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# ROYAL GREENWICH OBSERVATORY

*Director*, *E.Margaret Burbidge*, *FRS* (until 30 November)
*A.Hunter* (from 1 December)

(Report for the year ending 1973 December 31)

## INTRODUCTION

This Report concerns work performed under the immediate direction of the Director RGO: the work of the Radcliffe Observatory, for which the Director is also responsible, is reported elsewhere.

The recent activities of the RGO have been concentrated in three main areas: astronomical research, the provision of national and international services, and instrumentation.

Astronomical research work has covered a wide area, from observations of X-ray sources and quasars to studies of the rotation of the Earth. The Observatory's national and international commitments have remained basically unchanged, the main activities being the computation and publication of astronomical and navigational tables by HM Nautical Almanac Office, and the provision of the national time service. A considerable effort has gone into the operation, maintenance and improvement of the Isaac Newton Telescope (INT) as a national facility. The other equatorial telescopes at the RGO have also been used by, or operated for, university astronomers from time to time. The main effort in instrumental development has been directed towards the development of larger and more efficient electronic imaging devices and their use in spectrographs and for direct photography. Lecturing, and the supervision of research students have occupied a substantial portion of the time of a few members of the staff.

The total complement of the RGO at 1973 December 31 was 256, including 17 staff at the Radcliffe Observatory and two at the South African Astronomical Observatory, Cape Town. Of the staff serving at RGO, 100 were members of the Science Group and 26 members of the Professional and Technology Category; there were 100 industrial and non-industrial support staff and 11 vacancies.

## X-RAY SOURCES

In collaboration with the X-ray astronomy group at Mullard Space Science Laboratory, Dr P.G.Murdin and Mrs A.Savage have been studying the location in the Cygnus X-1 binary system of material observed to give isolated X-ray absorption events. The material has

been identified by them as the gaseous stream which transfers material from the supergiant primary to the secondary, which is said to be a black hole. A modulation over six days of the X-ray light curve was shown to have a maximum within one and a half hours of conjunction of the two stars, and provided the first detection of a signature of the binary motion on the X-ray characteristics of Cygnus X-1.

Mr E.N.Walker's photometry of HDE 226868, the optical counterpart of Cygnus X-1, has continued in collaboration with a group of astronomers at the University of Granada, Spain, in order to see whether extensive monitoring would supply further information on the possible existence of a black hole in this system. The amplitude of light variation seems to be randomly variable and on occasions the secondary minimum does not exist, a result which imposes important constraints on possible models (**101**). Furthermore, the mean brightness in 1973 exceeded that found in 1972 by about $0^m{\cdot}01$ in blue light, and extrapolation by archival material suggests that Cygnus X-1 has been steadily brightening at a rate of about 1 per cent per annum for at least the past 18 years.

Following publication of X-ray data that showed the source 2U 1700-37 to be variable, probably with eclipses, Walker has studied spectra of the emission-line star HD 153919 (lying near the X-ray position) taken by him at the Radcliffe Observatory in 1967. He has classified the star as type O5·5f with atmospheric expansion, typical of Of stars, but with abnormally strong C III; more remarkably, H$\beta$, H$\gamma$ and H$\delta$ have emission wings with the unprecedented width in optical stellar spectra of 12 000 km $s^{-1}$ (**102**). In collaboration with Thackeray (Radcliffe Observatory), Walker has shown that the radial velocity of HD 153919 varies with the period of the X-ray source and with the appropriate phase for eclipses of the latter by the Of star (**100**).

Dr K.P.Tritton and Dr R.A.E.Fosbury have collaborated with a group at the Institute of Astronomy, Cambridge, in initiating a programme to make optical identifications for northern X-ray variables with small error boxes. Observations are made at approximately monthly intervals using a Varo image tube on the 26-in. refractor (reaching about $19^m$ in $V$ on a sky-limited exposure) and with the Cambridge Schmidt telescope.

HD 154431, listed in the *General Catalogue of Stellar Radial Velocities* as a velocity variable, lies near the Hercules X-1 source and there has been speculation that it might be the optical counterpart. However, Murdin and Savage (**58**) could find no velocity variation, especially with the Hercules X-1 period, and concluded that there was no reason to link it with Hercules X-1. This conclusion is borne out by the subsequent identification of the optical counterpart as another star.

Mr L.V.Morrison co-operated with the X-ray astronomy groups at the University of Leicester and the Mullard Space Science Laboratory in the prediction and analysis of the observations by the *Copernicus* satellite of the lunar occultations of the source GX5-1 on 1973 March 26 and April 22. The uncertainty in the position of the source has been greatly reduced, but no sure optical identification has been made (**57**). Dr M.V.Penston and Murdin, together with Willmore (Birmingham University) and Sanford, Mason and Hawkins (MSSL) (**75**) have reported that X-ray observations by the *Copernicus* satellite rule out four identifications of X-ray sources with bright stars proposed by Gursky (*Astrophys. J.*, **175**, L141, 1972). The same consortium has made X-ray position measurements of several X-ray sources observed by the *Copernicus* satellite, accurate to $\pm 30''$. First results identify the X-ray source 3U 0614+09 with a 19th magnitude blue variable star and support Dr I.S.Glass's identification of 3U 1728-24 with an infrared source.

Follow-up work in South Africa by Murdin, M.V.Penston and Dr M.J.Penston has yielded *UBV* photometry of 77 stars in the fields of 20 X-ray sources. Several of these stars have been observed at high time-resolution for rapid variability. Reduction of these data is still continuing. Pursuing spectroscopic observations of variations in the longward component of the H$\beta$ emission in the X-ray source candidate X Persei by M.J.Penston and Savage, Murdin and M.V.Penston have found variations in the H$\alpha$ emission on the time scale of one minute. Up to 50 per cent modulation of the variable component, sometimes in anti-correlation with the continuum, was revealed by narrow-band photoelectric photometry on the 74-in. Radcliffe telescope.

The error box for the X-ray source GX2+9 has been searched by Glass for infrared radiation and a source with $K = 8^{m}\cdot1$ found. A spectrogram obtained by Feast (Radcliffe Observatory) shows that it is a heavily-reddened emission-line object. The error boxes of other X-ray sources have been unsuccessfully searched by Glass and M.V.Penston. Miss E.A.Epps has suggested possible optical identifications for LMCX-1, 2 and 3 from accurate positional measurements on Cape plates.

## EXTRAGALACTIC STUDIES

### *Quasars and Seyfert galaxies*

Professor E.M.Burbidge continued her spectroscopic work on quasars using the Wampler–Robinson image-dissector scanner at the Cassegrain focus of the 120-in. Lick telescope. Some observations were also made with the Cassegrain spectrograph of the 90-in. telescope at Steward Observatory, in collaboration with Strittmatter. The objects observed

included identifications suggested by Hazard and Murdoch for radio sources in the Molonglo survey, also some from the Royal Radar Establishment, Malvern, and Nuffield Radio Astronomy Laboratories, Jodrell Bank. The quasar OQ 172 (≡ 1442+101) was found to have a very large redshift, $z = 3{\cdot}53$. The objects 1331+170 and 1442+101 have rich absorption-line spectra. Photographic spectrograms of a large number of quasars have been microphotometered by Mrs A.Savage to obtain quantitative emission-line intensities. Dr K.P.Tritton and Dr M.V.Penston, with Henbest (Mullard Radio Astronomy Observatory, Cambridge) have shown that 4C 31·63 is a quasar with an emission redshift of 0·298 and $V = 15{\cdot}47$ (**94**). This quasar is among the ten brightest known, and shows absorption at Mg II λ 2798 and in the Balmer series.

