Q. Jl R. astr. Soc. (1973) **14**, 81–102

ROYAL GREENWICH OBSERVATORY

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

(Report for the year ending 1971 December 31)

STELLAR KINEMATICS, DYNAMICS AND AGES

Nearby stars

An analysis of the properties of the orbits of stars within 25 parsecs based on material in *R.O. Annals* No. 5 has been carried out under the direction of the Astronomer Royal (**69**).

Mrs Penston has used the coudé scanner on the 100-inch reflector on Mount Wilson to investigate the strength of the H and K emission in late-type dwarfs in the manner described by Wilson (*Astrophys. J.*, **153**, 221, 1968). Members of stellar groups were observed to investigate isochrones in the intensity/(B-V) diagram, and she hopes to apply the results of this to field stars observed from the *Catalogue of Stars within 25 pc.*

Radial Velocities

A catalogue of about two thousand unpublished stellar radial velocities measured at Herstmonceux is in the final stages of preparation. The velocities have been the basis of several past and present studies in galactic kinematics and stellar statistics. The solar motion of G and K stars deviates from the value in the solar neighbourhood at distances of around 500 pc in certain directions. Spectra of faint K stars at $l \sim 90°$, $b \sim |45|°$ were taken at 180 Å mm^{-1} and measured with a new set of empirical wavelengths. They are being analysed by Mrs Sinclair to determine the V galactic-rotation component of K giants 400 pc above the plane. The catalogue will also contain radial velocities of stars within 25 pc, A and K stars in the north galactic cap, spectroscopic binaries and the results of other smaller programmes.

Mr Wood has observed velocities of B stars in the Sco–Cen association with the 74-inch reflector at Pretoria.

Proper motions

Dr Clube has studied techniques for handling the analysis of stellar proper motions. A weakness of conventional least-square analysis has been pointed out, which is of special significance in the study of stellar kinematics. He has devised an analytical procedure for seeking the solar motion vector and the eight determinate components of the differential

velocity field corresponding to the mode of any observed distribution of proper motions. The method reduces distortions introduced by high-proper-motion stars, and has the advantage of being independent of any presumed model of local stellar kinematics. Extensive investigations of proper motions in the FK4 and AGK3 have been carried out, and the results give revised corrections to the precession constant and motion of the equinox as well as values for the constants of galactic rotation. Preliminary indications are that Oort's B constant is numerically larger than supposed heretofore.

Using first-epoch plates taken with the 60-inch reflector on Mount Wilson, and the second-epoch plates taken with the same telescope by Mrs Penston, Mr Murray has determined absolute proper motions of 21 faint M dwarfs in SA57 and the region of the Coma cluster of galaxies. These were selected on the basis of an objective prism survey by N. Sanduleak of the Warner and Swasey Observatories. These stars appear to have a velocity dispersion of only about 10 km s^{-1}, and to be heavily concentrated towards the galactic plane.

The repetition of the astrometric plates on the Kapteyn Selected Areas has continued.

An examination of the validity of standard procedures for reducing relative proper motions to absolute by kinematic methods has been made by Mr Aslan. When due allowance is made for the exclusion of large proper motions in a sample of reference stars, he finds that absolute proper motions agree systematically with those on the FK4 system, corrected to Fricke's values of the precessional constants, rather than to either the Lick or Pulkovo values (**4**, **5**).

TRIGONOMETRIC PARALLAXES

Twenty-six inch refractor

A preliminary analysis of the results in 19 fields is being carried out by Dr Thomas. Two of the fields contain wide binaries for which parallaxes have been measured for each component. A further 22 fields are awaiting measurement. An additional 90 stars have been phased into the observing programmes.

The new parallaxes of 17 late-type stars in Gliese's catalogue are on average 0″·01 smaller than the values given by Gliese.

The average standard error of a parallax is 0″·0075 which represents a gain in weight, compared with observation at Greenwich, of a factor between 2 and 5 depending on right ascension. This has been achieved mainly by a significant increase in the total numbers of plates measured, but there is also an increase of 40 per cent in the weight of the plates due to improved reduction techniques.

Isaac Newton telescope

A programme for measuring parallaxes of faint stars has been started. So far, plates have been taken on 19 fields, mostly selected from Luyten's *Catalogue of Stars of Low Luminosity*.

VARIABLE STARS

The Astronomer Royal and Mrs Savage have modified the Baade–Wesselink method of radius determination to allow for the effect of surface gravity on the specific intensity in B and V. They have used this to classify the field RR Lyrae stars into five groups which it is hoped are homogeneous. These have been further analysed using the methods of statistical and secular parallaxes and of pulsation theory. Limits have been set on the values of mass and absolute magnitude pertaining to each group (**70**).

A spectrum of BS Aqr was obtained to see if there was any repetition of the peculiar behaviour reported in *ROB* 37. This was not detected.

Dr N.Yilmaz, of the A.U. Fen Fakultesi, Turkey, spent a year at the RGO on a U.N. fellowship. She collaborated with Dr M.W.Feast in a kinematic study of the semi-regular variable stars.

Mr Z.Aslan has discussed his proper-motion material on semi-regular variables and derived absolute magnitudes as a function of period and spectral type.

Mr Walker has studied the radial velocity and light curve of HD 152667, a spectroscopic binary P Cygni star; this star lies close to the position of the X-ray source Sco X2, and the two objects may be associated (**63**).

At the Cartuja observatory, Walker has searched for short-period variations in early-type stars. Several stars have been found with suspected variations with periods less than an hour. The spectroscopic observations of a suspected β Cephei star, HD 214080, have been studied, and confirm its variability.

X-RAY SOURCES

Dr P.Murdin and Dr Webster have identified HD 226868, a BoIb supergiant at a distance of 2kpc, with the Cygnus X-1 X-ray source (**38**). The star was found to be a spectroscopic binary in which the radial velocity and the hard X-ray flux vary with the same period of 5·6 days. The surprising result emerged that the hard X-rays are dimmest when the mysterious companion is nearest to the observer. Dr Jackson explained this neatly on the assumption that the companion is a source of relativistic electrons, which produce inverse Compton X-rays from the B star's photons. The photons bounce off as the hardest X-rays when the collisions are head-on.

Following the publication in September 1970 of the positions of three galactic X-ray sources with an accuracy better than $\pm 2'$, Mr Morrison published predictions for a series of occultations for one of them, GX3+1, during 1971. Two of the possible occultations were successfully observed by groups from the University of Leicester and the Mullard Space Science Laboratory, using rocket-borne instruments launched from Woomera. The observed times provided strong evidence for the association of GX3+1 with a star of the 16th magnitude. For this work, plates were specially taken on the Cape 24-inch refractor and measured in the Astrometry Department (**34**).

