessed. Modification of the three sets of variometers to 7-day running has been started, the conversion of one set having been completed.

An analysis has been made of secular change on a world-wide basis for the period 1940 to 1965. One result of this analysis is what is believed to be the first meaningful determination of secular acceleration. The publication of *Royal Observatory Bulletin* No. 134 giving the annual values of geomagnetic elements since 1941 for all known magnetic observatories was the culmination of a three-year effort of data acquisition and verification. Tananarive, Lerwick, Valentia, Eskdalemuir and Hollandia were added to the list of I.G.Y. stations whose data have been analysed for luni-solar tidal effects using the Leaton-Malin-Finch 1962 modification of the Chapman-Miller method (66)-(68). Two models of the main and secular-change fields were produced and others assessed for incorporation into the International Geomagnetic Reference Field.

INSTRUMENTATION

Isaac Newton Telescope

The polar axis has been aligned and preliminary optical and mechanical tests carried out at the prime and Cassegrain foci.

Instrumentation for the Isaac Newton Telescope

Cassegrain spectrograph. This is now nearing completion. The optical components for the $f/3$ and $f/1.5$ cameras have been received and are undergoing tests.

Coudé spectrograph. Design of the main structural components has been completed. The contract for the camera providing the highest

linear dispersion, a spherical mirror of focal length 340 cm with the grating at the centre of curvature, and for a parabolic collimator mirror of 20 cm aperture, has been placed. The camera design has been based on a 30 cm beam, and a larger collimator will be required when gratings of this size can be obtained from manufacturers in 3–5 years. The design of the two intermediate cameras with focal lengths of 170 cm and 85 cm has been investigated by the optical section of Imperial College, headed by Dr Wynne, and completed designs were decided upon at the end of 1967. The 170 cm camera is of classical Schmidt design, and the 85 cm camera has a modified form of corrector plate. Both cameras are of single-pass form to avoid spurious image formation on the grating-corrector plate space, and to provide maximum flexibility in use.

Image intensifiers

Cassegrain spectrograph. The basic design for a versatile spectrograph of unit construction, adaptable to the Isaac Newton or 36-in. telescopes at Herstmonceux or the 74-in. or 40-in. telescopes at Pretoria and the Cape, has been investigated. The design specification for the image-tube cameras was drawn up in co-operation with Professor McGee and Dr Wynne of Imperial College. The design for an $f/2.2$ camera has been completed, and that for an $f/1.5$ camera has been submitted by Dr Wynne.

Tests. The 6-in. $f/10$ lens camera was installed in the 30-in. coudé spectrograph late in 1966 and brought into use in 1967 January for assessing the performance of existing image intensifiers for astronomical spectrography.

An E.M.I. 4-stage cascaded phosphor tube was set up by Messrs Hewitt (Oxford) and Charman (Harwell). Observations of $H\gamma$ profiles in the Orion cluster were made and the results published by Hewitt. Nine radial-velocity observations, including a complete period, were secured on the RR Lyrae variable VZ Cnc, covering 100 Å of the spectrum centred on $H\gamma$.

Tests were made on an experimental 3-stage tube of the cascaded phosphor type, provided by Professor McGee. These were very encouraging, resolution and speed being noticeably good. The tube is being redesigned at Imperial College to provide a more compact form and to overcome image drift found during the experiment.

Tests with the nuclear-emulsion recording spectracon tube have been made throughout the review period, and are still in progress, in close co-operation with Imperial College. Two major advances in the design of this tube were made by Professor McGee in 1967 to meet the problems of astronomical recording. A compact solenoid with full magnetic shielding, and provision for cooling, has been designed, and the tube

has been provided with an earthed plate in front of the photo-cathode and external to the glass window, while still maintaining the 40 kV accelerating potential applied to this electrode. Consideration is now being given to using this tube with the high-performance optical cameras required for the Cassegrain spectrograph. Resolution of at least 80 line pairs/mm has been held for considerable periods of time, at the telescope.