M.V.Penston and Dr M.J.Penston together with Becklin and Neugebauer (Hale Observatories), have made broad-band optical and infrared observations of 11 bright Seyfert galaxies, in a continuation and extension of earlier work. The ultraviolet and two-micron fluxes of NGC 4151 have both increased by about $0^m{\cdot}3$ between 1970 and 1971, while 3C 120 was constant to within about $0^m{\cdot}1$ in the infrared in a period when it varied by about $0^m{\cdot}8$ in the optical. Comparison with published data shows NGC 4051 to be a new optical variable. The spatial and spectral distributions of the emitted flux are consistent with the combination of an extended source with galaxy-like colours and a nuclear source with quasar-like colours.

M.V.Penston and Wing (Ohio State University) have published a photoelectric sequence in the field of the blue compact object OJ 287 suitable for use by optical monitoring programmes (**80**). The two-star photometer has been used on the INT by Dr R.G.Bingham, Dr P.G. Murdin and K.P.Tritton to monitor OJ 287 and BL Lac; the former was found to vary by $0^m{\cdot}1$ in as little as one hour. Photographic monitoring of NGC 4051 and Markarian 79 by Mr H.Netzer (research student) has revealed variations of $0^m{\cdot}2$ in both galaxies in the course of the year. The optical monitoring of quasars and other radio sources has continued on the 26-in. telescope under the direction of K.P.Tritton. The results for 26 quasars, seven compact galaxies and three BL Lac type objects for the period 1970–73 are in preparation. Intensive observations have been made of OJ 287 and BL Lac.

*Radio sources*

A completely new model for head-tail radio sources has been developed by K.P.Tritton. The motion of a galaxy through an intergalactic medium can produce a magneto-tail in which charged particles are accelerated. The model requires no injection mechanism for the particles and low values of the magnetic field (**93**).

*Optical identification of radio sources*

The results of two programmes of optical identifications of far-southern radio sources have been published by K.P.Tritton in collaboration with Whitworth and Schilizzi (Owens Valley Radio Observatory). Ten new identifications have been made and three others confirmed (**95, 96**). Curtis–Schmidt plates of fields near IC 4499 have been measured to get accurate positions for possible optical identifications with PKS radio sources.

*Optical positions of extragalactic radio sources*

This continuing programme has been run by Mr C.A.Murray and Dr B.D.Yallop in collaboration with Ryle (Mullard Radio Astronomy Observatory, Cambridge) and Argue (Institute of Astronomy, Cambridge). Sources with small radio diameters are being observed at the prime focus of the INT and with the 26-in. refractor. Plates on all fields are being obtained with the 13-in. astrographic refractor in order to strengthen the tie-in to the AGK3 System. INT observations have now been completed on 25 sources optically fainter than about $m_{pg} = 17$, and a further 30 plates are needed on 20 more sources. All these plates will be measured on GALAXY. Results have also been obtained for 30 bright sources from 26-in. plates; observations are still needed on a further 12 sources.

*Clusters of galaxies*

The INT Unit Spectrograph equipped with a three-stage cascade image intensifier was used on the INT and the 36-in. telescope by Dr R.J.Dickens and Mr C.Moss (research student). The spectrograms are recorded on baked IIa–O emulsion at a dispersion of 210 Å $mm^{-1}$. The three clusters principally being studied are Abell 262, Abell 1367 and Zwicky 135+39. Galaxy types for the 177 brightest galaxies in Abell 1367 were obtained by Moss using plates obtained with the Palomar 48-in. Schmidt by Mackay and Kraft (Institute of Astronomy, Cambridge). Approximately equal numbers of elliptical, So and spiral galaxies were found, contrary to the situation in the Shapley–Ames field galaxies, which contain many more spirals.

*Double galaxies*

Dickens, in collaboration with van Albada and Schwarz (Kapteyn Laboratory, Groningen) has proposed a programme to measure line-of-sight H I velocities of double galaxies, using the Westerbork radio telescope. The high resolution of the telescope (~20 arcsec) and large velocity range should make it possible to obtain accurate velocities of many pairs of spiral galaxies, in order to study their dynamics and to

obtain their masses by statistical analysis. A pilot observing run will study a few selected pairs with known velocities and, if successful, will be followed by an extensive survey of close pairs with separations less than 10 arcmin. Eventually, when combined with H I velocities of wider pairs currently under study in the USA, these data should provide the best possible material for the investigation of the double-galaxy problem.

*Normal galaxies*

Bingham and Peat (Institute of Astronomy, Cambridge) have commenced a programme of mapping absorption line strengths in the nuclear region of M31, using the INT Unit Spectrograph with a Spectracon tube.

*JHKL* photometry of a number of southern galaxies by Dr I.S.Glass has shown that a nucleus with a $K-L$ excess is not universally present in, or exclusive to, Seyfert galaxies (**32**). Some barred spirals have been found to show strong excesses.

*Supernovae*

Mr R.Wood and M.V.Penston confirmed the presence of Goranskij's supernova in NGC 3147. M.V.Penston has collaborated with Kirshner, Oke and Searle (Hale Observatories) in a study of the spectra of supernovae obtained by spectrophotometric scans (**78**). This study has shown that: (i) type I and type II supernovae have continua that change slowly and uniformly with time and carry the bulk of the flux; (ii) for part of their evolution both types exhibit P Cygni profiles; (iii) emission lines, common to both types, persist through the evolution of the spectra. The emission spectra of type II supernovae can be explained by resonance scattering in an expanding neutral atmosphere of solar composition. Hydrogen may be deficient in type I supernovae.

Wood, in collaboration with Andrews (Radcliffe Observatory) has studied the 1968 type II supernova in NGC 5236. Redward drifts of several spectral features have been found. One week after maximum the continuum could be fitted to an 11 000 K blackbody, consistent with scanner observations of other type II supernovae.

## GLOBULAR AND GALACTIC CLUSTERS

Dr R.D.Cannon has discussed the *UBV* photometry of bright ($V \leqslant 16$ to 17) stars in the southern globular clusters 47 Tuc, NGC 6397 and NGC 288, using data obtained at the Mount Stromlo and Siding Spring Observatories. These three clusters have been compared with $\omega$ Cen and NGC 6752 and with four northern clusters investigated by Sandage. Composite C–M and two-colour diagrams have been constructed and several standard globular cluster parameters have been

derived; it appears that NGC 6752 is similar to M13 in having a purely blue horizontal branch but intermediate metallicity, and that NGC 288 is a more extreme example of this type of cluster. The remaining clusters follow the usual horizontal-branch-metallicity correlation. Cannon and Dr R.J.Dickens have extended this discussion to a larger sample of clusters, and have attempted to interpret the results on current evolutionary theory. Using only the best-observed clusters, it appears that at least two parameters are required to classify all the galactic globular clusters. However, the majority of clusters belong to a one-parameter (metallicity) family, and it appears that the second parameter is not continuously variable but rather that there may be two distinct families of galactic globular clusters, possibly with different ages.

Cannon and Mr C.Lloyd have obtained a C–M diagram for the distant globular cluster IC 4499, which contains an exceptionally large proportion of RR Lyrae variables. The cluster has a well-marked horizontal branch at $V \sim 17^{m}{\cdot}7$, with probably over 100 RR Lyrae variables. The high proportion of RR Lyrae stars seems to be a consequence of the distribution of the horizontal branch stars, which has a strong maximum in the RR Lyrae strip; the ratio of the total number of horizontal branch stars to the number of red giants is normal.