STAR CLUSTERS

Dr Bingham and Mr W.Martin have developed a method of computing the relationship between the colour–magnitude array of a globular cluster and its integrated spectral properties. The results have been applied to thirty-eight globular clusters, and it appears that metal-rich ones are distributed in the Galaxy in a disk 6 kpc thick and 18 kpc in diameter.

STELLAR ATMOSPHERES AND ABUNDANCE STUDIES

The photographic Cassegrain spectrograph of the INT has been used by Mrs D.L.Harmer and Dr B.E.J.Pagel to investigate ultra-violet CN band intensities in subdwarfs and a few metal-deficient giants. By comparing the band intensity with that found in F stars with known atmospheric parameters, one can investigate differential variations in the N/Fe abundance ratio thus following up the interesting results previously obtained from curve-of-growth analyses of the halo subgiant ν Indi (very weak CN) and the halo subdwarf HD 25329 (strong CN). Recent theories of explosive nucleosynthesis lead to the possibility that the nitrogen abundance in the interstellar medium varies with the general degree of enrichment more rapidly than that of many other elements, and this prediction is consistent with the earlier work on ν Indi and with results published by L.Searle in 1971 on composition gradients displayed by H II regions in Sc galaxies, from which one may speculate that, roughly, $[N/Fe] \simeq [Fe/H]$, where square brackets indicate a difference in the logarithm of the relevant abundance ratio. Results obtained from the INT programme to date suggest that the extreme subdwarf Groombridge 1830 conforms to this pattern, while for the mild subdwarfs 85 Peg and μ Cas the value of [N/Fe] compared to the Sun is only marginally below zero. HD 25329 is an outstanding exception to all expectations and to the general observation of weak CN in low-metal stars, having $[N/Fe] \simeq +0{\cdot}9$. A curve-of-growth analysis of Groombridge 1830 by J.Tomkin indicates that $[Fe/H] = -1{\cdot}0$ and that carbon and especially nitrogen are overdeficient; the results are being checked with model-atmosphere studies of the profiles of strong lines.

Other abundance studies have yielded results for the δ Scuti variable 20 CVn (Dickens *et al.* (16)), for ε Aur (D.J.Stickland & D.R.Branch) and for seven double-lined, metallic-line binary systems (Stickland). Like δ Sct and ρ Pup (but not δ Del), 20 CVn turns out to be metal-rich ([Fe/H] = +0·4) in agreement with suspected membership of the Hyades moving group; no significant anomalies in individual metal: iron ratios have been found. ε Aur was found by comparison with α Per to have quite a normal composition, despite the anomalous features of the double system. The study of the metallic-line binary confirms M.A.Smith's finding that microturbulence varies with effective temperature, reaching a peak near 8000°K, and suggests that there may also be an inverse correlation between microturbulence and [Fe/H].

Mr Alexander and Dr Branch are studying the problem of explaining colour indices of metal-rich stars like δ Pav and η Boo, and they find that molecular bands (e.g. of C_2, CH, CN) contribute appreciable blanketing in *B* and *U*. However, even so, the *U-B* colours are hard to explain. Alexander has made a photometric study of the RR Lyrae variable HD 176387 of Bailey type c discovered by A.Przybylski. In this case it appears that the general features of the anti-clockwise loop in the (*U-B*, *B-V*) plane can be explained by the variations of temperature and surface gravity throughout the cycle.

A suggestion made by Pagel and Tomkin in 1969, that estimates of red-giant luminosities using the Wilson–Bappu effect are often appreciably influenced by an effect of metal abundance on the width of the K_2 emission core, has received some support from independent investigations carried out by R.M.West, H.L.Helfer and P.Kjaergaard, but reasons for doubting this suggestion have been put forward by O.C.Wilson. A new investigation has therefore been carried out by Pagel, using trigonometric parallaxes of an almost complete sample of G and K giants brighter than $V = 3^{m}{\cdot}8$ and north of declination $-20°$ to deduce a mean correction to K-line luminosities. The correction turns out to be close to $0^{m}{\cdot}6 \pm 0^{m}{\cdot}1$ (s.e.), in good agreement with comparable corrections deduced from recent luminosity calibrations of MK classes by B.Ljunggren and T.Oja (in 1965) and by J.Jung (in 1970). If the moving-cluster modulus of the Hyades is accurate, then the above correction can plausibly be attributed to the fact that most nearby red giants have lower metal abundance than the Hyades. If, alternatively, one accepts G.Wallerstein's conclusion in 1971, that the Hyades modulus should be increased by $0^{m}{\cdot}2$, then there is a residual effect of about $0^{m}{\cdot}4$ due to differences in metal abundance.

Further studies of stellar chromospheric effects are being carried out by Mr R.A.E.Fosbury, using a spectracon image tube at 10 Å mm^{-1} in the 30-in. coudé spectograph to study the profile of the Hα line allowing for instrumental profile. Variable Hα depths have been discovered in λ And

and in some supergiants. Another stellar chromospheric effect is the appearance of an emission line of Nd II in the wing of the K-line of Arcturus (**21**), similar to one or two lines that have been known for a long time near the limb of the Sun.

Branch is seeking further identifications for features in supernova spectra, using diagrams of feature wavelengths plotted against time. Type II spectra show a well-defined behaviour, with absorption lines of hydrogen blue-shifted, in the mean, by 700 km^{-1}. Comparison with the spectrum of the 'narrow-line' supernova of 1961 in NGC 1058 suggests the presence of Fe II absorptions in Type II spectra. Spectra of Type I supernovae are being compared to the narrow-line supernova of 1954 in NGC 4214.

Using the linear response of the spectracon, with the image tube spectrograph on the INT, Dr Webster has measured the intensities of the Balmer lines in planetary nebulae relative to the Balmer continuum, up to H 28, and found them to agree with theoretical values.

THEORETICAL STUDIES

Dr Lynden-Bell completed studies, stimulated by Schmidt, of a new method of dealing with observational selection. Applied to the 3CR quasars and to the N galaxies the method shows unambiguously that the dimmest quasars are by far the most common, so that quasars are not a well-isolated class of objects (**27**). He further studied black-hole models of quasars (**29**) and in cooperation with Rees (**31**) he reviewed all the data on the galactic centre in the light of such models. Working with Kalnajs on another topic he concludes that the transfer of angular momentum outwards is the basic process behind the generation of spiral waves in galaxies.