A two-stage R.C.A. tube, also of cascaded phosphor type, was installed by Messrs Ford (Carnegie Institution) and Purgathofer (Vienna). The observatory is grateful to the Carnegie Institution of Washington for the indefinite loan of this equipment. This tube has been used, in conjunction with a compact 2-in. aperture lens-grating spectrograph, with the existing slit and guiding arrangement on the 30-in. reflector. Spectra of radial velocity standard stars have been obtained at 34 Å/min. The gain in speed is about a factor of 25 compared with a conventional photographic plate, but this is to some extent offset by loss of resolution.

New equipment. A helium-neon laser has been obtained. This has been used for miscellaneous alignment work on various telescopes.

The electronic parts of a two-channel pulse-counting photometer have been built; the programming unit awaits specification.

Considerable progress has been made with the design of a multi-channel pulse-counting photometer, and work has started on the electronic parts.

A new and improved exposure meter for the Yapp 36-in. reflector has been built and installed.

A digitized Zeiss Ascorecord two-coordinate measuring machine with paper tape output was installed in 1967 January. This replaced the 30 × 30 Comess machine, which was transferred to the Cape.

Progress has been made in digitizing the pre-war Zeiss Asiran two-coordinate instrument, with a Ferranti moiré fringe counting system. New slides, incorporating Schneeberger linear bearings, have been fitted.

H.M. NAUTICAL ALMANAC OFFICE

The three principal activities of the Office have continued to be the preparation and publication of ephemerides for astronomical and navigational 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: *Astronomical Ephemeris* for 1968, together with a *Supplement* on the introduction of the IAU system of astronomical constants; *Nautical Almanac* for 1968; *Air Almanac* for September 1966 to April 1968 (in 5 parts); *Star Almanac for Land*

Surveyors for 1968. (The editions of the *Astronomical Ephemeris* and of the *Nautical Almanac* for 1969 were ready for publication in January 1968.) Advance proofs of the first part of the *Astronomical Ephemeris* for 1971 were distributed in December 1966, but those for 1972 have been delayed owing to the need for recomputation of some of the ephemerides as a consequence of resolutions passed at the General Assembly of the International Astronomical Union at Prague in August 1967; programmes for the computer composition of this material are almost complete.

In addition, special predictions have been prepared and distributed as follows: occultations of stars by the Moon for about 100 standard stations and also supplementary predictions of fainter stars for about a further 30 regular observers; occultations of radio sources by the Moon for about 30 observatories; a weekly service of 'look-data' predictions for visual and kinetheodolite observations of artificial satellites (on behalf of the Radio and Space Research Station); transit ephemerides of the Sun and planets for Herstmonceux and the Cape; doppler ephemerides of radio sources for Jodrell Bank; and miscellaneous astronomical data for civil and defence purposes.

Volumes 2 and 3 of the new edition of *Sight Reduction Tables for Air Navigation* (A.P. 3270) have been published and Volume 1 (for epoch 1970.0) should be published early in 1968. Work on the preparation of the new *Sight Reduction Tables for Marine Navigation* has been continued in co-operation with U.S. Naval Observatory and U.S. Naval Oceanographic Office. In addition, plotting data for two Decca-navigator chains have been supplied to the Hydrographic Department of the Ministry of Defence—the use of the I.C.T. 1909 computer has led to a large saving in the amount of time and effort required to supply the data in a suitable form.

Assistance was given to the National Maritime Museum in the preparation of a special exhibition, called 'Man is Not Lost', to celebrate the bicentenary of the publication of the *Nautical Almanac* for 1767. The exhibition was opened on 9 February 1967, and will be continued until December 1968.

The special publication *Interpolation and Allied Tables* continues to be in strong demand, and another reprint was published.