The chemical composition of southern globular clusters is being studied by Dickens and Dr A.L.T.Powell, in collaboration with Bell (University of Maryland), using spectra of individual stars taken with the 74-in. Radcliffe telescope. Bell's spectrum synthesis computer program is being used to supplement curve-of-growth analysis. A value for [Fe/H] of about $-2$ has been obtained for NGC 6397.

Dr R.G.Bingham and Mr R.W.Smith (vacation student) have investigated the physical significance of reddening-independent parameters for the integrated light of globular clusters. In the case of Racine's parameter $R$, the globular clusters of M31 show a systematic gradient decreasing outwards from the centre, but no equally clear trend was found in our Galaxy. None of the parameters considered emerges as a uniquely effective criterion of metal content. HR diagrams of globular-like clusters in the Magellanic Clouds have been investigated by Bingham and Martin (Radcliffe Observatory) on the basis of model computations of integrated *UBV* colours. Those of NGC 121 and NGC 1466 are consistent with their being old and metal poor. Kron 3 seems to be a cluster of intermediate age like NGC 2158, as found by Gascoigne, rather than an old globular-like cluster resembling 47 Tuc, as found by M.F.Walker.

In co-operation with Coutts (David Dunlap Observatory), Miss E.A. Epps is measuring a long series of Curtis–Schmidt plates of IC 4499 to determine light curves of the RR Lyraes. She is also analysing

GALAXY measurements of $B$ and $V$ Cape plates with a one-degree field centred on 47 Tuc.

Dr B.F.Jones is investigating proper motions and magnitudes in the cluster NGC 1528. Twenty astrometric plates taken with the Yerkes 40-in. and Lick 36-in. refractors, and five photometric plates taken at Herstmonceux, have all been measured on GALAXY.

Mr C.A.Murray's programme of first-epoch plates on nearby clusters for proper-motion studies of faint members has continued at the prime focus of the INT, using the Wynne corrector.

## VARIABLE STARS

Dr D.H.P.Jones, in collaboration with Shobbrook (University of Sydney), has discussed the location of the $\beta$ Canis Majoris instability strip in the observational HR diagram. It proves to be surprisingly narrow—its width cannot be resolved with currently available techniques of luminosity estimation. The identification of the strip with the 'S bend' phase of stellar evolution, originally proposed by Schmalberger is confirmed. If the radial pulsation hypothesis is to be retained, then two different modes must occur, probably the fundamental and the first overtone.

Dr E.G.Schmidt, in collaboration with Rosendhal and Jewsbury (University of Arizona), has completed a study of non-variable stars in the Cepheid instability strip (**82**). High-dispersion spectra were analysed using a grid of model atmospheres constructed for the purpose. The gravities of the Cepheids are found to be smaller than those of the non-variables, suggesting that the Cepheids either have lost mass or had higher initial helium abundances than the non-variables. Additionally, atmospheric parameters have been derived for the 'beat Cepheid' TU Cas. Both the gravity of this star and the differential and microturbulent velocities are greater than those of other Cepheids. This indicates that the classification of this star as a classical Cepheid may be incorrect. Working at the Kitt Peak National Observatory, Schmidt has measured $R-I$ colours for a number of Cepheids which are members of galactic clusters. These data will provide the basis for determining whether the temperatures, and hence pulsational masses, derived for Cepheids from $B-V$ colours are in error as suggested previously (**81**).

Dr I.S.Glass has collaborated with van Genderen (Leiden Observatory) and Feast (Radcliffe Observatory) in observations of V748 Cen (= Cen X-4) and BL Tel, two high-latitude eclipsing binaries with late-type secondaries. A small group of extreme WC stars has been observed by Glass and Webster (Radcliffe Observatory). The stars all have very strong infrared excesses, characteristic of low-temperature (~700 K) dust. Glass and Webster (Radcliffe Observatory) have shown that certain symbiotic stars and planetary nebulae possess dust, and that certain

other symbiotic stars contain cool components. The slow nova RR Tel has been examined by Glass, with Webster and Feast (Radcliffe Observatory): it appears to consist of a late-type variable component and dust. Cool components have also been confirmed or inferred in some other old novae.

Mr E.N.Walker has continued his search for optical variations in early-type stars and has accumulated large amounts of data. Mr B. Emerson has co-operated in analyses which suggest that many early-type stars have small-amplitude periodic magnitude variations which can be detected by observing for sufficient lengths of time.

## STAR FORMATION AND INSTERSTELLAR MATTER

Dr D.A.Allen and Dr M.V.Penston (**9**) have interpreted infrared and spectroscopic observations of hot stars with circumstellar dust shells. Stellar and dust temperatures are found to be anti-correlated. Alternative explanations of this effect, sputtering or ultraviolet destruction of dust, both require density inhomogeneities with similar maximum values.

Dr I.S.Glass and M.V.Penston have carried out an infrared survey of RW Aurigae stars in both hemispheres. This has revealed a small number of highly-reddened late-type stars included amongst the RW Aurigae stars. All T Tauri and hot Orion population stars show infrared excesses, and the infrared properties mark certain field stars as being young. The largest infrared excesses are found for A and F stars while young variable B stars show no excesses. The infrared colours favour dust re-radiation over free-free emission as the mechanism responsible for the infrared emission.

Glass and Feast (Radcliffe Observatory) have shown that an object in the Chameleon T association, thought by Henize and Mendoza to be a Herbig–Haro object, more closely resembles T Tauri stars such as R Mon and R CrA. Glass's work on R Coronae Borealis variables has been extended: monitoring is continuing at *UBVJHKL* in collaboration with Andrews (Radcliffe Observatory).

Dr E.G.Schmidt has carried out Strömgren photometry of stars behind Bok globules using the INT and telescopes at the Kitt Peak and Wise Observatories. These observations will be used to determine the reddening in these objects and, hence, the masses and distribution of material. This information can then be used to discuss the question of whether these objects are actually protostars.

M.V.Penston has shown that recent ultraviolet observations made by the *Copernicus* satellite suggest that the heating rate in interstellar clouds exceeds that estimated hitherto.

## H II REGIONS

Drift scans in Hα across the λ Orionis region and Barnard's Loop have been made by Dr P.G.Murdin with the Wise Observatory 40-in. reflector and supplemented by Hβ scans made with a 2-in. refractor at Herstmonceux. The λ Orionis region seems to be in an early stage of development, just beginning its pressure expansion. A search for young infrared stars has been made by Dr M.V.Penston, with one success.

Dr E.G.Schmidt, together with Mr C.Ruggles and Mr M.McEllin (vacation students), has begun analysing a series of spectra of shock fronts in H II regions. The purpose of this work is to obtain the variation of density and temperature through these features for comparison with theoretical models.