Dr Yallop has also continued his theoretical work on the equilibrium and stability of the high angular momentum differentially rotating polytropes.

Dr Jackson has studied possible explanations for the virial theorem discrepancies in small groups of galaxies. He concludes that the discrepancies are certainly real and that none of the conventional explanations seems likely.

EXTRA-GALACTIC STUDIES

The programme for optical monitoring of quasars and radio sources with the 26-inch refractor has continued under the direction of Dr Yallop (**62**).

A co-operative programme of monitoring the Seyfert galaxy NGC 4151 has been carried out in 1970 and 1971 with photographic observations on the 26-in. and photoelectric *UBV* photometry on the 20-in. at Mount

Palomar by Mrs Penston, contributing to an investigation of the correlation between the optical and infra-red variations in the Galaxy (47). The infra-red observations have been made by workers at the Hale Observatories, Pasadena and the Kitt Peak National Observatory. During the first season an infra-red maximum followed an optical maximum by about 70 days suggesting a dust shell surrounding the galaxy for the infra-red emission. The data from the second season are less clear. Other Seyfert galaxies have also been followed with less complete coverage.

Mr Tritton has been studying the results of his programme of southern hemisphere radio-source identifications for which he took observations at Pretoria. He also measured redshifts of about 15 southern radio galaxies and a few southern quasars (61). It was possible to get spectra of objects at 17^m with the image-tube spectrograph on the 74-in. telescope but, although quite possible, the work became less productive when the object was invisible on the slit.

Also with Pretoria material, Mr Wood is completing his spectrographic study of the 1968 supernova in NGC 5236.

During his tenure of a Carnegie Fellowship at the Hale Observatories, Dr M.V.Penston completed his work on the identification of radio sources in the Ryle–Neville north polar survey. The 48-in. Schmidt telescope proved to be a more suitable instrument for this project than the INT on which it had been started (46).

Dr Webster has obtained spectra of several galactic nuclei with strong emission-lines. The profiles of the hydrogen lines in Markarian 1 are indistinguishable from those of the forbidden oxygen lines, in contradiction to a report in the literature.

Radio sources

Following the successful completion of tests on the astrometric performance of the Wynne corrector at the prime focus of the INT (39) Mr Murray has continued with the programme of optical positions of radio sources. New positions of nine sources were obtained during the year.

Messrs Morrison and Murray have collaborated with astronomers at the Institute of Theoretical Astronomy and the Cambridge Observatories in a rediscussion of the radio occultations and the optical position of 3C 273B; it now appears that the optical and radio positions are coincident (36).

PHOTOELECTRIC PHOTOMETRY

Herstmonceux

The two-star photometer designed by Dr Bingham is being tested on the 36-in. reflector. Five two-channel 'people's' photometers have been

completed; Dr Bingham has made Hβ measurements of faint objects with one of these on the INT, and the four others have been sent to St Andrews, Armagh, Pretoria and the Cape.

Sierra Nevada

Photoelectric observations continued to be made at the Cartuja Observatory until August, 1971. The main observing programmes were nearby stars, and local standards in the fields of quasars and in Selected Areas. Miss Epps has almost completed the reduction of all observations, 1969 to 1971, to the *UBV* system.

Twenty-inch Mount Palomar

While a guest investigator at the Hale Observatories, Mrs Penston made observations of the light and colour curves of several RR Lyrae variables. Sequences were also set up in the Selected Areas 3, 5, 83, 85, 89, 91, 93, 95, 97, 99 with 12 to 15 stars in each reaching $V=13^{m}$. In addition, observations were made of hot blue stars currently being studied by Professor J.L.Greenstein.

Israel

Drs Pagel and Penston carried out photoelectric *UBV* observations during Oct and Nov 1971 from the Florence and George Wise Observatory of Tel Aviv University at Mitzpeh Ramon, Israel, using the new 40-in. Boller and Chivens telescope dedicated on 1971 Oct 26 and a simple photometer belonging to the RGO. The results were encouraging, and have produced valuable data on the photoelectric sequence for NGC 1275 and young stars in Orion. It is hoped that further programmes can be carried out with the permanent photometer and image-tube spectrograph of the Wise Observatory installed at about the end of 1971.

POSITIONAL ASTRONOMY

Meridian observations

Satisfactory progress has been made with the observations with the Cooke Transit Circle of the zodiacal stars which are required for lunar occultations, some 40 per cent of the observations having been completed.

Observations of the Sun and planets continue to be made regularly. The reductions of the observations of these bodies accumulated at Herstmonceux since 1957 are at last being resumed.

Preparations are in hand for starting observations of the Northern PZT stars in an international programme being organized by Tokyo Observatory.

The new type of graticule (with two interrupted parallel lines) has achieved a significant improvement in the accuracy of measurement of the circle-camera films.

The Herstmonceux and Cape Meridian Departments continue to keep in close contact. Mr A.Shortland, head of the Cape Meridian Department, spent some weeks at Herstmonceux for consultation. The Cape T.C. information is now sent to Herstmonceux in written form, laid out for routine punching onto cards.

Mr Blackwell has continued with the assembly of the correction tables for direct access, and a start has been made on transferring the early observations of selected stars to punched cards for proper-motion determinations.

Photographic star positions

The densely overlapped survey of the southern sky using the Cape wide-angle camera is now essentially complete (mean epoch 1969), and half the 5000 plates have been transferred to Herstmonceux. Approximate (x,y) co-ordinates of stars brighter than $m_v \sim 11$ are being recorded with a D-Mac table, prior to measurement on the Galaxy machine, and, to date, some 500 plates have been taken through the first stage of the process—which gives an edited paper tape for controlling Galaxy in its measurement mode. An additional D-Mac table has now been set up at the Cape, with a view to increasing the rate of measurement in the coming year.

TIME AND LATITUDE SERVICE

PZT

The PZT continued in service throughout the year and observations of 2400 star transits were obtained on 132 plates. The improved mechanical operation of the plate-carrier drive following the installation of the stepping motor, described in last year's report, has been maintained without loss in accuracy.

The new catalogue contains 120 stars (98 of which appeared in the previous catalogue, used since 1965) and it was introduced simultaneously at Herstmonceux and Calgary in 1971 April. The 22 new programme stars were observed at the two stations in 1969 and 1970 and the corrections to the provisionally adopted positions determined at the two stations were in close agreement. At the same time, corrections to the positions of the 98 stars retained in the new catalogue were also computed and revised positions were adopted. The results have also shown that corrections to the proper motions can be determined with only a few years' observation.