Astronomical research activities. The collected series of observations of occultations of stars by the Moon have been re-reduced back to 1960 taking into account limb corrections. The analyses of the residuals to determine the errors in the lunar ephemeris and to improve the ephemeris-time scale has been started. The I.C.T. 1909 computer has made possible the immediate reduction of all observations received; observers are notified of the results at once and it is hoped that this

will assist and encourage them to make further observations. Special reductions to determine accurate positions of radio sources have also been made on behalf of the observers. A new catalogue of radio sources that can be occulted by the Moon is being prepared.

Methods for the redevelopment to a higher precision of Brown's theory of the planetary perturbations on the motion of the Moon have been under investigation, and progress has been made on a procedure that is similar to that used by Brown, but taking advantage of the power of the I.C.T. 1909 computer. The direct evaluation of the perturbations by numerical integration is being carried out in parallel in order to provide values for immediate use and for checking the new theory.

Preliminary work on a new development of the theory of Mercury and on the techniques for the numerical integration of planetary and cometary orbits has had to be abandoned owing to a shortage of suitable staff. Computer programmes for the manipulation of harmonic series and for the inversion of ill-conditioned matrices have been written. The development of a new theory of the motions of the satellites of Mars has been started, but has also had to be left in abeyance.

Computer service. The power of the I.C.T. 1909 computer was increased by the addition of a second module of 16K words of core store in 1967 August; this has improved the efficiency of operation of several large programmes and has made possible the more frequent use of the multi-programming facilities. An incremental graph plotter was fitted in 1967 February. The computer has proved to be reliable—the average serviceability ratio being 0.96. With single-shift working the average amount of *useful* computing time (i.e. excluding all hardware and software maintenance and faults) used per week has been 32 hours, of which about 34 per cent has been for N.A.O. work, 47 per cent for the rest of the Observatory, and about 19 per cent for external users (e.g. Ministry of Defence and the University of Sussex). As far as resources have allowed, the Computer Section have provided a programming advisory service (including in some cases the writing of special programmes) and a punching service for all users. Training has also been given to operators from other establishments before the installation of their own I.C.T. 1900-series computers.

ADMINISTRATION, STAFF, CONFERENCES AND COURSES

The Natural Environment Research Council assumed responsibility for the geomagnetic work carried out at Herstmonceux and at the Hartland outstation with effect from 1967 September 1. Magnetic work started at Greenwich in 1840; under N.E.R.C. it will be integrated administratively with that done at Eskdalemuir and Lerwick. Physical removal of the department from Herstmonceux will not take place until

satisfactory alternative arrangements, especially as regards access to computer and electronics facilities, have been made.

A colloquium on the World Magnetic Survey was held at Herstmonceux on 1966 October 4–6; the proceedings have been published in *Geophys. J. R. astr. Soc.*, **12**, 521 (1967).

The XIVth General Assembly of the International Union of Geodesy and Geophysics in Switzerland in 1967 September/October was attended by two members of the Herstmonceux staff. Mr B.R. Leaton was elected Chairman of IAGA Commission II.

The XIIIth General Assembly of the International Astronomical Union in Prague in 1967 August was attended by six members of the Herstmonceux staff and two from the Cape. Dr G.A. Wilkins was elected President of Commission 4 (Ephemerides), Dr A.W.J. Cousins of Commission 25 (Stellar Photometry), and Dr D.S. Evans of Commission 30 (Stellar Radial Velocities).

At approximately quarterly intervals since 1964, small parties of R.G.O. staff, led by the Astronomer Royal, have visited the U.A.R. observatory at Kottamia to make observations with the 74-in. reflector there. The last such visit took place in 1967 March/April, since when the hostilities between Israel and the Arab countries have prevented further expeditions. Reciprocal arrangements by which Egyptian astronomers take up short-term posts or research fellowships at Herstmonceux have, however, continued. At the end of the report period Mr F. Fahim occupied a post as Assistant Experimental Officer and Dr M.K. Aly, Director of the Helwan Observatory, had been appointed a Principal Research Fellow for six months. It is hoped on both sides to resume observing at Kottamia as soon as the political situation permits.

