Standard Magnitude Sequences in the Harvard Standard Regions at - 45° Declination

by

A. W. J. Cousins, B.Sc. (Eng.)

Summary

Accurate stellar magnitudes on a uniform system are necessary for astronomical research. The North Polar Sequence, which defines the International System, is not accessible to southern observers so it has been necessary to establish magnitude sequences in the Southern Hemisphere. A number of observing programmes to establish such sequences in the nine Harvard Standard E Regions have been carried out using modern methods. Two of these programmes employing the Fabry method and a photoelectric photometer, respectively, are described in some detail. A special series of observations was made to ensure that the nine E regions have the same zero point. Accurate photographic and photovisual magnitudes were obtained for about 270 of the brighter stars.

In a concluding section modern material is collected and combined to give accurate magnitudes, the majority in two colours, for 640 stars, and approximate data for many more. The data have been examined and found to be free from systematic errors between magnitudes 3.0 and 10.0. The reductions to the adopted colour systems are also satisfactory. The most urgent need at present is for more observations of the fainter stars.

STANDARD MAGNITUDE SEQUENCES IN THE HARVARD STANDARD REGIONS AT - 45° DECLINATION

A Thesis for the Degree of Doctor of Philosophy
of the University of Cape Town

by

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PREFACE

This thesis gives an account of work done at the Cape Observatory in connection with the establishment of standard magnitude sequences in the Southern Hemisphere.

Reference is made to the characteristics and limitations of stellar magnitudes and the importance of accurate magnitudes for astronomical research. A brief account is given of the development of standard sequences at the North Pole and in the Harvard Standard E Regions at -45° declination. Later sections describe in detail two series of observations that have been made to determine accurate magnitudes for the brighter stars in the E regions.

In a final section magnitudes from a number of series, observed with different instruments, are collected and combined to give accurate magnitudes for a considerable number of stars in the E regions. The agreement between the various series is found to be, on the whole, very satisfactory, but further research is needed to extend the sequences to fainter stars and to include measures of the ultra-violet light.

I wish to express my thanks to my three supervisors, Professor Hales, Professor James and Dr. Stoy for their encouragement during the progress of this research and to those of my colleagues at the Cape Observatory who have assisted in the routine work involved.

I am especially indebted to Dr. Stoy, under whom I have worked since my association with the Cape Observatory, for many helpful discussions on photometry and for the great interest he has taken in this particular research programme.

Finally, I wish to thank Mrs P. Delport for the care she has taken in typing this thesis, and Mr F. Driver for the photographs illustrating the Fabry and photoelectric photometers.

Royal Observatory,
Cape of Good Hope.
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CONTENTS

Enclosures:

1. "Magnitudes of Bright Stars in the E Regions Observed by the Fabry Method", Reprinted from M.N., 110, No. 6, 1950.
2. "A Finding List for the Standard Stars in the E Regions", Cape Mimeogram, No. 2, 1953.
3. "Standard Magnitudes in the E Regions", Cape Mimeogram, No. 3, 1953.

SECTION I

INTRODUCTION

I. GENERAL CONSIDERATIONS

The largest single units in the universe are the galaxies. There is some tendency for them to form clusters but the intervening space appears to be almost completely devoid of matter. Some galaxies are flattened and may show a spiral structure, others are spheroidal and others again are irregular in shape. It is now known that the spheroidal systems and the nuclear regions of the spirals are composed of stars of certain types (Population II), while the spiral arms contain other types of stars (Population I), notably the hotter, early type, stars, associated with clouds of dust and gas. Even the very nearest systems can be only partly resolved into stars and we are to a large extent forced to study our own Milky Way system to fill in the details of our knowledge.

This is complicated by our position within that system, but there is no longer any doubt that our galaxy is a spiral system of moderate size. The nucleus or 'bulge' is in the direction of Sagittarius and the Sun is located near the central plane in or near one of the outer spiral arms. There are large quantities of dust and gas, mostly distributed in clouds and near the central plane. These obscure our view and complicate the interpretation of results.

What is known of the structure, dimensions and distances of the galaxies, including our own, is to a very large extent a result of the study of stellar photometry. The correctness (or otherwise) of the proportions depends on the accuracy of the photometric measurements.