Co-operation with the BIH has continued and the observations were reduced daily in October and November, for the rapid determination of

the data supplied by the BIH for the guidance of the Mariner 9 space probe.

Research on the polar motion for the years 1916–33 was completed and the results were presented in *IAU Symposium No.* 48.

Danjon Astrolabe

The Danjon astrolabe which was returned from South Africa in 1970 was refurbished in the engineering workshop and made ready for service. The method of observation based on photographic recording of the micrometer at preset times has been discontinued and the instrument is now connected to a paper-tape punch for recording the clock times of micrometer contacts.

The Herstmonceux computer program providing for the re-reduction of all the 1965–69 observations on a uniform system independent, to a first approximation, of observer, observing clock, group, the selection of standard stars observed, and time of night, and empirically corrected for variation of prism angle, was completed and proved early in the year. A preliminary analysis of the time and latitude results for the determination of observer and group corrections, and examination of diurnal variations, has now been completed. A preliminary analysis of the prism angle results, and determination of provisional corrections to the adopted places of standard stars is still in progress. Most of this work has been undertaken at the Cape, under the direction of Dr Thomas at Herstmonceux.

Rotation of the Earth

At the end of March there was a change in the rate of rotation of the Earth relative to the atomic time scale from 2·7 ms day^{-1} to 3·1 ms day^{-1} losing.

By international agreement the offset of the carrier frequencies of the co-ordinated radio time signals remained at —300 parts in 10^{10}, equivalent to a losing rate of 2·6 ms day^{-1}.

Atomic time scale

The Greenwich atomic time scale GA2 has been published quarterly in the Greenwich Time Reports; it is one of the seven independent atomic time scales from which the International Atomic Time Scale is formed and has been within two and a half microseconds of IAT throughout the year. GA2 is formed from selected caesium clocks at Herstmonceux and, in order to maintain uniformity, rate corrections have been applied to minimize the effects of the introduction or removal of clocks. It follows that GA2 no longer represents the true mean of the clocks on which it is based, and it has therefore been decided to publish five-day values of the individual clocks referred to GA2. No rate corrections have been applied for slow frequency drifts in the

clocks. The co-ordinated time scale UTC(RGO) is obtained arithmetically from GA2. To meet the new requirements, additional equipment has been developed and installed and external modifications made to existing units. International comparisons of atomic clocks are made by measurements of Loran-C pulses and by travelling clocks, and additional Loran-C receivers have been brought into service. The USNO has made two visits with caesium clocks on regular flights.

International co-operation

The outstanding feature of current developments is the increasing degree of international co-operation. In order to achieve the standards of accuracy now demanded in the up-to-date knowledge of UT and polar variation, it is necessary to combine the observational results from some 15 to 20 astronomical stations geographically widely spread. The excellent results being attained with the Herstmonceux PZT make a significant contribution to the provisional figures computed by the Bureau International de l'Heure (BIH). In the event of the present BIH programme being discontinued owing to lack of funds, the RGO is able to furnish, by the co-operation of the observatories concerned, provisional values based on the current results at Herstmonceux, Washington, Richmond and Calgary.

The scale of atomic time is formed by summation from an adopted initial epoch. There is no independent check which can be applied to determine the amount of any accumulated time error. While the AT scale may conform to ET, there are possible theoretical differences, and the accuracy with which ET can be determined is comparatively poor. It is therefore essential to form a mean of a large number of independent atomic standards, preferably at widely-separated locations, to establish a reference scale of AT. Again this is a matter of co-operative action, co-ordinated by the BIH. In this continuing commitment, the RGO again plays its full part.

Radio time signals

The desirability of international synchronization of radio time signals has been evident from their inception over 60 years ago, and has now been realized by the general adoption of a new form of Co-ordinated Universal Time (UTC) from 1972 January 1. Mr H.M.Smith has been largely involved in the preparations for the new system, and continues to be concerned with its implementation, through active participation in the work of the IAU and the Consultative Committee for the Definition of the Second set up by the International Committee of Weights and Measures (CIPM), as Chairman of the Directing Board of the BIH and as Chairman of Working Party 7/1 of the International Radio Consultative Committee (CCIR).

Following discussions and negotiations over a number of years, the following international agreements were adopted:

> CCIR Recommendation 460 (New Delhi, 1970); IAU Resolution 1 of Commission 31 (Brighton, 1970); CCIR Report 517 (Geneva, 1971); and CGPM Resolution 1 (1967), Resolutions 1 and 2 (1971).

As a result of these arrangements the new system of co-ordinated Universal Time (UTC) was introduced at midnight on December 31. Under this system standard frequency emissions and radio time signals will be broadcast without offset so that the rate is in accordance with the IAT Scale and the time intervals between pips correspond exactly to the second as defined in 1967. In order that the broadcast time scale shall not depart from UT1 by more than 0·7 s, the time signals will be adjusted by the introduction of a leap second, when required, preferentially on June 30 or December 31. The approximate value of the difference UT1–UTC will be given in code in the time signals to 0·1 s.

A special adjustment was made to the time signals at midnight on December 31 so that they differ from the International Atomic Scale by an integral number of seconds.

THE SUN

The Sun was photographed at Herstmonceux in white light on 290 days and in Hα light with the Lyot filter on 191 days.

Solar activity, which had remained at an almost constant level for three years, decreased very sharply during 1971, although minimum phase cannot be expected before 1974 or 1975.

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

GALAXY MEASURING MACHINE

During December, the Galaxy machine which is being built for RGO by Messrs Faul Coradi (Scotland) Ltd, successfully performed its basic functional tests. Mr Long of the Electronics Department spent several weeks at the factory during the second half of the year, studying the machine which is due for delivery early in 1972.

An air-conditioning system and other facilities needed for Galaxy are being installed in the sub-basement of the West Building.

An extensive series of computer programs for processing the search data derived from the D-Mac table, and the output from Galaxy, is being prepared in the Astrometry Department under the direction of Mr W.Nicholson.

INSTRUMENTATION AND ELECTRONICS

Isaac Newton telescope

The Mk II version of the Unit Spectrograph was completed and installed on the telescope in July. It has been in considerable observational demand since that time. The camera mainly used with the instrument is of focal ratio $f/1{\cdot}4$. This provides, with the present choice of gratings, linear dispersions of 30, 75 and 210 Å mm^{-1}. The only detector in use has been the original Spectracon tube provided, and this tube, including test exposures, has now nearly completed 1000 film applications. Spectrum broadening has mainly been performed using the new facility of 'electronic trailing'. Further details of this instrument are similar to the description of the Mk I instrument which has already been published (**33**).