Close relations continue with the University of Sussex. The Astronomer Royal and two other members of the staff hold honorary visiting posts and lecture regularly to M.Sc. students in astronomy, many of whom in this initial period have been from Herstmonceux; nine staff members completed the requirements for the degree in 1967. Currently, eight members of the staff are reading for a Sussex D.Phil. The possibility of thus engaging in further academic study has reacted favourably on recruitment. The summer vacation course at Herstmonceux, always well attended, is now greatly over-subscribed and is in due course resulting in a waiting list for staff vacancies and an overflow into other observatories. Sixteen students attended the course in 1967.

The 11th Herstmonceux Conference was held on 1967 April 12–13, and was devoted to a discussion on 'Helium'. It was attended by 68 visitors including Professor P. Ledoux (Liège).

Mr R.J.Dickens returned in 1967 November, after spending two years as a Carnegie Fellow at Mount Wilson and Palomar Observatories.

Co-operation between the Royal Observatory, Cape and the University of Cape Town is maintained. Dr Stoy, as Professor of Astronomy, and Dr Clube gave courses of lectures during 1967. Staff and students from the university worked at the observatory and observed regularly.

PUBLICATIONS

The following publications have appeared during the period under review, or were in an advanced stage of publication at the end of 1967, in addition to the routine publications of the Nautical Almanac Office which are referred to in the corresponding section of this Report:

Annals of the Cape Observatory Vol. XXI (Cape Photographic Catalogue for 1950.0. Zones -64° to -80° .)

Royal Observatory Bulletins Nos 116–141. Nos 116, 123, 133, 138, 140 (Time and Latitude Service Bulletins), No. 132 (Photoheliographic Results 1960) and No. 134 (Annual values of Geomagnetic Elements since 1941) were published anonymously. Other papers, which have appeared in *R. Obs. Bull.* or elsewhere, are listed below:

- (1) Alexander, J.B., 1967. On the distance to the Hyades cluster, *Observatory*, **87**, 213.
- (2) Alexander, J.B., 1967. A possible source of lithium in the atmospheres of some red giants, *Observatory*, **87**, 238.
- (3) Alexander, J.B., 1967. The chemical composition and ultra-violet excess of G dwarfs, *Mon. Not. R. astr. Soc.*, **137**, 41.
- (4) Alexander, J.B. & Pepper, S., 1967. The helium content of Groombridge 1830, *Observatory*, **87**, 267.
- (5) Alexander, J.B. & Stansfield, R., 1966. The $B-V$ of the Sun, *R. Obs. Bull.*, No. 119.
- (6) Alexander, J.B. & Yallop, B.D., 1967. The $G-R$ and $R-I$ colours of late-type dwarfs, *R. Obs. Bull.*, No. 131.
- (7) Ball, C. & Pagel, B.E.J., 1967. Abundances of carbon and nitrogen in the halo red giant HD 122563, *Observatory*, **87**, 19.
- (8) Barker, E.S., Evans, D.S. & Laing, J.D., 1967. Orbital elements of nine spectroscopic binaries, *R. Obs. Bull.*, No. 130.
- (9) Bingham, R.G. & Shakeshaft, J.R., 1967. Local structure of the galactic magnetic field, *Mon. Not. R. astr. Soc.*, **136**, 347.
- (10) Bingham, R.G., 1967. Magnetic fields in galactic spurs, *Mon. Not. R. astr. Soc.*, **137**, 157.
- (11) Cannon, R.D., 1966. Light variations in an infra-red object, *Observatory*, **86**, 150.
- (12) Cannon, R.D., 1967. Light variations in the Taurus infra-red object, *Observatory*, **87**, 231.
- (13) Cannon, R.D. & Penston, M.V., 1967. Optical variations of 3C 446, *Nature, Lond.*, **214**, 256.
- (14) Catchpole, R.M., Pagel, B.E.J. & Powell, A.L.T., 1967. Chemical composition of the mild subdwarf μ Cassiopeiae, *Mon. Not. R. astr. Soc.*, **136**, 403.
- (15) Clube, S.V.M., 1967. An absolute system of proper motions, *Q. Jl R. astr. Soc.*, **7**, 257.