Individual stars can be measured for position; if close enough the proper motions can be found, and if nearer still their parallaxes can be measured. Their brightness and the colour and polarization of their light can be observed, and if bright enough their spectra can be studied and radial velocities measured. If double, it may be possible to determine their masses and, in some cases, their linear dimensions, surface brightness and density. This material, taken together, has led to the realisation that the physical characteristics of the stars are inter-related and that the determination of one characteristic defines others uniquely or limits them to two or three discrete values with little dispersion between. It is this knowledge that makes stellar photometry such a powerful tool for astronomical research.

to measure visual and red magnitudes photographically and are extensively used in connection with photoelectric photometers. The choice of filters has nearly always been made on practical rather than theoretical grounds, to obtain as long a 'base line' as possible for colour measurements without too much loss of light, or possibly to simulate existing photographic and photovisual colour systems. The importance of measuring or avoiding the ultra-violet light is now being appreciated.

Both the spectral type and the colour of a star depend on its surface temperature and though the 'excitation' and 'colour' temperatures are not usually the same there is a close correlation between spectral type and colour index. A recent comparison between photoelectric colours (measured at the Cape Observatory) and spectral types on the Yerkes system (mainly those determined by Miss M. L. Woods at Canberra Observatory (1)) shows that the dispersion in colour for stars of the most numerous luminosity class III is only $0^{m}.02$ (A.D.), including observational errors. For a given spectral type the colour varies according to the luminosity. Supergiant stars of the later types are redder and the dwarfs less red than the normal giants of class III.

The normally close correlation between the spectral type and colour of the brighter stars has led to the discovery of stars of abnormal colour. The majority of these are too red and in most cases the 'colour excess' can be attributed to selective absorption in interstellar space. Ultra-violet - blue colour indices vary with the spectral type and luminosity in a different way from the usual blue - yellow or blue - red colour indices, which makes it possible to infer the normal colours and spectral types of stars from colour measurements even when the stars are reddened (2) (3).

Several workers (4) (5) (6) have attempted to determine the relation between the total absorption (usually of photographic light) and the observed colour excesses. The results differ somewhat but a factor between 4 and 5 seems the most probable when using the international system of Pg magnitudes and colours. (7) Seares has shown (8) that the ratio will vary with the colours of the stars but this refinement is usually ignored. The importance of this factor is that it provides a means of estimating the total absorption from a measure of the colour excess and so leads to an improved measure of the distance of a star. There is no certainty that the ratio is constant for different absorbing clouds but the evidence seems to show that it is nearly so. Near the galactic plane the absorption is often large and very irregular and it is impossible to form any true picture of our galaxy without making allowance for the absorption between us and distant stars. Towards the poles of the galaxy the general absorption is small and fairly uniform and can be allowed for as a function of the distance and the galactic coordinates.

The reduced absorption experienced in red and infra-red light has stimulated the use of these longer wavelengths for galactic studies. Not only does this reduce the necessary corrections (7) but it frequently permits the observation of stars so much reddened as to be invisible on ordinary plates. The longer base line possible with red magnitudes is another factor in their favour.

Since it is to be multiplied by a factor of 4 or 5, the colour excess requires to be known with greater accuracy than the magnitude. The change of absolute magnitude with colour index is equally rapid. This emphasises the need for high precision when star colours are being measured. It is particularly important that there should be no change in the colour index system with change of magnitude. The magnitudes (as such) do not, as a rule, require to be known with the same precision. This encourages the direct measurement of colours as distinct from their derivation from two more or less independent series of (Pg and Pv or red) magnitudes. Circumstances may, however, compel the observer to adopt the latter expedient. Where the stars are congested or the numbers are very large, individual observations may be impracticable or uneconomical and in-focus photography in two or more colours still seems to be the best solution.

It may be well to mention that some theoretical workers are inclined to take published magnitudes too much for granted without realising their limitations. Systematic errors in the magnitudes may be objectionable in cases where comparatively large random errors can be tolerated and they can lead to false conclusions. Even when the magnitudes do not enter explicitly into a discussion there may be a practical limit of faintness involved and a false evaluation of this limit may affect the deductions. This emphasises the importance of making every effort to ensure systematic accuracy in the magnitudes even when these are observed by 'mass production' methods.

II. MAGNITUDES AND COLOUR INDICES

The mathematical relation between magnitude m and brightness B, proposed by N. R. Pogson (9) and now universally adopted, can be expressed in the form

$$m = -2.5 \log_{10} B + z \qquad (1)$$

where z depends on the unit of brightness and the zero point of the magnitudes and is constant so long as m and B refer to the same colour system. Magnitudes derived from measures of brightness in this way are said to be on the natural system of measurement.