Progress has been made with the coudé spectrograph system during the year and this should be operational in the spring of 1972.

A 15-in. aperture Cassegrain finder telescope has been mounted to replace the 8-in. refractor at present in use with the television field display. As well as remotely operated colour filters, a test pattern projector is provided for television tube adjustments *in situ*.

A new and improved Cassegrain observer's chair has been fitted to the INT. This chair was designed in the Engineering Department, and was constructed by a local engineering firm.

More cable capacity through the telescope axes has been provided and the existing circuits have been rationalized.

Miscellaneous

An auto-guider head received from ROE has been used experimentally on the Merz guiding telescope of the 26-in. refractor, with success, and final installation of this equipment is nearing completion.

Two photographic step-wedge calibration spectrographs of Czerny–Turner design have been completed. One is in use in the INT and one at the Radcliffe Observatory.

Design and construction work continues on the intermediate-dispersion Cassegrain Spectrograph for the AAT Board.

Testing of Spectracon tubes manufactured by Instrument Technology Ltd has commenced in the last quarter of the year.

A considerable increase in the usual contract work on aluminized coating of larger mirrors was experienced in 1971 both on the 40 in. and 98-in. plants.

During the year various items of equipment have been designed and manufactured for use at the Cape Observatory. In the main this has been automatic data-processing equipment and has included digitization of measuring machines and new timing circuits for the transit circle.

Work on the updating of the PZT control circuits was deferred in favour of providing new time-recording equipment for the Astrolabe. A final model is now being manufactured and this will also form the basis for future updating of the RTC time and data recording.

PHYSICS

Kron electronic cameras

Development continues on the Kron electronic cameras which have been modified to incorporate a mica window and vacuum lock for introduction of the electronographic emulsion. Some preliminary tests have been made at the Cassegrain focus of the 36-in. Yapp telescope and the equipment has operated satisfactorily except for the relatively high dark current which limits exposures to about 1 hr on L4 emulsion.

Magnetically focused tube

A prototype has been assembled and tested using a palladium photocathode (sensitive only to ultra-violet) incorporating a resolution test pattern. The diameter of the photocathode and mica window in this tube is 40 mm and it has a vacuum-lock film holder. Tests have shown that there is some variation in resolution over the image area (the best approaches 100 lp/mm) but the geometrical distortion is reasonably low.

The photocathode processing equipment is nearly completed. This equipment will enable the mica window to be sealed on after an alkali-metal photocathode, sensitive in the visible, has been processed on the tube faceplate.

The manufacture of three more tubes is well advanced. One of these will have a rectangular photocathode and mica window ($4 \times 0{\cdot}5$ cm^2) for possible eventual use for spectrographic recording.

Mica windows

Work continues on the preparation of thin mica windows. Mr Curtis has succeeded in splitting sheets of mica to 4 μm thickness and mounting an 8-cm diameter window.

The application of electronographic plates and film to mica windows is being studied. During exposures it is essential that the emulsion should be in as intimate contact as possible because electron scattering in the mica will cause loss of resolution if there is a gap. Pressing film against the mica with a low pressure of air (10 Torr) behind the film is reasonably satisfactory but closer contact still is desirable, particularly if there are dust particles in the surface of the emulsion. Electrostatic pull-down of the mica on to the emulsion gives much better contact

because relatively high pressures (up to 1 atmosphere) can be produced without danger to the thin mica. However, so far it has been possible to use this method for short exposures only (a few minutes) because of charge migration which causes the mica to stick to the emulsion after the external potential has been removed, and produces fogging if the mica and emulsion are forcibly separated. Ways of avoiding this are being investigated.

Electron optics

Theoretical investigations have been carried out by Mr Hartley and Dr Pilkington on the relation of field non-uniformities to the distortions produced, and resolution of electron focusing systems using approximately uniform electric and magnetic fields. Some progress has been made in computing the magnetic field of shielded solenoids. Measurements have been made on a solenoid and the interpretation of the first results from the RGO magnetically focused tube has been attempted.

Data reduction

Dr Pilkington has continued with the development of computer programs for the analysis of microdensitometer scans of direct electronographic exposures; the method of analysis has been extended so that it should now be usable for the reduction of overlapping stellar images.

A new X–Y scanning table for the Joyce-Loebl Autodensidator has been fitted by the makers with the object of improving the Y-scan regularity but there are at present problems caused by mechanical feedback between wedge and table.

Measurements of an exposure, made on L4 emulsion, with a Kron-RGO camera on the 36-in. telescope have shown good linearity over a range of almost 3 magnitudes.

The effects of the size of the microdensitometer aperture on the apparent integrated densities of stellar images, and the effects of imperfect imaging in microdensitometers employing single and double defining apertures, have been studied theoretically.

Silicon diodes

The use of back-biased silicon diodes as electron detectors has been studied using a Kron electronic camera. The diodes used had an associated amplifier integrated on the same silicon chip and it was found that single electrons could be easily detected. It is intended that 4-quadrant diodes will be used for autoguiding and remote focusing in electronographic tubes, and the development of such a system is proceeding. There is also the possibility of making an image tube with

direct electronic read-out for spectrographic use. An array of several hundred diodes, associated amplifiers (1 per diode) and a shift register for serial read-out on a single line, can be integrated on a monolithic silicon chip.

H.M. NAUTICAL ALMANAC OFFICE

Ephemerides

The following almanacs were published during the year: *The Astronomical Ephemeris* for 1972; *The Nautical Almanac* for 1972; *The Air Almanac* for 1971 September to 1972 April (two parts); *The Star Almanac for Land Surveyors* for 1972. The Office also prepared and distributed special predictions and ephemerides as listed in the report for 1970. An improved astrometric ephemeris of Pluto was derived from heliocentric positions computed at the U.S. Naval Observatory.

Experimental editions of an *Astrophysical Observers Almanac* were prepared for the second half of 1971 and for 1972, and were distributed for comment and trial on a strictly limited basis. The almanac is in duplicated, loose-leaf form and consists partly of topocentric data, such as twilight times, and partly of common data, such as special lists of stars with mean places for the year. The almanac is intended to supplement and not to replace the *Astronomical Ephemeris*, which is predominantly concerned with lunar and planetary ephemerides.

As a consequence of an earlier survey of the requirements of users, new material was prepared for the *Star Almanac* for 1973, including positions of supplementary stars with high declinations and a list of radio time signals. The opportunity was taken to make other minor changes in content and layout.