- (16) Clube, S.V.M., 1967. The kinematics of Gould's Belt, *Mon. Not. R. astr. Soc.*, **137**, 189.
- (17) Clube, S.V.M., 1967. Gould's Belt, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 118.
- (18) Clube, S.V.M., 1968. Proper motions of RR Lyrae Variables, I, *R. Obs. Bull.*, No. 136.
- (19) Corben, P.M., 1966. Photoelectric magnitudes and colours for bright southern stars, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 44.
- (20) Cousins, A.W.J., Lake, R. & Stoy, R.H., 1966. Photoelectric magnitudes and colours of southern stars, II, *R. Obs. Bull.*, No. 121.
- (21) Cousins, A.W.J., 1966. Fabry photometry of bright southern stars, *R. Obs. Bull.*, No. 122.
- (22) Cousins, A.W.J., 1966. Methods of observation and reduction of photometric observations at the Cape Observatory, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 100.
- (23) Cousins, A.W.J., 1967. Comments on the *UBV* system in the southern hemisphere, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 8.
- (24) Cousins, A.W.J., 1967. *U-B* for stars in the E regions, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 151.
- (25) Cousins, A.W.J. & Evans, D.S., 1967. Further remarks on the cepheid HR 5527, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 84.
- (26) Cousins, A.W.J. & Lagerweij, H.C., 1966. BL Telescopii, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 170.
- (27) Cousins, A.W.J. & Lagerweij, H.C., 1967. Magnitudes of some very bright stars, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 83.
- (28) Danziger, I.J. & Dickens, R.J., 1967. Spectrophotometry of new short-period variable stars, *Astrophys. J.*, **149**, 55.
- (29) Dickens, R.J., 1967. A new Delta Scuti variable, *Astrophys. J.*, **148**, L33.
- (30) Dickens, R.J. & Carey, J.V., 1967. Studies of the globular cluster ω Centauri, VI. Photometry of cepheids with periods greater than one day, *R. Obs. Bull.*, No. 129.
- (31) Dickens, R.J. & Woolley, Sir Richard, 1967. Studies of the globular cluster ω Centauri, V. HR diagram, structure and dynamics, *R. Obs. Bull.*, No. 128.
- (32) Eggen, O.J., 1966. Three-colour photometry of the components of wide double and multiple systems, II. 298 systems, *R. Obs. Bull.*, No. 120.
- (33) Eggen, O.J., 1966. Colours, luminosities and motions of the nearer giants of types K and M, *R. Obs. Bull.*, No. 125.
- (34) Eggen, O.J., 1968. Three-colour photometry of 4000 northern stars, *R. Obs. Bull.*, No. 137.
- (35) Evans, D.S., 1967. The standardisation of plate sizes for astronomical use, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 42.
- (36) Evans, D.S., 1967. Radial velocities of southern galaxies, III, *Observatory*, **87**, 224.
- (37) Evans, D.S., 1967. The revision of the general catalogue of radial velocities, *I.A.U. Symposium*, No. 30, 57.
- (38) Evans, D.S., 1967. On period finding and on p Velorum, *I.A.U. Symposium*, No. 30, 205.
- (39) Fairall, A.P., 1966. A search for quasars, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 79.
- (40) Gasson, R.E.M. & Pagel, B.E.J., 1966. Forbidden lines in the spectra of the Sun and Arcturus, *Observatory*, **86**, 196.
- (41) Hartley, K.F. & Powell, A.L.T., 1967. The effect of slit width on equivalent width measurements, *Observatory*, **87**, 75.
- (42) Jones, D.H.P., 1966. A spectral classification scheme applicable to late-type stars of differing metal deficiency, *R. Obs. Bull.*, No. 126.