The apparent brightness of a star varies inversely as the square of its distance if the intervening medium is perfectly transparent, but in the more general case some fraction of the light is scattered and absorbed. If M is the absolute magnitude of a star (i.e. the magnitude as seen from a distance of 10 parsecs) and r is its actual distance in parsecs, it follows from equation (1) that

$$m - M = 5 \log r - 5 + A \qquad (2)$$

where A is the absorption in interstellar space (expressed in magnitudes) as affecting that particular star. It does not matter what system of magnitudes is used, but it is essential that the apparent and absolute magnitudes and the interstellar absorption should all be on the same system and that this system should be uniform and systematically accurate. In particular, equation (1) should apply to any two stars of identical spectral type and colour regardless of their brightness and positions in the sky. This thesis is primarily concerned with the establishment of a system conforming to these conditions.

If stars were perfect radiators the variations in the intensity of the radiation with wavelength could be expressed in terms of Planck's equation,

$$I(\lambda) = \frac{c_1 \lambda^{-5}}{e^{\frac{c_2}{\lambda T}} - 1}$$

or $$\log I(\lambda) = -5 \log \lambda - \log \left(e^{\frac{c_2}{\lambda T}} - 1\right) + k$$

This describes the radiation at its source. Astronomers are more often concerned with the radiation as received. If I (r,λ) is the monochromatic intensity of radiation received from an incandescent sphere of radius a at a large distance r, then:

$$\log I\,(r,\lambda) = -5 \log \lambda - \log \left(e^{\frac{c_2}{\lambda T}} - 1\right) - 2 \log r/a + k$$

Equation (1) may be written in the form

$$m = -1.086 \log_e B + z$$

so that when the monochromatic magnitudes of two sources are compared, we find the difference, $\Delta m_\lambda = m(r_1,\lambda) - m(r_2,\lambda)$

$$= 1.086 \left[\log_e \left(e^{\frac{c_2}{\lambda T_1}} - 1\right) - \log_e \left(e^{\frac{c_2}{\lambda T_2}} - 1\right) + 2 \log_e \frac{r_1\, a_2}{r_2\, a_1}\right]$$

The derivative,

$$\frac{d\,(\Delta m\lambda)}{d\,(1/\lambda)} = 1.086 \left[\frac{c_2}{T_1} \Big/ \left(1 - e^{\frac{-c_2}{\lambda T_1}}\right) - \frac{c_2}{T_2} \Big/ \left(1 - e^{\frac{-c_2}{\lambda T_2}}\right)\right]$$

is almost independent of λ for astronomically accessible **wavelengths**. This has given rise to the conception of spectrophotometric 'gradient' (10)(11). The expression $\frac{c_2}{T}\left(1 - e^{\frac{-c_2}{\lambda T}}\right)^{-1}$ defines the 'absolute gradient', a useful parameter for the 'colour temperature' of a radiator. While this theoretical treatment is strictly applicable only to monochromatic magnitudes of perfect radiators it is found that relative gradients (i.e. $0.921 \frac{d(\Delta m_\lambda)}{d(1/\lambda)}$) measured between the continua of normal stars are in fact nearly constant over the visible portion of the spectrum. There is, however, a discontinuity at the Balmer series limit (to the ultraviolet of 3700 Å), first noted by Sir William and Lady Huggins (12) and more recently investigated by Barbier, Chalonge, and others (13). When the Hydrogen lines are strong there is a marked increase in the absorption and a change in gradient on the short wavelength side of the Balmer limit.

The measurement of gradients is practically confined to the brighter stars of which spectra having sufficient dispersion can be obtained with reasonably short exposures and, valuable as the method is, its use for the measurement of colour temperatures is confined to a comparatively small number of stars. Fortunately similar information can be derived from conventional colour indices and these can be measured for any stars bright enough to be photographed.

Since relative gradients are insensitive to the range of wavelengths considered, $\frac{d(\Delta m_\lambda)}{d(1/\lambda)}$ may be written $\frac{\Delta m_{\lambda_1} - \Delta m_{\lambda_2}}{1/\lambda_1 - 1/\lambda_2}$ and this is true, to a first order approximation, for integrated magnitudes also if the reciprocal equivalent (14) wavelengths are used. The effect of the approximation is to introduce a small amount of non-linearity (15). Dr. A. D. Code has (verbally) reported that the use of effective (or equivalent) reciprocal wavelengths gives an even better approximation. However, when integrated magnitudes extending over considerable ranges of wavelength are used it is no longer possible to measure the continuum only and any absorption (or emission) lines that are present are inevitably included. Colour indices cannot therefore be expected to give results identical with gradients even when it is possible to define the equivalent wavelengths with sufficient precision.