## STELLAR ATMOSPHERES AND ABUNDANCE STUDIES

*Relationship between age, metal abundance and galactic evolution*

In the hope of clarifying the controversy about 'supermetallicity' with the aid of better observational material, spectra of μ Leo, α Ser and some other red giants, at a dispersion of 2·9 Å $mm^{-1}$ in the green and red, have been secured by Professor B.E.J.Pagel using the Mount Wilson 100-in. telescope. A preliminary analysis by Mrs D.L.Harmer and Pagel, in which it proved possible, by using the solar spectrum as a standard, to use weaker lines than has been done by others, suggests that μ Leo and α Ser have very closely similar compositions and that their iron abundance is not greater than that of the Hyades. The study of the distribution of metal abundances in G dwarfs has been continued by Pagel and Mr B.E.Patchett using catalogues by Gliese and Eggen which seem to contain less biased samples than are available in catalogues based on trigonometric parallaxes alone. Using simple analytical models of galactic evolution to represent the effects of prompt initial enrichment, metal-enhanced star formation, and accretion (with instantaneous mixing) of unprocessed gas, it appears that the first two mechanisms, but not the third, are easy to reconcile with the more-or-less Gaussian distribution in [Fe/H] that is observed. On the other hand, an accretion phase during the initial collapse of the Galaxy could possibly account for the fairly high metal abundances found both in the vast majority of nearby G dwarfs and in the disk globular clusters as a result of the study of integrated (*UBV*) colours by Dr R.G.Bingham and Martin (Radcliffe Observatory).

The instrumental profile of the Y camera of the Radcliffe Observatory's high-dispersion (6·8 Å $mm^{-1}$) spectrograph has been determined by Dr A.L.T.Powell. The reduction of spectra of α Men, ν Indi, γ Pav and $\zeta^2$ Ret obtained on this instrument is well in hand.

*Atmospheres of A and B-type stars*

The Hg II line λ 3984 has been studied by Dr D.J.Stickland in order to verify the anomalous mercury isotope ratios found in some manganese stars by Dworetsky and Preston. While some of the anomalous ratios seem real, it may yet be possible to explain them on the basis of diffusion theory. HD 23325, a relatively cool star in the Pleiades classified as Am, has been found by Stickland to have anomalous abundances, but with Ca and Sc possibly enhanced rather than depleted. Since it lies close to the ZAMS, it could be related to a special class of 'metallic-lined' stars found earlier as secondary components of several double-lined Am spectroscopic binaries. The Hyades Am star 88 Tau has been measured and analysed by an automated procedure (**67**) and found to have [Fe/H] = 0·27, with typical Am characteristics (similar to those found by M.A.Smith) superimposed. Spectroscopic and scanner studies of the double-lined binary α Equ by Stickland and Dr J. Tomkin (research student) suggest that it consists of a G3 III star with an A4 V secondary; the preliminary period of about 96 days is in agreement with earlier results by Deutsch, although a mass ratio nearer unity is suggested.

Published data on Si III line intensities in a number of B-type stars have been examined by Pagel in order to check an identification of lines of the doubly-excited multiplet 13 in the B6 star ζ Dra. The lines are anomalously strong for the star's effective temperature, and alternative identifications are suggested. The determination of spectral types and projected rotational velocities for 101 southern OB stars on the basis of Radcliffe Observatory spectrograms has been completed by Mr E.N.Walker (**103**).

*Stellar chromospheres*

Dr R.A.E.Fosbury has shown that the relation between line-broadening, velocity and height in the low and middle solar chromosphere required to explain Ca II and Mg II emission-line profiles is in good agreement with the relation between the velocity-amplitude of acoustic waves and height, deduced from radiative losses on the assumption that the acoustic flux is the main source of chromospheric heating. Using a simple density-scaling law, and arguing by analogy with the Sun, the observed relations between stellar line-widths and luminosity have been used to investigate the scaling of the chromospheric acoustic flux over the cooler part of the HR diagram. The ratio of chromospheric mechanical energy flux to radiative flux is found to be only weakly dependent on effective temperature and luminosity (**29, 30**).

R.A.E.Fosbury has studied the classification of the source functions of Balmer and strong neutral metal lines in the chromospheres of late-type stars. All these lines can become strongly collisionally controlled

in M dwarfs, so that a chromospheric temperature rise leads to emission cores. These are seen, of course, in the Balmer lines of the dMe stars, and INT image-tube spectrograms of AD Leo (M4 Ve) also show emission cores in Ca I $\lambda$4227. In giants, on the other hand, the Balmer lines are photoelectrically controlled, so that the H$\epsilon$ 'emission' sometimes seen in the wing of Ca II H must be a fluorescence effect not directly related to the local electron temperature.

*Emission-line stars*

Dr D.A.Allen (4) used the South African Astronomical Observatory 40-in., the Kitt Peak National Observatory 50-in. and the Mount Lemmon Infrared Observatory 60-in. telescopes to make infrared observations of faint emission-line stars. Two distinct types can be identified by their infrared colours: symbiotic stars and low-excitation forbidden-line stars. The identification of both is considerably faster using this technique than by conventional spectroscopy.

## GALACTIC ASTRONOMY

*Kinematics and photometry in Selected Areas*

Mr C.A.Murray is directing a programme aimed at the derivation of the stellar density distribution, luminosity function and force law within a volume of about 1 kpc from the observed numbers, kinematics and photometry of a large number of stars in Kapteyn's Selected Areas.

The astrometric observations on all 115 northern areas have now been virtually completed. Plates on the first seven fields (SA 51, 54, 57, 71, 82, 94, 107) are in various stages of preparation for, or measurement on, GALAXY. Detailed investigations of the pilot measures on SA 54, made on the GALAXY at the Royal Observatory, Edinburgh, have been carried out by Mr K.Muanwong (research student) in order to improve the plate modelling and weighting system for the final plate overlap solution. In support of this programme, spectra of stars in the Selected Areas brighter than twelfth magnitude are being obtained for radial velocity measurement and spectral classification.

*Solar neighbourhood*

Dr D.H.P.Jones has extended his narrow-band observations of faint red stars to the North Galactic Cap, using the INT and a newly acquired pulse-counting data acquisition system. He confirms that the majority of the stars observed by Murray and Sanduleak are, indeed, dwarfs, but finds a significantly greater distance, implying a substantially smaller space density of red dwarfs than those authors suggested.

Observations have been completed on three INT parallax fields. Two of these have been measured on GALAXY, and preliminary values of the parallaxes obtained by Dr B.F.Jones are:

for Luyten 30-331, $\pi = 0''.068 \pm 0''.007$
for Luyten 34-134, $\pi = 0''.018 \pm 0''.011$.

D.H.P.Jones has measured photoelectrically the photometric parallax of the first star, and his distance modulus agrees within $0^m.4$. Three fields have been removed from the INT parallax programme because the parallax stars were too faint, and one field has been added. There are now 14 fields containing 18 parallax stars on the programme. Eleven fields should have the observations completed during 1974 and the remainder during 1975.

The 26-in. refractor parallax programme has continued under the direction of Dr D.V.Thomas and Mr J.B.Alexander. The majority of the stars are red dwarfs discovered spectrophotometrically by Vyssotsky. The reduction of ten fields was completed during the year. Analysis of the results has continued in an attempt to determine the most satisfactory system of weighting individual plates on the basis of internal criteria. A possible correlation between systematic errors in the measured parallactic displacement in the declination co-ordinate and ambient temperature variations is being examined. As part of an international collaborative programme, 28 plates of a field containing five members of the Hyades cluster are being measured on GALAXY.

D.H.P.Jones has measured many stars from the 26-in. programme on his photoelectric narrow-band system, using the 36-in. telescope. Few of them appear to be later than dMo. Other stars observed on this system are either (i) in Upgren's spectral survey at the North Galactic Pole, (ii) faint red stars in selected areas, or (iii) stars of known parallax or spectral type observed for calibration purposes.