- (43) Jones, D.H.P., 1966. HR 1653—A new δ Scuti variable, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 97.
- (44) Jones, D.H.P. & Lagerweij, H.C., 1966. The δ Scuti variable I Monocerotis, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 168.
- (45) Lagerweij, H.C., 1967. Three-colour observations of η Chamaeleontis, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 53.
- (46) Laurie, P.S., 1967. The Board of Visitors of the Royal Observatory—I: 1710–1830, *Q. Jl R. astr. Soc.*, **7**, 169.
- (47) Laurie, P.S., 1967. Sunspots (1965), *Q. Jl R. astr. Soc.*, **7**, 201.
- (48) Laurie, P.S., 1967. Sunspots (1966), *Q. Jl R. astr. Soc.*, **8**, 272.
- (49) Laurie, P.S., 1967. The Board of Visitors of the Royal Observatory—II: 1830–1965. *Q. Jl R. astr. Soc.*, **8**, 334.
- (50) Laurie, P.S. & Leaton, B.R., 1966. Solar activity and geomagnetic storms, 1965, *Observatory*, **86**, 170.
- (51) Laurie, P.S. & Leaton, B.R., 1967. Solar activity and geomagnetic storms, 1966, *Observatory*, **87**, 181.
- (52) Leaton, B.R. & Malin, S.R.C., 1967. Recent changes in the magnetic dipole moment of the Earth, *Nature, Lond.*, **213**, 1110.
- (53) Lourens, J.v.B., 1966. Astrometric observations of comet Ikeya-Seki (1965f), *Mon. Notes astr. Soc. Sth Afr.*, **25**, 54.
- (54) Lourens, J.v.B., 1966. Observations of the minor planet 1566—Icarus, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 147.
- (55) Lourens, J.v.B., 1967. Very red star in Vela, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 114.
- (56) Lourens, J.v.B. & Russo, T.W., 1966. A new determination of the proper motion of BL Telescopii, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 95.
- (57) Lynden-Bell, D., Cannon, R.D., Penston, M.V. & Rothman, V.C.A., 1966. Correlation between peculiar galaxies and radio sources, *Nature, Lond.*, **211**, 838.
- (58) Lynden-Bell, D., 1966. Encounterless stability of stellar systems, *I.A.U. Symposium*, No. 25, 78.
- (59) Lynden-Bell, D., 1967. Co-operative phenomena in stellar dynamics. Lectures in applied mathematics **9**: Relativity theory and Astrophysics, 2, Galactic Structure, *Am. Math. Soc.*
- (60) Lynden-Bell, D., 1967. On the origin of space-time and inertia, *Mon. Not. R. astr. Soc.*, **135**, 413.
- (61) Lynden-Bell, D., 1967. Statistical mechanics of violent relaxation in stellar systems, *Mon. Not. R. astr. Soc.*, **136**, 102.
- (62) Lynden-Bell, D. & Ostriker, J.P., 1967. On the stability of differentially rotating bodies, *Mon. Not. R. astr. Soc.*, **136**, 293.
- (63) Lynden-Bell, D., 1967. Are giant galaxies helium rich?, *Observatory*, **87**, 163.
- (64) Lynden-Bell, D., 1967. The formation of the Galaxy, *I.A.U. Symposium*, No. 31, 257.
- (65) Malin, S.R.C. & Leaton, B.R., 1966. Discussion of Papers by P.F.Fougere 'Spherical Harmonic Analysis, 1 and 2', *J. geophys. Res.*, **71**, 4698.
- (66) Malin, S.R.C., 1967. Luni-solar daily variations of the geomagnetic field at observatories in the British Isles during the I.G.Y., *Geophys. J. R. astr. Soc.*, **13**, 397.
- (67) Malin, S.R.C., 1967. Luni-solar daily variations of the geomagnetic field at Tananarive during the I.G.Y., *Nature, Lond.*, **215**, 719.
- (68) Malin, S.R.C. & Leaton, B.R., 1967. The solar and luni-solar daily variations of the geomagnetic field at Hartland during the I.G.Y., *Geophys. J. R. astr. Soc.*, **13**, 359.