There is no difficulty in computing the equivalent wavelength of a system of magnitudes if the sensitivity curve of the receiver and the transmissions of filters and other optical components are known (16), but in practice it is difficult to make the measurements with sufficient accuracy and the equipment for doing so is not usually available at observatories. It is, therefore, more usual, and in most cases more satisfactory, to define a colour system empirically by comparison with an accepted 'standard' system. This is particularly true of in-focus photographic photometry where image structure is an added complication.

As a consequence of the similarity between colour indices and gradients, it might be expected that different systems of colour indices, e.g. (Pg - Pv) and (Pg' - Pv'), would bear a nearly linear relation to one another. This proves to be the case for many magnitude systems and provides a convenient and effective way of defining a difference in colour and of converting observed magnitudes to a standard system when required. The relation between colour indices and gradients is not so simple (17) because of the effect of spectral lines and continuous absorption. The close approximation to linearity of many colour relations cannot, therefore, be considered a necessary consequence of linearity in the gradients. It rather shows that there is a nearly linear progression in the effect of line absorption from one spectral type to another when the magnitudes are measured over the usual ranges of wavelengths. When the relations are not linear this is usually because the series include different amounts of ultra-violet light. The conversion of such magnitudes to other systems is less certain since a second parameter is then involved.

Interstellar absorption varies approximately as the reciprocal wavelength of the light (18) with the result that the linearity of the gradients is not much affected by the reddening. On the other hand the relation between spectral type and colour is changed, and the indiscriminate substitution of one for the other is no longer permissable. A non-linear colour correction derived from normal stars is not valid for reddened stars. There is, therefore, good reason for avoiding the shorter wavelengths (<3800 A) when measuring photographic (Pg) magnitudes and colours. Measurements in that region have, however, assumed considerable importance as a means of distinguishing between temperature effects and interstellar reddening (2) (3), but ultra-violet - blue colour indices should then be measured specifically.

Lenses made from ordinary optical glasses pass little light beyond 3800 Å. The Cape magnitudes and colours are, therefore, comparatively free from ultra-violet troubles. For the same reason it was not thought possible to obtain useful ultra-violet measures with these instruments but Code has recently demonstrated that such measures are practicable with the 24-inch Refractor.

III. STANDARD MAGNITUDES

Practically all stellar photometry is relative, that is, stars are compared with one another rather than with a terrestrial source or a laboratory standard. This is principally because of the difficulty of making allowance for the effects of the earth's atmosphere through which all observations have to be made. In South Africa (and probably in most parts of the world) the transparency usually varies to a greater or lesser extent in the course of a night. In the still dry air of the Transvaal winter there is a tendency for dust and smoke to settle. At the Cape the formation of mist and fog is a not infrequent cause of reduced transparency as the night progresses. It is virtually impossible to predict what changes will take place and the simplest way to allow for them is to compare the stars with one another simultaneously or in quick succession. Conditions may also vary from one part of the sky to another even when it appears to be clear. Both the Cape and Radcliffe Observatories are situated within comparatively short distances of industrialised and built-up areas where smoke, haze and the glow of city lights can be troublesome. For these reasons it is not only desirable that stars should be compared as quickly as possible but that they should be as near as possible to one another in the sky.

Experience has shown that most stars are sensibly constant in their light, over a period of several years at any rate, and, provided enough are used to insure against possible variability, they constitute very reliable standards. All stars appear as point sources so no complications arise from size or shape unless the star is double.

The number and distribution of the stars is such that there is rarely any difficulty in finding enough stars to serve as "working" standards for any particular purpose, but this wide distribution coupled with differences in colour and brightness makes the problem of standardisation a difficult one. Some stars have to be selected as "primary" standards to define a standard colour system and its zero point and the working standards have to be referred to these, either directly or through secondary standards, if uniformity is to be achieved.

The choice of stars for use as standards will naturally depend on the purpose for which they are required. Variable stars are normally compared with one or more comparison stars in their immediate vicinity and when much work is to be done in one area, it is desirable to establish a magnitude sequence there. On the other hand, when observations are to be made in various parts of the sky, it is necessary to have an adequate number of standard stars conveniently situated for use at any time of night. The number and distribution of these stars will depend to some extent on their use. Generally speaking, photoelectric observers are content with fewer stars but demand a higher accuracy than those using photographic methods, and while the former might be content with a number of single stars, it is essential for the latter to have their standard stars concentrated in one or more restricted areas. The former arrangement may be more economical of stars and permit a wider selection and distribution but the author questions whether it is as good as the latter for defining the characteristics of a magnitude system.

The number and selection of stars needed to provide an adequate sequence (for whatever purpose it is required) depends essentially on the number of degrees of freedom that have to be defined and the accuracy with which this has to be done. One star is theoretically enough to define the zero point if the other characteristics of a magnitude system are known, but this is never safe in practice. When non-linear relations have to be allowed for the number increases rapidly.