## INFRARED PHOTOMETRY OF STANDARD STARS

Using an infrared photometer on several telescopes at the SAAO, Dr I.S.Glass has observed about 200 stars several times each at *JHKL*. The intention is to set up a satisfactory network of reference stars for the Southern Hemisphere, based on Johnson's northern system.

## STELLAR POSITIONS

*Optical positions of stellar radio sources*

In order to determine the zero point of the right-ascension system of the Cambridge 5-km radio telescope, special observations of $\beta$ Per (Algol) have been made photographically with the 26-in. refractor and visually with the Cooke Transit Circle. The photographic observations have been reduced to the AGK3 System and the meridian observations to the FK4 System. The results of these observations and also optical and radio observations made at Cambridge have been discussed in a joint publication (**99**). Plates are also being taken of $\beta$ Lyr and P Cyg.

*Meridian observations*

Observations of the Sun, planets, azimuth stars and clock stars continue to be made regularly with the Cooke Transit Circle under the direction of Mr R.H.Tucker. The programme of observations of lunar-occultation (zodiacal) stars is 81 per cent complete, and the Northern PZT star programme is 72 per cent complete. Preliminary reductions of Sun and planet observations since 1957 have been carried out; the provisional positions for 1957–71 are in press (**17**). The occasional observations of the Moon have also been reduced and the results will be published in *Royal Observatory Bulletins*. Other catalogues are in various stages of preparation. Satisfactory progress has been made in setting up the fundamental Herstmonceux positional system in both right ascension and declination.

Work is in progress at the National Engineering Laboratory, Kilbride, on the development and construction of an automatic digital circle-reading system to replace the circle cameras of the Cooke Transit Circle. The observations made with the Gill Transit Circle at the SAAO, Cape Town, are sent to Herstmonceux for computer processing, reduction and ledgering. Close collaboration is maintained between the Meridian Departments at the Cape and Herstmonceux.

*Astrolabe observations*

Provisional catalogue corrections have been derived by Dr D.V. Thomas from the 36 000 observations made with the Danjon astrolabe at the Royal Observatory, Cape, during 1965–69. Nearly 900 values of $\Delta\alpha$ and more than 600 of $\Delta\delta$ have been obtained and distributed to interested parties. The standard errors average $\pm 7$ ms in $\Delta\alpha$ and $\pm 0''{\cdot}15$ in $\Delta\delta$.

## THE SUN

Under the direction of Mr P.S.Laurie, the Sun has been photographed at Herstmonceux in white light on 285 days and in H$\alpha$ light with the Lyot filter on 210 days. With the continued co-operation of the SAAO, white-light photoheliograms for transmission to RGO were also obtained on 281 days at Cape Town. A considerable fall has occurred in the general level of Solar activity during 1973, a total of 28 spotless days being recorded during the second half of the year.

## TOTAL SOLAR ECLIPSE 1973 JUNE 30

A further attempt to observe the Einstein light deflection has been made by a team from the University of Texas, which included Dr B.F. Jones. Three successful plates on the eclipse field and a comparison field were obtained during totality and a number of second-epoch plates were taken later in the year. All the plates are now at Herstmonceux and will be measured on GALAXY.

Four members of the staff joined the British Astronomical Association's expedition to make observations from a ship off West Africa. Arrangements had been made by Mr G.E.Taylor (one of the joint organizers) to obtain precise timings from an accurately-known position. Unfortunately the marker buoys, which had been positioned by satellite navigation by the Royal Navy in order to fix the position of the ship accurately, were missing!

## TIME AND LATITUDE SERVICE

### *Photographic Zenith Tube*

The PZT continued in service throughout the year, and 2960 star transits were observed on 161 nights, i.e. 54 per cent of the nights scheduled. Up-to-date results of the time and latitude observations have been communicated weekly to the Bureau International de l'Heure, and the collaboration with the International Polar Motion Service has also been maintained. The quality of the observations is recognized in the exceptionally high weights assigned to the Herstmonceux PZT results by the BIH. Maintenance of this high standard is becoming increasingly difficult because of delays in the installation of the Moiré fringe timing system and new control equipment.

Mr N.P.J.O'Hora has completed his analysis of the effects of deflexions of the vertical, referred to in last year's Report (**60**). Further analysis of the PZT observations by O'Hora has confirmed the existence of the quasi-diurnal term predicted by Atkinson (**59**). This term arises from the use of nutation corrections computed for the Earth's pole of rotation. The widely publicized notion that the great solar storm at the beginning of 1972 August significantly affected the rate of rotation of the Earth has been shown by O'Hora and Miss C.J.A.Penny (**61**) to be inconsistent with the observations made by six national observatories, including the RGO. This work has led to a more extensive examination of geophysical phenomena that might affect the rotation.

All star transits observed at Herstmonceux since 1958 and at Calgary since 1968 have been analysed for the determination of improved star positions; this work is now nearly complete and improved positions and proper motions for the catalogue stars should be available for use in 1974. The availability of improved star co-ordinates will warrant re-reduction of all previous observations, and the subsequent processing of such a large number of observations has emphasized the need for computer methods of smoothing results. The implications of Vondrak's method of smoothing non-uniform time series have been investigated by Dr D.V.Thomas, and O'Hora has devised a computer-application of this method to the PZT observations.

*Danjon astrolabe*

This instrument is at present being modified in the Engineering Department to enable observations to be carried out with a reflecting objective prism of Cer-Vit in place of the transmission prism. The advantages of the use of such a prism were set out several years ago by Thomas. A satisfactory method of mounting the prism has now been devised through collaboration of the Time and Engineering Departments.

*Rotation of the Earth*

Mean Solar time was losing on the atomic time scale by an average of 3·2 ms per day until mid-September when the rate changed to 2·8 ms per day losing.

*Atomic time scale*

The Greenwich atomic time scale GA2 is an independent atomic time scale based on the mean of selected caesium standards at Herstmonceux. On 1958 January 1 GA2 was in agreement with the International Atomic Time Scale (TAI) of the Bureau International de l'Heure; at the end of 1973 the difference TAI–GA2 was approximately $+27\ \mu s$, and the frequency of GA2 was 0·5 parts in $10^{12}$ less than that of TAI. In 1971 evidence from three independent laboratories using primary standards indicated that the frequency of TAI was about one part in $10^{12}$ too high. For the past four years GA2 has been one of the seven independent atomic time scales from which TAI has been determined. A new method of determining TAI has been adopted by the BIH since 1973 July 1; it uses the results of individual atomic clocks which are compared by means of measurements of the reception times of pulses of the Loran–C radio-navigation system. The results of all the RGO atomic standards are sent to the BIH for inclusion in TAI, which is then published a month or two in arrear. GA2 is available as a national scale on a day-to-day basis.

Staff of the US Naval Observatory have made two visits to RGO with portable caesium clocks in order to check the differences between atomic clocks and to investigate the cause of small discrepancies, of the order of $3\ \mu s$, between clock comparisons made by travelling clocks and by reception of Loran–C pulses in Europe and America.

*Radio time signals*

In accordance with international agreements, and in order to keep broadcast time scales within agreed limits of UT1, a positive leap second was inserted in the UTC time signals emitted by Rugby and the BBC as the last second of 1973 December 31.

## INSTRUMENTATION

### *Isaac Newton telescope*

The INT was scheduled for operation on 330 nights during the year. Standdown of 26 nights was used for preventive maintenance (there were no mechanical breakdowns during the year) and nine nights were lost in December owing to national emergency power restrictions. Some observing was possible on 215 of the scheduled nights (65 per cent), and 75 nights (23 per cent) were completely clear.