- (69) Menzies, A., 1966. Astronomy of position, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 59.
- (70) Murray, C.A. & Clements, E.D., 1968. Investigation of proper motions in the field of the Cluster M67, II. The outer region, *R. Obs. Bull.*, No. 139.
- (71) Murray, C.A., 1968. Investigation of proper motions in the field of the Cluster M67, III. The field stars and the motion of the cluster, *R. Obs. Bull.*, No. 141.
- (72) Ostriker, J.P., Bodenheimer, P. & Lynden-Bell, D., 1966. Equilibrium models of differentially rotating zero-temperature stars, *Phys. Rev. Lett.*, **17**, 816.
- (73) Pagel, B.E.J., 1966. Classification of K dwarfs according to metal abundance, *I.A.U. Symposium*, No. 24, 231.
- (74) Pagel, B.E.J., 1966. Critical summary of abundance determinations in stars of type G8 and later, *I.A.U. Symposium*, No. 26, 272.
- (75) Pagel, B.E.J., 1966. Summary on the correlation between stellar chemical composition and age and kinematic properties, *I.A.U. Symposium*, No. 26, 359.
- (76) Pagel, B.E.J., 1966. Abundance differences among population I stars, *Stellar evolution*, ed. by A.G.W.Cameron, p. 431, Plenum Press, London.
- (77) Pagel, B.E.J., 1967. The search for ageing effects in the composition of red stars of the galactic halo, *Trieste Colloquium on Late-Type Stars*, ed. by M.Hack, p. 133.
- (78) Pagel, B.E.J., 1967. Models of the outer layers of the Sun, *N.A.T.O. Course on Solar Physics*, ed. by J.Xanthakis, p. 1.
- (79) Pagel, B.E.J. & Powell, A.L.T., 1966. Analysis of the cool halo subdwarf HD 25329, *R. Obs. Bull.*, No. 124.
- (80) Palmer, D.R., Walker, E.N., Jones, D.H.P. & Wallis, R.E., 1967. The radial velocities, spectral types and projected rotation velocities of 633 bright northern A stars, *R. Obs. Bull.*, No. 135.
- (81) Penston, M.V., 1966. Dynamics of self-gravitating gaseous spheres, I. The collapse of an isothermal gas sphere, *R. Obs. Bull.*, No. 117.
- (82) Penston, M.V., 1966. On the nature of the Neugebauer-Martz-Leighton objects, *Observatory*, **86**, 121.
- (83) Penston, M.V., 1967. The polarization of NML Cygnus, *Observatory*, **87**, 276.
- (84) Penston, M.V. & Cannon, R.D., 1967. Variation of 3C 345. *I.A.U. Circular*, No. 2000.
- (85) Penston, M.V. & Rowan-Robinson, G.M., 1967. On the anisotropic distribution of quasars at large red-shift, *Nature, Lond.*, **213**, 375.
- (86) Pope, J.D., Palmer, D.R. & Alexander, J.B., 1966. The Cassegrain spectrograph of the Yapp 36-in. reflector at Herstmonceux, *R. Obs. Bull.*, No. 118.
- (87) Sadler, D.H., Blythe, J.H. & Duncombe, R.L., 1966. Sight reduction tables for marine navigation, *J. Inst. Nav., Lond.*, **19**, 281.
- (88) Sadler D.H. 1966. Dirk Brouwer *Nature Lond.* **211**, 241.
- (89) Sadler D.H. 1966. Prediction of eclipses *Nature Lond.*, **211**, 1129.
- (90) Sadler, D.H., 1967. The bicentenary of the Nautical Almanac, *J. Br. astr. Ass.*, **77**, 237; *Q. Jl R. astr. Soc.*, **8**, 161.
- (91) Smith, H.M., 1967. Astronomical time scales, *Colloquium on the Definition, Realization and Use of Time and Frequency*, Institute of Electrical Engineering.
- (92) Smith, H.M., 1967. Report of Commission 31 (Time) of the I.A.U., XIII General Assembly, Prague.
- (93) Taylor, G.E., 1967. A mariner's equinoctial dial of 1634?, *J. Inst. Nav., Lond.*, **20**, 343.