If magnitudes were convertible from one system to another with an accuracy consistent with the internal errors, a few stars properly chosen and adequately observed would be sufficient to define a system. This might be the case if stars had strictly continuous spectra but with stars as they are no simple conversion formula can possibly give an exact transformation from one natural system of magnitudes to another. For this reason, it is preferable to use a larger number of stars no matter how well they may be observed individually.

Standard sequences for general use should contain enough stars to define a colour equation whether or not the relation is linear. They must, therefore, include stars of all the more usual spectral types, though not necessarily in every sequence. If the latter were insisted on it would seriously limit the choice of regions, more particularly because of the absence of early type stars away from the galactic plane. It would be a convenience if such a selection were available in various magnitude ranges, but here again blue stars are certain to be a stumbling block. To be faint a B-type star must either be very distant or much obscured and in either case it is likely to be reddened, since distant stars of this type lie close to the galactic equator where obscuring matter abounds. The only consolation is that if stars of any type and magnitude are not found in a region, they are probably rare in the neighbourhood, and the information may not be needed.

A photographic observer needs enough stars to provide a plate calibration and as this is usually a non-linear function of the quantity measured and the accuracy of the measurement is comparatively low, he needs a number of stars in every magnitude interval and in every standard region he uses. Furthermore, there should be a suitable selection of stars to fix a linear colour equation from one sequence alone. It may be possible, with careful selection, to ensure that a sequence is suitable for both photographic and photovisual use, but in general, a few additional stars will be needed for the second colour. Non-linearity in the colour equation and variation in the colour equation with magnitude must also be allowed for, but these can usually be determined from the aggregate of stars without insisting on a sufficient number in every sequence. The distribution of the stars over the region is also important if field corrections have to be determined. Between 10 and 20 stars per magnitude interval has been suggested as an appropriate number for a single standard sequence (19). The smaller number would seem sufficient when several standard regions are available provided that the stars are carefully chosen. A larger number will almost certainly have to be measured in the first instance if a good selection is to be made.

IV. THE N. P. S. AND THE INTERNATIONAL SYSTEM

The idea of transferring a magnitude sequence from one part of the sky to another by photographing both regions on the same plate or on plates taken "in series" seems to have originated with E. C. Pickering (20). He established a sequence of photographic magnitudes near the North Pole to serve as standards (21). This original sequence of ten stars was later increased to 96 (22), usually referred to as the "North Polar Sequence" (N. P. S.) or sometimes as the "original" N. P. S.. After further revision a final list of photographic magnitudes was published in Harvard Annals Vol. 71, Pt. 3 (23). A list of provisional photovisual magnitudes is also included. A detailed account of the methods used in establishing the sequence is given by Miss H. S. Leavitt, who was mainly responsible for the work. In spite of the efforts made to conform to Pogson's Rule it was later found that the scale was not correct.

During the years that followed several observatories made contributions towards improving the magnitude sequences, sometimes by checking the scale and sometimes merely by helping to reduce the accidental errors. These included the Greenwich, Harvard, Mount Wilson and Yerkes Observatories. F. H. Seares undertook the coordination of the results and submitted revised sequences of magnitudes to the First General Assembly of the International Astronomical Union in 1922 (24). These magnitudes were adopted as the standards defining the "International System" of photographic and photovisual magnitudes (IPg and IPv).

The number of stars in the N. P. S. is somewhat limited and this led to the provision of a "supplementary list" of stars (25) and later to the much more extensive catalogue of "Magnitudes and Colours of Stars North of +80°", frequently referred to as the "Mount Wilson Polar Catalogue" (26).

All the observational material on which these catalogues are based was obtained photographically and it is a tribute to Seares and his co-workers that these sequences have needed so little revision in the course of time.

Since 1922 several observers have used photoelectric photometers to check the N. P. S.. In 1938, J. Stebbins and A. E. Whitford (27) reported a considerable scale error at the bright end of the sequence but there was some doubt about its reality (28), especially as it was not confirmed by W. Hassenstein (29) (30). Since then further measures have left no doubt about the error being real (31). Professor Redman has combined the new photoelectric measures to give more reliable magnitudes for the brighter stars. These "interim values" remove the systematic errors of the magnitudes adopted in 1922 but have not received unanimous approval.

When fast red sensitive plates became available, there was a demand for standard red magnitudes. Red magnitudes for the North Polar Sequence were measured at Harvard and published in Harvard Annals, Vol. 89, No. 5 (32). These magnitudes have since been revised by J. J. Nassau and Virginia Burgher (33) (34).