The printing of the six volumes of the new *Sight Reduction Tables for Marine Navigation* (H.D. 605) is in progress. Work on the preparation of a new edition (for epoch 1975·0) of Vol 1 of *Sight Reduction Tables for Air Navigation* was started.

Programmes for the automatic editing and composition for photosetting of the main tabulations for the *Star Almanac* and for the first part of the *Astronomical Ephemeris* were completed. Production on a Linotron 505 filmsetter at the H.M.S.O. Press at Gateshead was eventually successfully completed for the editions for S.A. 1972 and A.E. 1973.

At the request of the Admiralty Compass Laboratory, an investigation was made into the possibility of providing an economic representation of the planetary data in the *Nautical Almanac* for use in the automatic reduction by on-board computers of navigational sights. It was concluded that Chebyshev series, each covering 100 days, would be suitable, and the appropriate data for 1972 were prepared for trial use.

Research activities

The programme for the prediction, reduction and analysis of occultations of stars by the Moon was continued under the supervision of Mrs F.M.Sadler. About 8500 observations were received, coded and reduced during the year and the preliminary residuals of the observations were sent to the observers. About 50000 total-occultation observations collected by the Office since 1943 have now been reduced with the application of limb corrections, using a digitized version of Wats's charts (**35**) to give residuals from the lunar ephemeris $j=2$. These residuals are being analysed in order to derive corrections to the arbitrary constants of the lunar theory and to determine the relationships between ephemeris time and other time scales.

The programme for the prediction of grazing occultations was expanded, and maps of the tracks were prepared for publication in several astronomical journals and handbooks. Many successful observations of grazes were received and analysed; these will greatly increase the weight of latitude-dependent parameters when combined with the total occultations in the main analysis.

An investigation into the methods of timing occultations, using the residuals from several thousand observations, showed that there was effectively no personal equation associated with the eye-and-ear method.

The NAO catalogue of positions of discrete radio sources was extended to 582 sources and revised before being used for the 1972 predictions of occultations for 38 radio observatories. Analyses of the occultation data on 3C 273B and the X-ray source GX3+1 are referred to elsewhere in this report.

The regular search for occultations of stars by planets and satellites led to the prediction by Mr G.E.Taylor (**57**) of an occultation of β^2 Scorpii by the satellite Io (Jupiter I) on 1971 May 14, some 7 hr after its occultation by Jupiter. Such events are extremely rare, and so it is fortunate that, despite the short notice and the uncertainty in the track, several successful photoelectric observations of the event were made in the West Indies and in Florida (**58**). The timings indicate that the diameter of the satellite is 3660 ± 4 km, and suggest that the star may be a double.

Dr A.T.Sinclair completed his new theory of the motion of the satellites of Mars, and compared it with all available observations of the positions of the satellites in order to obtain improved values of the orbital elements and of the parameters defining the gravitational field of Mars (**54**). His results show that the secular accelerations of the satellites must be regarded as very uncertain. He also studied the mechanism by which two satellites of a planet may be driven into a librational resonance due to the attraction of the tidal bulges that they

cause on the planet. He has shown that this mechanism provides a satisfactory explanation of the resonance of Mimas and Tethys, and that of Enceladus and Dione, in the Saturnian system.

Some further work has been done by Mr B.Emerson, in collaboration with Dr T.Lloyd Evans of the Radcliffe Observatory, on the determination of the elements of the orbits of some spectroscopic binaries.

Computer services

During the year, the reliability of the ICL 1909 computer system decreased, the average serviceability ratio being 0·93 compared with 0·97 in 1970. The average amount of useful time (i.e. excluding time lost for faults and all hardware maintenance) increased slightly to 45 hours per week. The delay time, especially for longer runs, increased considerably during the year. Of the useful time, 22 per cent was for NAO work, 44 per cent for the rest of the Observatory, 19 per cent for the Geomagnetism Unit of the Natural Environment Research Council (based at Herstmonceux) and 15 per cent for software maintenance and development.

The IBM card-controlled typewriter system that has been used since 1963 for the preparation of copy for photolithographic reproduction of the *Nautical Almanac* and of tables for *R.O. Bulletins*, etc, is no longer in use. A UDS 6000 automatic typewriter, with paper-tape readers and punch, was installed in March for similar work, and for use in the editing of reports, preparation of semi-standard letters, etc.

The Computer Section continued to provide a programming advisory service and a punching service for all users, in addition to operating the computer. Some job programming was also carried out for other departments, and the library of astronomical data on magnetic tape was extended.

GENERAL

Dr D.H.Sadler formally retired from the post of "Superintendent of the Nautical Almanac" on 1971 February 18, although he had been seconded to other duties since 1970 January 1. He joined the staff of H.M. Nautical Almanac Office on 1930 October 13, was appointed Deputy Superintendent on 1933 June 26, became Acting Superintendent on 1936 August 27, and Superintendent on 1937 May 27. During his period of office he was responsible for the introduction of several new almanacs and tables for navigation and surveying, for many major improvements in the other publications of the Office, and for directing many investigations in navigation, numerical analysis and dynamical astronomy, particularly in connection with the motion of the Moon. During the period 1941–1945 he also directed the work of the Admiralty Computing Service, and he was awarded the Order of the British Empire in 1949. He retires from RGO service on 1972 February 18.

The Astronomer Royal has been awarded the Gold Medal of the Royal Astronomical Society for his contributions to observational and theoretical astrophysics, particularly in the field of stellar dynamics.

The annual Herstmonceux Conference was held on April 5–6, the main subject being the origin and distribution of the chemical elements. One session was however devoted to image-tube developments. Amongst those who attended were Dr H.Reeves from the Institut d'Astrophysique, Paris, Professor P.H.Fowler and Dr J.V.Jelley.

A gathering of some 30 astronomers from all parts of the world met at Herstmonceux in August to mark Sir Richard Woolley's retirement, and spent four fruitful days in a discussion of the Galaxy and the Distance Scale (*Q. Jl R. astr Soc.* **13,** 131 1972).

The 28-in. refractor was removed from Dome F and returned to its former site at Greenwich during November. The National Maritime Museum plans to house it under a replica of the Christie 'onion' dome, the original of which was destroyed during the war.

Professor E. Margaret Burbidge, Director-Designate of the Observatory, paid a private visit to the Astronomer Royal at Herstmonceux during a short stay in the U.K. during November.