Design work is in progress on a new breech end for the prime focus. This will permit the use of 16-cm square plates and offset autoguiding, and will accommodate the 8-cm electronographic image tube which is being developed at RGO.

Good progress is being made by Dr J.S.Beale with the programming of the Nova 1200 computer which is to be used to control the telescope. Plans have been drawn up for providing better facilities at the control console and for interfacing the computers.

The new camera mirror was installed in the coudé spectrograph early in the year. Its performance is entirely satisfactory and the full field coverage of 1200 Å is now available. A new single-ruled grating of 632 grooves/mm, blazed at 1·2 $\mu$m, has been ordered; it is intended for use in the second order and will give a dispersion of 2·3 Å $mm^{-1}$ at 6000 Å. No cure has yet been found for the temperature-induced image shifts, in spite of many tests and experiments. The advice of the Engineering Division of the Rutherford Laboratory has been sought and their preliminary recommendations have been received. Detailed plans for carrying out the preferred remedies are being drawn up by the SRC Works Unit.

The Michelson interferometer, designed and built by the Astronomy Department of the Imperial College of Science and Technology, has been installed and used for preliminary observations. The Mark II Unit Spectrograph has been fitted with a prototype solenoid to enable the EMI 3-stage cascade image intensifier to be used observationally, pending the design and construction of a universal solenoid to take both this tube and the Spectracon. This type of intensifier will resolve upwards of 40 line pairs per millimetre when used in conjunction with IIIa–J emulsion. Ion noise and phosphor persistence effects are observed when recording with faster emulsions.

Mr P.J.Willmoth was appointed manager of the telescope early in the year. An INT Users' Group composed of University and RGO astronomers has been formed, and two meetings were held during 1973 to discuss the instrumentation and facilities at the telescope. A third full-time night assistant has been appointed.

*Other equatorial telescopes*

The secondary mirror mounting of the Yapp 36-in. reflector has been redesigned to improve its stability and provide remote control and indication of focus setting. Access to Dome B has been improved and there has been a frequent interchange of instruments (mainly the Mark II Unit Spectrograph) between the INT and the 36-in. telescope. Dr P.G. Murdin has initiated a renovation programme to facilitate quick instrument changes.

The 30-in. telescope has been modified to provide an accessible $f/14$ focus on the ground floor. The échelle spectrograph constructed by Learner (Imperial College) is to be transferred to Herstmonceux for final assembly and testing at this new focus. The Hargreaves (Congo) telescope has been erected in Dome F and is now almost ready for preliminary testing. A start has been made on the erection of the Steavenson telescope in Dome C. A new base has been installed and work is now in progress on the new right ascension and declination drives and clamping systems.

*Miscellaneous instruments*

Integrators for the 'People's Photometer' have been completed by the Electronics Department to designs by Mr G.B.Wellgate and Dr R.G. Bingham. Three such units have been constructed and tested, and used on the 36-in. (RGO), 74-in. (Radcliffe) and 20-in. and 40-in. (SAAO) telescopes. Various additional facilities have been provided and assistance has been given to users.

A collaborative project on polarimetry has been started by Bingham in collaboration with Axon and Scarrott (Durham University). Mrs D.L.Harmer and Mr C.F.W.Harmer are collaborating with Hutley (National Physical Laboratory) in investigating the use of a holographic grating to give a dispersion of 10 Å $mm^{-1}$ in the Unit Spectrograph. A grating is to be produced by NPL and tried out at Herstmonceux in 1974.

The main constructional work on the Intermediate Dispersion Spectrograph for the Anglo-Australian Telescope has been completed and all components have been assembled and aligned. Initial test plates with both cameras show satisfactory optical performance. The Cer–Vit rod system for monitoring the case expansion has been proved over the range $-7$ °C to $+20$ °C. The electronic wiring is almost complete and final adjustments of the circuits are now well under way. Astronomical tests on the INT are scheduled for 1974 March.

Two sets of Hartmann test plates of the main optics of the Anglo-Australian Telescope were measured on GALAXY during the course of the year, at the request of Willstrop (Institute of Astronomy, Cambridge).

*Electronographic tube development*

Substantial progress was made during the year, although no working tubes were actually available for astronomical use because of the short life of the photocathodes (a few weeks). Dr D.McMullan has made a study of the vacuum requirements for the preservation of a trialkali photocathode. Pressures widely quoted in the literature as being acceptable appear to be at least four orders of magnitude too high, and it was concluded that the photocathodes in the RGO tubes were deteriorating because of very small air leaks which were not being detected with the helium mass spectrometer. New leak-testing procedures have now been adopted and the sensitivity is estimated to be $10^{-13}$ Torr litres per second. This should in theory be adequate, and the indication from the first tube subjected to these stringent tests before processing is that its photocathode should have a life of several years. Improved photocathode processing schedules have been introduced under the supervision of Dr J.R.Powell. Trialkali photocathodes having luminous efficiencies of 180 $\mu$A $lm^{-1}$ and peak quantum efficiencies of 20 per cent can now be produced routinely. A further study by McMullan of the causes of fogging of nuclear emulsion when electrostatic pull-down of the mica window is employed (see 1971 Report) has led to a successful solution of this problem. Dr K.F.Hartley has verified that the method can be used with nuclear emulsion on 50 $\mu$m Melinex and that resolutions in excess of 100 line pairs per millimetre can be achieved. The design of the tube with an 8-cm diameter mica window is continuing, and the major components are on order.

A vacuum furnace for outgassing image tube parts has now been completed. The testing of Spectracon image tubes manufactured by Instrument Technology Ltd under SRC contract has continued throughout the year. A new contract has been placed with the firm for Spectracons with S.20 photocathodes and larger mica windows. The first of the former has been received for testing.

*Electron optics*

Hartley has completed his theoretical study of magnetically-focused image tubes. He has shown that if the fields are uniform more than 400 line pairs per millimetre should be resolved, and that non-uniformity causes astigmatism related to the amount of geometrical distortion produced. If the latter is small compared with any magnification or rotation the resolution will be as good as in uniform fields. These computer studies have been verified on the electron-optical bench. An uncorrected solenoid and an accurately built electrode structure produced a magnification of 5 per cent and rotation of 2 degrees, but less than 70-$\mu$m distortion. A resolution of well in excess of 200 line pairs per

millimetre (the limit of the test pattern) was obtained. The bench has also been used to test various emulsions and methods of securing good contact with the mica windows.

Programs written at the Rutherford Laboratory have been used by Hartley to study the magnetic fields of solenoids in the presence of magnetic materials. The solenoid for the 8-cm tube at the prime focus of the INT has been designed by this method.

*Application of silicon diodes*

Quadrant silicon diodes suitable for use as autoguider sensors in image tubes have been supplied by the Nuclear Physics Division of UKAEA, Harwell. Because of the difficulty with photocathode life the diodes have not yet been tried in image tubes. A contract has been placed with The Plessey Company Ltd for the development of silicon diode arrays with associated amplifiers and shift register for serial read-out, all integrated on a single monolithic silicon chip. It is hoped that they will be able to produce chips having two parallel arrays each of 512 diodes for single-electron detection in a small magnetically-focused image tube which is being designed at RGO for spectrographic use. A contract has also been placed with the Department of Astronomy, Imperial College, for the development of silicon diode arrays (with external amplifiers) which can be brought up to the mica window of a Spectracon in place of an electronographic emulsion.