There is now considerable interest in the ultra-violet end of the spectrum and provision will probably have to be made for defining a system of ultra-violet magnitudes or colour indices.

The N. P. S. has been transferred to a number of areas in the northern hemisphere. In some cases this was done merely to standardise magnitudes for a particular research programme. In other cases sequences have been set up for more extended work. Much of this has been done photographically on or near one of the three recognised colour systems, with the result that the secondary standards tend to have the same systematic errors as the polar standards themselves. Even when the scale has been set up independently, the zero points are uncertain because of the scale error in the primary standards.

*At the present time there is not unanimity as to how the N. P. S. should be revised or whether it should be replaced. Difficulties in using a standard sequence at the North Pole and the absence of a sufficient variety of stars in this area make it clear that other standard sequences and selected stars are necessary to meet the needs of present day photometry. Some generally accepted standard sequence or homogeneous series of sequences is obviously necessary to define standard colour systems and zero points, but the choice of location and of other characteristics inevitably leaves room for disagreement.

The situation in the southern hemisphere is different. Until recently there was no sequence south of the equator whose accuracy compared with that of the N. P. S. as revised in 1922. The new sequences discussed in this thesis do not depend on the N. P. S., but in order to secure uniformity between the results of workers in the two hemispheres, it is of great importance that the relation between the southern magnitude systems and the international or other standard systems adopted by the northern observers should be known.

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*Insert concluding paragraph here.

R. H. Stoy has recently made use of the material presented in later sections, in conjunction with other observations, in an effort to derive a definitive relation between the southern and the international systems (36). The agreement between the different series of magnitudes is not all that could be desired, probably because of differences in the ultra-violet content of the different magnitudes. Stoy adopts the following relations as giving the best linear relation between the southern system (SPg, SPv, SCI) and the international system (IPg, IPv, ICI):

$$\begin{aligned} \mathrm{IPg} &= \mathrm{SPg} + 0.01\ \mathrm{SCI} + 0.05 \\ \mathrm{IPv} &= \mathrm{SPv} + 0.08\ \mathrm{SCI} - 0.06 \\ \mathrm{ICI} &= 0.93\ \mathrm{SCI} + 0.11 \end{aligned}$$

Insert on previous page.

Another complication that has arisen in connection with the N. P. S. is due to the varying amounts of ultra-violet light that have been included in the photographic magnitudes observed with different instruments. Seares suspected trouble from this cause as early as 1938 (28) and H. L. Johnson has since shown how serious the effect can be (35). In the majority of cases the observed magnitudes showed reasonable agreement with the standard magnitudes after the application of linear colour corrections and it was assumed that the same corrections were valid for stars of all spectral types and absolute magnitudes. The effect of including ultra-violet light is greatest with the early type stars, where it is most plentiful, and drops off rapidly for main sequence stars as type A0 is approached due to the strong hydrogen absorption. For this reason the colour corrections for B-type stars and supergiants of type A may differ considerably from a linear relation derived from other stars. The N. P. S. does not include any early type stars and is, therefore, not suitable for showing up differences in the ultra-violet content of magnitudes.

V. THE HARVARD STANDARD REGIONS

In 1885 E. C. Pickering divided the sky into forty-eight equal areas occupying six zones of declination identified by the letters A to F. These were used to study the bright stars (37) and sequences were established with a view to studying a sample of fainter stars near the centre of each. Although much work was done in connection with this programme, the plan finally gave way to Kapteyn's more ambitious scheme of Selected Areas. The sequences have, however, remained in use for other purposes.

The original sequences of photographic magnitudes for the A, B, C and D regions were set up by direct comparison with the North Pole. The sequences for the E and F regions (Decl. -45° and -75°) were obtained by comparison with the C regions. The measurements and reductions were largely the work of Miss Leavitt (38). The magnitudes were supposed to be on the system of the N. P. S. and therefore to require the corrections adopted by the I. A. U. in 1922 to reduce them to the international system (39). Magnitudes of the brighter stars with these corrections applied are given in Harvard Annals, Vol. 89 (40).

Visual (photometric) magnitudes for some of the sequence stars are included in the lists given in Harvard Annals, Vol. 71. Photovisual magnitudes for stars brighter than the twelfth magnitude are given in Harvard Annals, Vol. 89, together with the visual magnitudes reduced to the same colour system. The determination of these magnitudes was started by Miss Leavitt and completed by Miss C. H. Payne.