- (94) Taylor, G.E., 1967. A brief review of visual satellite tracking, *J. Br. astr. Ass.*, **77**, 196.
- (95) Thomas, D.V., 1966. Results of observations made with the Danjon Astrolabe O.P.L. No. 11 at the Cape, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 115.
- (96) Thomas, D.V., 1966. Polar-axis adjustment and flexures of the Elizabeth Telescope, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 155.
- (97) Thomas, D.V., 1967. A proposal for a reflecting astrolabe, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 2.
- (98) Thomas, D.V., 1967. Group corrections and the optimization of an observing programme, *R. Obs. Bull.*, No. 127.
- (99) Thomas, D.V., 1967. A reflecting astrolabe?, *Observatory*, **87**, 139.
- (100) Walker, E.N., 1966. A comment on the pole-on hypothesis for peculiar A stars, *Observatory*, **86**, 110.
- (101) Walker, E.N., 1966. A list of newly identified metallic-line A stars, *Observatory*, **86**, 154.
- (102) Warren, P.R., 1966. Three-colour photometry of RR Lyrae stars, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 103.
- (103) Warren, P.R., 1967. Three-colour photometry of RR Lyrae stars, II, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 20.
- (104) Wild, P.A.T., 1966. Astronomy and modern physics, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 131.
- (105) Wild, P.A.T., 1967. Colour equations for the Victoria refractor, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 128.
- (106) Wild, P.A.T. & Lagerweij, H.C., 1967. Preliminary photometric elements of the eclipsing binary system 9 Chamaeleontis, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 144.
- (107) Wilkins, G.A., 1966. Report of the proceedings of joint discussion on the I.A.U. system of astronomical constants, *Trans int. astr. Un.*, **12B**, 599.
- (108) Wilkins, G.A., 1966. A new determination of the elements of the orbits of the satellites of Mars, *I.A.U. Symposium*, No. 25, 271.
- (109) Wilkins, G.A., 1967. The determination of the mass and oblateness of the Earth from the orbits of its satellites, *Mantles of the Earth and Terrestrial Planets*, ed. by S.K.Runcorn, p. 77.
- (110) Williams, P.M., 1966. Photometry of NGC 2451, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 122.
- (111) Williams, P.M., 1967. Photoelectric photometry of NGC 2451, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 30.
- (112) Williams, P.M., 1967. The open cluster Cr 140, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 126.
- (113) Williams, P.M., 1967. The open cluster NGC 2451, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 139.
- (114) Willstrop, R.V., 1967. A note on HR 5527, *Mon. Notes astr. Soc. Sth Afr.*, **26**, 13.
- (115) Woolley, Sir Richard & Stewart, J.M., 1967. Motion of A stars perpendicular to the galactic plane—II, *Mon. Not. R. astr. Soc.*, **136**, 329.
- (116) Woolley, Sir Richard & Palmer, D.R., 1967. Halo characteristics of W Virginis stars, *Observatory*, **87**, 173.
- (117) Yallop, B.D., 1966. The background radiation of the Universe, *Mon. Notes astr. Soc. Sth Afr.*, **25**, 137.