*Measuring machines*

Work has continued on the design and construction of the new data processing electronics for the Zeiss Ascorecord. The design has also been used as the basis of the specifications for digitizing and read-out circuits for the Mann two-coördinate machine and the Sartorius iris-diaphragm photometer.

Special plateholders have been designed and made for the GALAXY measuring machine.

*Routine services*

The Electronics and Engineering Departments have continued to be responsible for the maintenance of all the telescopes, measuring machines, and electronic equipment of the Observatory. During the year, the staff of the Engineering Department carried out 72 major instrument changes on the INT and 32 changes on the Yapp 36-in. reflector. One hundred telescope faults were reported and rectified but no observing time was lost through mechanical trouble.

## NORTHERN HEMISPHERE OBSERVATORY

The RGO has co-operated in all the preliminary investigations related to the setting-up of a Northern Hemisphere Observatory. In collaboration with other members of the NHO Estimating Team, Dr M.G.Smith (Cerro Tololo Inter-American Observatory), who spent about six months at the RGO as a Science Research Council consultant, and Mr J.D.Pope have undertaken several major studies for the NHO Planning Committee.

Proposals have been put forward by Dr R.G.Bingham that the NHO should be equipped with a 2·5-m telescope having an optimized coudé focus and a Cassegrain focus, and a 1·5-m telescope with an $f/4$ prime and a Cassegrain focus. An outline scheme for photoelectric photometers for these telescopes has been prepared for PILOT (Panel for Instrumentation on Large Optical Telescopes). Arguments in favour of providing an optimized coudé (or equivalent) focus on 2·5-m and larger telescopes, for use in studying faint objects at about $17^m$ (including quasars) as well as brighter objects, have been put forward to PILOT and the NHO Planning Committee by Professor B.E.J.Pagel.

## HM NAUTICAL ALMANAC OFFICE

*Publications and data services*

The following almanacs have been published during the year: *The Astronomical Ephemeris* for 1974; *The Air Almanac* for 1973 May to 1974 April (in three parts); *The Star Almanac for Land Surveyors* for 1974. Lightly-bound copies of advanced data for the Ephemeris for 1977 and 1978 have been distributed for use in the preparation of the almanacs of other countries. The publication of AE 1974 on March 2 was a considerable improvement over the late publication of the previous issue, but unfortunately delays occurred in the printing of *The Nautical Almanac* for 1975. Progress on the reprinting of the *Explanatory Supplement to the Astronomical Ephemeris* was disappointingly slow; final reproducible copy was sent for printing in October.

The publication, by the Hydrographer of the Navy, of the British edition of the new series of *Sight Reduction Tables for Marine Navigation* (NP 401) has been completed. The new edition (for epoch 1975·0) of Volume 1 of *Sight Reduction Tables for Air Navigation* has been published. The explanation of the *Air Almanac* has been revised in consultation with the Nautical Almanac Office of the US Naval Observatory so as to reduce the number of changes required between successive parts for 1975 onwards. Consideration has also been given to the possibility of publishing the Almanac in only two parts each year, and appropriate changes in the form of presentation of the auxiliary data have been proposed.

Discussions have been held at the IAU, and at other meetings, with members of the ephemeris offices of other countries and with other interested astronomers on the improvements that might be made in the content and form of publication of the astronomical ephemerides for 1980 onwards (**105**). In particular, consideration has been given to the possibility of publishing the precise positional ephemerides of the Moon and planets separately, and including a greater variety of material in the annual volumes, but no consensus of opinion on these matters has been reached.

Topocentric astronomical data for 1974 for 24 observatories and possible observatory sites have been distributed. Transit ephemerides of the planets have been prepared for Herstmonceux and the Cape. Additional information for civil purposes has been supplied to newspapers, diary publishers and many other organizations and individuals.

*Occultations and dynamics*

The regular programme for the prediction and reduction of the occultations of stars by the Moon has continued under the direction of Mr L.V.Morrison. Worldwide predictions of the lunar occultations of stars and radio sources were distributed to individual observatories and observers, and for publication; in particular, reproducible copy for total or graze predictions was supplied for publication in *Sky and Telescope* and by astronomical societies in Australia, Britain, Canada, New Zealand and South Africa. During the year about 10 000 observations were received, coded and reduced, and the preliminary residuals in the timings have been sent to the observers. Observations of grazing occultations have also been reduced (**54**).

The analysis of past occultation data has continued (**55**); corrections to four of the planetary terms in the lunar theory have been determined from residuals in the data for 1943–72. Observations made before 1943 have been collected from the literature, coded and reduced ready for a new analysis that should improve the determination of the past variations of the rate of rotation of the Earth. Data on the transits of Mercury have also been collected for study in order to provide an independent assessment of the variations of universal time with respect to ephemeris time.

Charts showing the predicted areas and times of the series of occultations of the Crab Nebula by the Moon, which will occur in 1974–5, have been distributed to potential observers (**56**). Morrison's work on the occultations of X-ray sources has been reported above.

Regular searches for the occultations of stars by planets and satellites have continued (**87, 88**). Mr G.E.Taylor has completed his analysis of

the timings of the occultation of a star by Ganymede, and obtained the value of 5270 km for the diameter of the satellite; the occultation disclosed the presence of an atmosphere on Ganymede, but its thickness below the effective occultation layer is uncertain (**89**).

Dr A.T.Sinclair has made further observations of the positions of the satellites of Saturn using the 13-in. and 26-in. telescopes, and has used them to produce improved ephemerides for Dione, Rhea, Titan and Iapetus. He has also continued his study of the origin of the commensurabilities amongst the satellites of Saturn, and investigated the resonance effects in the orbital inclinations.

Mr B.Emerson has prepared an account of the methods currently used at the Observatory for the automatic computation of apparent places of stars (**27**). Emerson has also collaborated with Thackeray and Lloyd-Evans (Radcliffe Observatory) in the determination of orbital elements for a number of spectroscopic binaries observed at the Radcliffe Observatory.

*Computer services*

The ICL 1909 computer system has been operated for two shifts on working days. The average amount of useful time (i.e. excluding time lost for faults and hardware maintenance) has been 59 hours a week. Of this useful time, 20 per cent has been for NAO work, 52 per cent for the rest of the Observatory, 15 per cent for the Geomagnetism Unit of the Natural Environment Research Council (based at Herstmonceux), and 8 per cent for software maintenance and development. The average serviceability ratio was 0·93.

The Science Research Council has approved a proposal for the replacement of the central processor of the 1909 system by an ICL 1903T central processor, and also recommended the installation of a link to the ICL 1906A computer system at the Atlas Computer Laboratory. The link became operational in December; it uses a GEC 2050 computer for the remote job-entry work-station at the Observatory. Preparations for the installation of the 1903T, which will normally be run under a GEORGE 3 operating system, are largely complete.

The Computer Section continues to provide a programming advisory service for all users, in addition to operating the computer and ancillary equipment. Some programming for other departments has been carried out and studies of the use of mini-computers for on-line control of telescopes and instrumentation have continued. The library of astronomical data on magnetic tape has been extended and several requests from other establishments for copies of star catalogues have been met.

## VISITING OBSERVERS

The Isaac Newton Telescope was used during the year by 12 groups of visiting observers, mostly from the universities, engaged on programmes for which the Large Telescope Users' Panel allocated them 139 nights. In the same period the telescope was allocated to RGO observers for 200 nights.

Professor D.E.Blackwell (Oxford University) used the 30-in. coudé on nine nights during July to obtain a series of IIa–F and IN plates of $\theta$ Boo; the series was completed on his behalf by RGO observers during two further weeks.