When the Cape Observatory undertook the re-observation of the A. G. Zones to the south of -30° declination to determine accurate modern positions and proper motions for these stars, it was decided to include in the same catalogues measures of their magnitudes and colours and observations of their spectral types. It was planned to observe the magnitudes photographically and photovisually by in-focus methods and a pair of cameras was secured for the purpose. Except for the first series, when disappointing results were obtained by using coarse gratings (41), the scale, colour system and zero point are being fixed by photographing one of the E regions on each of the zone plates. The E regions were chosen because the available sequences of photographic and photovisual magnitudes covered the range of brightness required for the zone programmes and were thought to be adequate for the purpose.

When measuring the positions of stars photographically with a wide-angle camera of the type used at the Cape Observatory, it is found that there are errors correlated with both the magnitudes and the colours of the stars observed. It is, therefore, necessary to have these photometric data if a high precision is desired. On the other hand, the combination of data regarding the proper motions, spectral types, magnitudes and colours of such large numbers of stars provides extensive material for statistical studies. For this reason, if for no other, it is important that the magnitudes should be systematically accurate or, if not, that the nature and size of any errors should be known.

It was early apparent (42) that the Harvard magnitudes were neither individually nor systematically accurate enough for the purpose in view and that the number and the selection of the stars was inadequate to fix the scale and other characteristics of the photometric plates. Work was then started at the Cape Observatory in an effort to improve and extend these sequences.

The first revision was completed in 1943 (43). The observational material consisted of in-focus plates intercomparing the E regions and comparing them with the galactic clusters Pleiades, Hyades and Praesepe where the magnitudes were thought to be reliable.

Further comparisons were made with the Eros comparison stars (44) for which magnitudes were available from the Yerkes and Mount Wilson Observatories, and with the Pleiades again in 1944 (45). These comparisons were reviewed by Seares and Joyner who proposed further corrections to the Cape magnitudes (46).

During the years 1944-47 the Cape Photometric Cameras were used by R. O. Redman at Pretoria (47) to take further series of plates comparing the E regions with one another, with certain clusters and with the Eros comparison stars and finally with a number of Kapteyn's Selected Areas at +15° declination. In addition J. Jackson took a series of plates with the Victoria Telescope at the Cape to strengthen the data on the fainter stars. All these plates were measured and reduced at the Cape. This material provided magnitudes with small accidental errors on a system that was essentially uniform from region to region but the systematic accuracy was no better than that of the northern hemisphere "standards" with which they were compared. These comparisons were far from reassuring and led to several series of observations employing fundamental methods, two of which are described in detail in this thesis.

R. H. Stoy had tried course gratings for the purpose of fixing magnitude scales but found the method completely unreliable (41). Redman used rotating sectors and a variable exposure method in conjunction with in-focus plates with a certain amount of success (48). Both methods had been (49) (50) and have since been used at the Cape in different forms, but developments in photoelectric photometry have now rendered these methods obsolete except possibly for the faintest stars.

Redman also used the Fabry method, first for a series of photographic magnitudes in E3 (51) and later for an extensive series of photovisual magnitudes in E1, E5, E6, E7, E8 and E9. Some preliminary results from the programme of Fabry observations described in Section II were available early in 1948.

These observations led to two revisions of the E region magnitudes by Stoy. The first, in 1946, led to the "Q" system, the second, in 1948, produced the "S" system, which is the system to which the zone magnitudes are being reduced. In the course of these revisions, a number of stars were added to the sequences. In choosing these an effort was made to include a better selection of stars of different spectral types and a few stars situated farther from the centres of the regions were added to assist in determining plate distance corrections.

Since 1949 practically all the observations made to improve the accuracy of the magnitudes have been made photoelectrically or by the Fabry method. A summary of these observations is given in Section IV of this thesis, where they are combined to give accurate magnitudes for many of the stars. The numbers of stars brighter than the twelfth magnitude are adequate for many purposes but the selection still leaves something to be desired and it is proposed to review the position before embarking on further magnitude determinations.

A survey of the brighter stars has already been made and magnitudes in two colours are available for a considerable number of stars in all the E regions. This material will be used to select additional stars to improve the distribution according to colour in different magnitude ranges where suitable stars are available. A similar "durchmusterung" is in progress for fainter magnitudes and it is hoped to use this data to select stars to supplement the Harvard sequences. In the past, measurements in the fainter magnitude ranges have been practically restricted to these latter stars and, even for them, the data are far from adequate.

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SECTION II

THE FABRY METHOD OF STELLAR PHOTOMETRY

PLATE I

Fabry photometer (with plateholder removed) attached to 13-inch Astrographic Refractor.

The clinometer can be seen attached to the guiding telescope.