With the end of the report year the administrative association between the Royal Greenwich Observatory at Herstmonceux and the Royal Observatory at the Cape was terminated by the absorption of the latter establishment into the new South African Astronomical Observatory. Continuation of the scientific association is however assured by the signature during December of a ten-year agreement between the (South African) Council for Scientific and Industrial Research and the (British) Science Research Council which will cover the secondment of enough U.K.-based staff to conduct the observing programmes of the new observatory until they can be wholly taken over by astronomers trained in South Africa.

PUBLICATIONS

The following publications have appeared during the period under review (or early in 1972) in addition to the routine publications of the Nautical Almanac Office which are referred to in the corresponding section of this Report. The Greenwich Time Reports for 1970 April to December and Time and Solar Circulars have been published by the appropriate departments.

Other papers, including those in *Royal Observatory Bulletins*, Nos 160–170 are listed below under the names of the authors.

(1) Alexander, J.B., 1971. A search for metal-deficient stars in the Southern Hemisphere, *Mon. Notes astr. Soc. Sth. Afr.*, **30,** 139.

(2) Alexander, J.B. & Carter, B.S., 1971. Motion of Ao stars perpendicular to the galactic plane, V. *UBV* photometry of A stars in the south galactic cap, *R. Obs. Bull.* No. **169.**

(3) Alexander, J.B. (with Thackeray, A.D.), 1971. Photometry and spectroscopy of S Doradus 1948–1970, *Observatory*, **91,** 25.

(4) Aslan, Z., 1971. On the secular parallaxes of faint stars, *Observatory*, **91**, 11.
(5) Aslan, Z., 1971. On the kinematic reduction of relative proper motions to absolute, and proper motions of RR Lyrae variables, *Observatory*, **91**, 14.
(6) Bell, R.A., 1971. Theoretical colours for F and G dwarf stars, *Mon. Not. R. astr. Soc.*, **154**, 343.
(7) Bell, R.A. (with Gottlieb, D.M.), 1971. The calibration of narrow-band photometry—II. The gravity and Doppler-broadening velocity of G and K Giants, *Mon. Not. R. astr. Soc.*, **151**, 449.
(8) Branch, D.R. & Bell, R.A., 1971. An abundance analysis of the ultra-violet deficient subgiant HR 244, *Mon. Not. R. astr. Soc.*, **151**, 289.
(9) Branch, D.R. & Bell, R.A., 1971. The colours and chemical composition of the G dwarf HR 72, *Mon. Not. R. astr. Soc.*, **153**, 57.
(10) Branch, D.R. & Patchett, B.E., 1971. Wavelength shifts of intensity minima in Type I supernova spectra, *Nature Phys. Sci., Lond.*, **233**, 29.
(11) Branch, D.R. (with Greenstein, J.L.), 1971. The 1961 supernova in NGC 1058, *Astrophys. J.*, **167**, 89.
(12) Cannon, R.D., Penston, M.V. & Brett, R.A., 1971. Optical monitoring of radio sources—II. The N type and Seyfert galaxies, *Mon. Not. R. astr. Soc.*, **152**, 79.
(13) Clube, S.V.M., 1971. Absolute magnitudes of RR Lyrae variables. *Highlights of Astronomy*, **2**, 788.
(14) Clube, S.V.M., Aslan, Z., Russo, T.W. & Clements, E.D., 1971. The proper motions of RR Lyrae variables—II, *R. Obs. Bull.*, No. **161.**
(15) Clube, S.V.M. & Jones, D.H.P., 1971. The determination of statistical parallaxes, *Mon. Not. R. astr. Soc.*, **151**, 231.
(16) Dickens, R.J., French, V.A., Owst, P.W., Penny, A.J. & Powell, A.L.T., 1971. An abundance analysis of the Delta Scuti variable 20 CVn, *Mon. Not. R. astr. Soc.*, **153**, 1.
(17) Dickens, R.J. & Penny, A.J., 1971. Effective temperatures and gravities for A- and F-type stars in the Delta Scuti region, *Mon. Not. R. astr. Soc.*, **153**, 287.
(18) Dickens, R.J. (with Peach, J.V.), 1972. On the mass-to-light ratios for double galaxies, *I.A.U. Symposium* No. **44** (ed. D.S. Evans), 89.
(19) Emerson, B. & Wilkins, G.A., 1971. The I.A.U. System of Astronomical Constants, Proceedings of I.A.U. Colloquium No. 9, Heidelberg, 12–14 August 1970, *Celest. Mech.*, **4**, 2.
(20) Epps, E.A., 1971. The frequency of RR Lyrae companions, *Observatory*, **91**, 124.
(21) Fosbury, R.A.E., 1971. A possible identification of Nd II in emission in Arcturus, *Mon. Not. R. astr. Soc.*, **155**, 7P.
(22) Harding, G.A. & Candy, M.P., 1971. The Isaac Newton telescope Cassegrain spectrograph. Description and results of radial velocity observations of stars near δ^2 Lyrae, *R. Obs. Bull.*, No. **164.**
(23) Harding, G.A., Fahim, F. & Haslam, C.M., 1971. Motion of Ao stars perpendicular to the galactic plane, IV. Radial velocities in the south galactic cap, *R. Obs. Bull.*, No. **165.**
(24) Jones, D.H.P., 1971. A spectroscopic search for southern δ Scuti stars, *R. Obs. Bull.*, No. **163.**
(25) Laurie, P.S., 1971. Sunspots in 1970—Reports on the progress of astronomy—Council Note, *Q.Jl R. astr. Soc.*, **12**, 244.
(26) Laurie, P.S. (with Dyson, K.), 1971. Solar activity and geomagnetic storms, 1970, *Observatory*, **91**, 233.
(27) Lynden-Bell, D., 1971. A method of allowing for known observational selection in small samples applied to 3CR quasars, *Mon. Not. R. astr. Soc.*, **155**, 95.