Dr A.Boksenberg (University College, London) and his research team used the 30-in. coudé for three weeks in August to test the UCL photon-event counting system. The results were successful, and provided useful experience for Dr Boksenberg's subsequent observing runs at Palomar.

Dr A.D.Andrews (Armagh Observatory) used the two-star photometer on the 36-in. reflector for ten nights. He monitored the flare star EV Lac during the international monitoring week of 1973 September.

Dr C.Dainty and Dr B.L.Morgan (Imperial College of Science and Technology) made two short visits to use the 36-in. reflector. They are developing a new technique in stellar speckle interferometry.

Dr D.Clarke and Mr I.McLean (Glasgow University) used the 36-in. reflector for 14 nights for Cassegrain spectropolarimetry.

Assistance to visiting observers has been given by numerous members of the staff. Miscellaneous observations have also been made by RGO staff on several telescopes at the request of university scientists.

Professor R.L.Gregory of the Brain and Perception Laboratory in the Medical School at Bristol used the astrographic telescope to test his device for minimizing the effect of bad seeing on resolution in astronomical photography.

## GENERAL

Professor E.Margaret Burbidge resigned the directorship on November 30. She made a rapid recovery from injuries received in a road accident and returned to California in November. Dr A.Hunter, formerly Deputy Director, was appointed Director on December 1. Dr D.V.Thomas was temporarily promoted to the post of Assistant to the Director (Senior Principal Scientific Officer) on December 1.

Professor B.E.J.Pagel spent two weeks at the Anglo-Australian Telescope Project Office in Australia, serving on the Astronomers' Working Party.

Mr C.A.Murray has been elected Vice-President of IAU Commission 24 (Photographic Astrometry). He also served on the council of the

Centre de Données Stellaires at Strasbourg, continuing as Chairman during the early part of the year.

Dr G.A.Wilkins has continued as IAU representative on FAGS and CODATA. He has been elected Vice-President of the Council of the Federation of Astronomical and Geophysical Services and served as IAU delegate at the General Assembly of CODATA in Stockholm. He has also served on various national and international working groups on such topics as lunar laser ranging, astronomical data (**104, 106**), and the revision of the Universal Decimal Classification Scheme for Astronomy (class 52); he prepared reports on astronomical abstracting services and on activities in the United Kingdom on solar system mechanics (**107**).

Mr H.M.Smith has been re-appointed IAU representative on the Directing Board of the Bureau International de l'Heure (Chairman), and on the International Radio Consultative Committee (Chairman of IWP 7/1 on co-ordinated universal time). He has also been appointed Chairman of an international working party (CCDS/WP1), set up by the Comité Consultatif pour la Définition de la Seconde, to consider time scales.

Mr R.H.Tucker has been elected Vice-President of IAU Commission 8 (Positional Astronomy).

Dr R.G.Bingham, Mr J.W.Gietzen, Dr D.H.P.Jones and Dr B.D. Yallop have been promoted to Principal Scientific Officer. Mrs F.M. Sadler (Principal Scientific Officer) has retired after more than 35 years' service in the Nautical Almanac Office. Two members of the staff received awards in the 1973 New Year's Honours, Mr H.M.Smith the OBE and Mr A.L.Jeffries the BEM.

R.A.E.Fosbury, M.J.Penston, J.Tomkin (Research Student) and K.P. Tritton have been awarded DPhil degrees by the University of Sussex; K.F.Hartley has been awarded a PhD by the University of Leeds. MSc degrees have also been awarded following courses jointly organized by the Observatory and the University of Sussex.

Mr C.A.Murray, Dr R.J.Dickens and Dr M.V.Penston have been appointed Visiting Lecturers at the University of Sussex. Students from the University of Sussex continue to make use of the facilities of the RGO where these are appropriate to their studies. As in previous years, an eight-week course in astronomy was held in the long vacation and was attended by 12 students from various British Universities. Three sandwich students have worked at the RGO for extended periods during the year.

The seventeenth annual Herstmonceux Conference was held in the Castle on 1973 April 16–17, the subject being Infrared Sources. Papers were presented by five members of the RGO staff, and invited papers were given by Professor N.J.Woolf, Dr J.E.Beckman, Dr R.S.Booth,

Dr D.W.Dewhirst, Mr J.P.Emerson, Dr R.Foy, Dr R.F.Jameson and Dr M.J.Smyth (*Observatory*, **93**, 167).

Members of the staff have taken part in astronomical conferences, both in this country and abroad, too numerous for individual mention; papers have been presented in a number of cases. The RGO had a section of the Science Research Council's stand at Earls Court for the Physics Exhibition in April. One of the magnetically-focused 4-cm electronographic tubes, which are being developed in the Physics Department, was exhibited. Demonstrations were given of the operation of the automatic vacuum-lock film holder and the autoguider sensor positioner.

The Nautical Almanac Office prepared an exhibit on occultations and dynamics, and the Superintendent (Dr G.A.Wilkins) gave a review lecture for the Royal Society celebrations of the quincentenary of the birth of Copernicus. The exhibition material was also displayed at the University of Newcastle and as part of a Copernicus exhibition at the museum of the City of Portsmouth.

## RGO PUBLICATIONS

The quarterly *Greenwich Time Reports* covering the period 1972 January to 1973 March have been published. The *Time Service Circulars Series A* (weekly) and *Series B* (monthly), and *Solar Activity Circulars* (monthly) have been issued regularly.

Papers written by members of the staff, individually or in collaboration, are listed below alphabetically under the names of the staff involved. Those who were no longer members of the staff at December 31 are prefixed by an asterisk; non-members of the staff are shown in italics.

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(4) Allen, D.A., 1973. Near-infrared magnitudes of 248 early-type emission-line stars and related objects, *Mon. Not. R. astr. Soc.*, **161**, 145.
(5) Allen, D.A., 1973. Visual observations of twenty faint planetary nebulae, *Observatory*, **93**, 28.
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(8) Allen, D.A. & Morrison, L.V., 1973. Lunar occultation of Ve2-45, *IAU Circ.* No. **2521**.
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(10) *Loer, S.J.*, Allen, D.A. & *Dyck, H.M.*, 1973. 2·2 and 3·5-micron polarization measurements of the Becklin–Neugebauer object in the Orion Nebula, *Astrophys. J.*, **183,** L97.
(11) *Swings, J.P.* & Allen, D.A., 1973. MWC 645 and MWC 819: two stars resembling $\eta$ Carinae, *Astrophys. Lett.*, **14,** 65.
(12) Blackwell, K.C., 1973. Cooke Transit Circle Collimation Investigation, *R. Obs. Ann.* No. **9,** Appendix.
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(16) *Branch, D.R. & Patchett, B.E., 1973. Type I Supernovae, *Mon. Not. R. astr. Soc.*, **161,** 71.
(17) Buontempo, M.E., Carey, J.V. & Eldridge, P., 1973. Provisional Positions of the Sun and Planets 1957–1971, *R. Obs. Bull.* No. **178.**
(18) *Burbidge, E.M., 1973. Redshifts of Quasistellar Objects, *Nature, Lond.*, **246,** 185.
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(20) *Baldwin, J.A.*, *Burbidge, E.M., *Hazard, C., Murdoch, H.S., Robinson, L.B.* & *Wampler, E.J.*, 1973. A spectroscopic survey of 92 QSO candidates, *Astrophys. J.*, **185,** 739.
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