(28) Lynden-Bell, D., 1971. Note on N galaxies and mini-quasars, *Mon. Not. R. astr. Soc.*, **155**, 119.
(29) Lynden-Bell, D., 1971. Formation and evolution of bright black holes. Semaine d'Etude sur les Noyaux des Galaxies, April 1970, *Pontificiae Academiae Scientiarum Varia, No.* **35**.
(30) Lynden-Bell, D. (with Ekers, R.D.), 1971. High resolution observations of the galactic centre at 5GHz, *Astrophys. Lett.*, **9**, 189.
(31) Lynden-Bell, D. (with Rees, M.J.), 1971. On quasars, dust and the galactic centre, *Mon. Not. R. astr. Soc.*, **152**, 461.
(32) McMullan, D., 1971. Electronographic image tubes, *Observatory*, **91**, 199.
(33) Milsom, A.S., 1971. The R.G.O. Cassegrain image tube spectrograph at the Radcliffe Observatory, *Observatory*, **91**, 202.
(34) Morrison, L.V., 1971. A comparative study of visual and photoelectric timing of occultations, *Highlights of Astronomy*, **2**, 589.
(35) Morrison, L.V. & Martin, R.J., 1971. A digitized version of C.B. Watts' charts of the marginal zone of the Moon, *The Moon*, **2**, 463.
(36) Morrison, L.V. & Murray, C.A. (with Hazard, C., Sutton, J., Argue, A.N. & Kenworthy, C.M.), 1971. Accurate radio and optical positions of 3C273B, *Nature Phys. Sci., Lond.*, **233**, 89.
(37) Morrison, L.V. (with Janes, A.F., Pounds, K.A., Ricketts, M.J. & Willmore, A.P.), 1972. Identification of GX3+1 from lunar occultations, *Nature, Lond.*, **235**, 152.
(38) Murdin, P. & Webster, B.L., 1971. On the identification of Cygnus X-1, *Nature, Lond.*, **233**, 110.
(39) Murray, C.A., 1971. On the astrometric use of the prime focus of the Isaac Newton Telescope with the Wynne field corrector, *Mon. Not. R. astr. Soc.*, **154**, 429.
(40) Murray, C.A., Tucker, R.H. & Clements, E.D., 1971. Optical positions of radio sources, *R. Obs. Bull.*, No. **162**.
(41) O'Hora, N.P.J., 1971. The longitude of Herstmonceux, *Observatory*, **91**, 155.
(42) O'Hora, N.P.J. & Thomas, D.V., 1970. An investigation of PZT observations for evidence of the existence of polar disturbances due to large earthquakes, *Earthquake displacement fields and the rotation of the Earth* (ed. Mansinha, L. *et al.*).
(43) Pagel, B.E.J., 1971. Importance of spectral line shapes in astrophysics, *J. Phys. B (Atom. Molec. Phys.)*, **4**, 279.
(44) Pagel, B.E.J. (with Mihalas, D. and Souffrin, P.), 1971. *Theorie des Atmospheres Stellairs: 1er Cours Avance de la Soc.* Suisse d'Astron. et d'Astrophys., Geneva Observatory.
(45) Penny, A.J. & Powell, A.L.T., 1971. Stellar Evolution and Variable Stars, *Earth extraterres. Sci.*, **1**, 229.
(46) Penston, M.V., 1971. Identification of the Ryle-Neville radio sources, *Astrophys. J.*, **170**, 395.
(47) Penston, M.V., Penston, M.J. & Tritton, K.P. (with Neugebauer, G., Becklin, E.E. and Visvanathan, N.), 1971. Observations of NGC 4151 during 1970 in the optical and infra-red, *Mon. Not. R. astr. Soc.*, **153**, 29.
(48) Pilkington, J.D.H., 1971. Electronographic stellar photometry, *Observatory*, **91**, 200.
(49) Pope, J.D., 1971. Optical performance criteria for telescope tube design. *ESO/CERN Conference on large telescope design, Geneva*, 1971, 299.
(50) Powell, A.L.T., 1971. The equivalent widths of spectral lines in twelve late F Dwarfs, *R. Obs. Bull.*, No. **167**.

(51) Powell, A.L.T., 1971. Spectral lines for curve-of-growth analysis of late type stars–I, *R. Obs. Bull.*, No. **168.**
(52) Sadler, D.H., 1972. The new system of co-ordinated Universal Time, *J. Navigation*, **25,** 32.
(53) Sadler, D.H., 1972. Gaussian logarithms and navigation, *J. Navigation*, **25,** 252.
(54) Sinclair, A.T., 1972. The motions of the satellites of Mars, *Mon. Not. R. astr. Soc.*, **155,** 249.
(55) Stickland, D.J., 1971. On the determination of effective temperatures from line ratios (Research Note), *Astr. Astrophys.* **10,** 478.
(56) Stickland, D.J., 1971. On the energy distributions of main sequence stars, *Mon. Not. R. astr. Soc.*, **153,** 501.
(57) Taylor, G.E., 1971. Possible occultation of a star by Io (Jupiter I), *J. Brit. Astr. Assoc.*, **81,** 303.
(58) Taylor, G.E. (with ten others), 1971. Occultation of Beta Scorpii C by Io on 1971, May 14, *Nature, Lond.*, **234,** 405.
(59) Thomas, D.V. & Wallis, R.E., 1971. Results obtained with a Danjon Astrolabe at Herstmonceux–II. Analysis and discussion: Herstmonceux astrolabe Catalogue, *R. Obs. Bull.*, No. **160.**
(60) Tritton, K.P., 1971. *UBV* Photometry of the quasar 3C 273, *Mon. Notes astr. Soc. Sth Afr.*, **30,** 113.
(61) Tritton, K.P., 1971. Spectroscopy and photography of Southern Hemisphere quasar identifications, *Mon. Not. R. astr. Soc.*, **155,** 1P.
(62) Tritton, K.P. & Selmes, R.A., 1971. Optical monitoring of radio sources–III. Further observations of Quasars, *Mon. Not. R. astr. Soc.*, **153,** 453.
(63) Walker, E.N., 1971. HD 152667. A spectroscopic binary P Cygni star, *Mon. Not. R. astr. Soc.*, **152,** 333.
(64) Woolley, Sir Richard, 1970. The stars and the structure of the Galaxy, *Q. Jl. R. astr. Soc.*, **11,** 403.
(65) Woolley, Sir Richard, 1971. Stellar movement, *Contemp. Phys.*, **12,** 395.
(66) Woolley, Sir Richard, 1970. Deviation of the vertex of the velocity ellipse of young stars and its connection with spiral structure, IAU Symposium No 38, *The spiral structure of our Galaxy* (eds. W. Becker and G. Contopoulos), 423.
(67) Woolley, Sir Richard, 1971. Motions of the nearby stars, *Structure and evolution of the Galaxy* (ed. Mavridis, L.N.), 178.
(68) Woolley, Sir Richard, 1971. The absolute magnitudes of the RR Lyrae stars, *Highlights of Astronomy*, **2,** 771.
(69) Woolley, Sir Richard, Pocock, S.B., Epps, E.A. & Flinn, R., 1971. The statistics of the nearby stars, *R. Obs. Bull.*, No. **166.**
(70) Woolley, Sir Richard & Savage, A., 1971. Masses, radii and luminosities of RR Lyrae variable stars, *R. Obs. Bull.*, No. **170.**