PLATE II

A. Components of Fabry photometer.

The plateholder is on the left. Above it are the filter holder, the diaphragm and lens mount, and the Fabry lens. On the right is the base plate with a sliding stage. The propelling screw is partly concealed by the plateholder clamp. A spring-loaded ball at the centre of the latter engages with a series of depressions on the back of the plateholder and fixes the lines of images on a plate.

B. The stepped rotating sector.

The knob at the end of the supporting arm by means of which the sector may be inserted into or withdrawn from the light path is just visible in the left hand corner, below the focusing screw. (It is more clearly shown in Plate IV A).

PLATE III

Close-up views of Fabry photometer,

A. without plateholder

B. with plateholder in position.

PLATE I

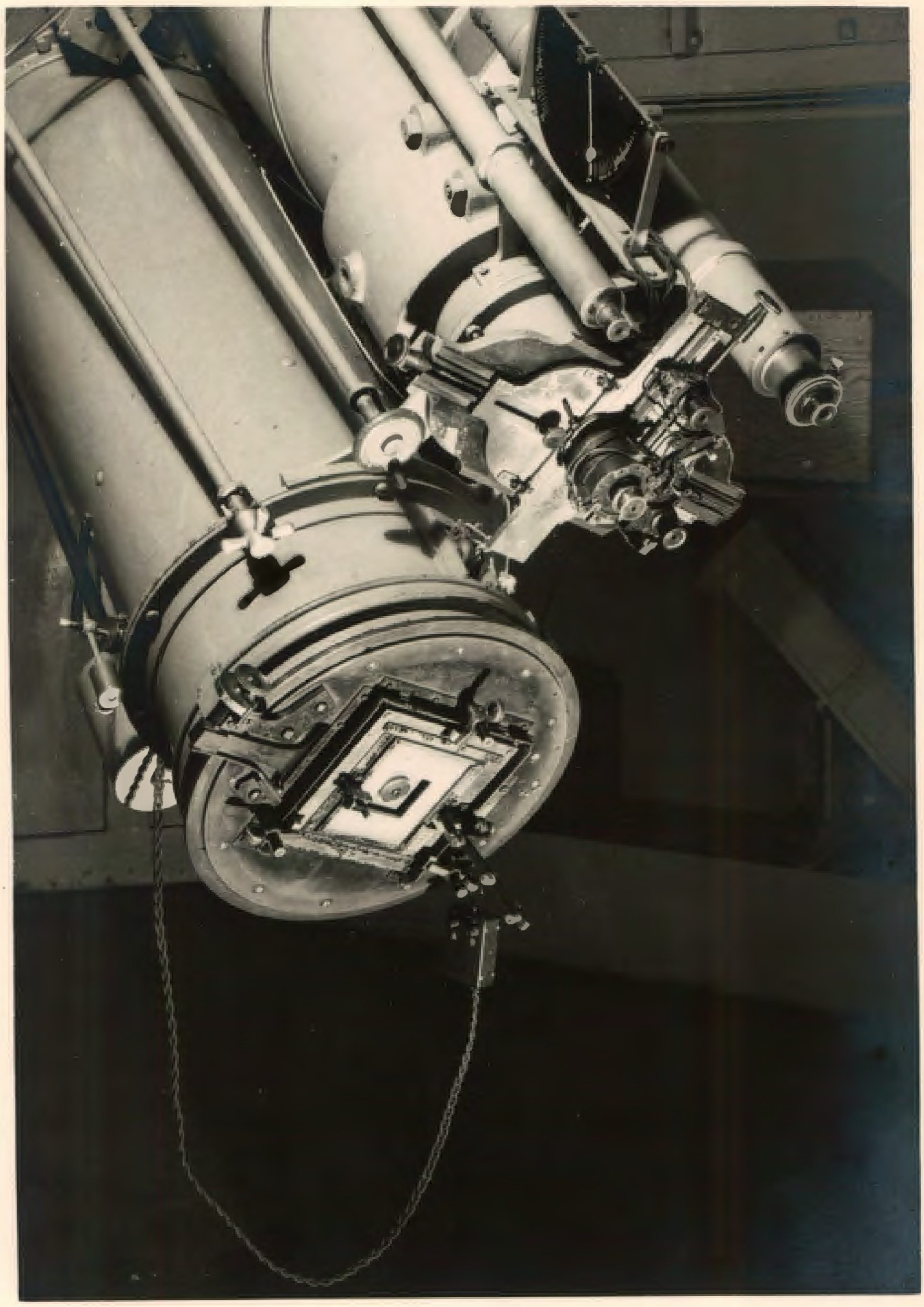
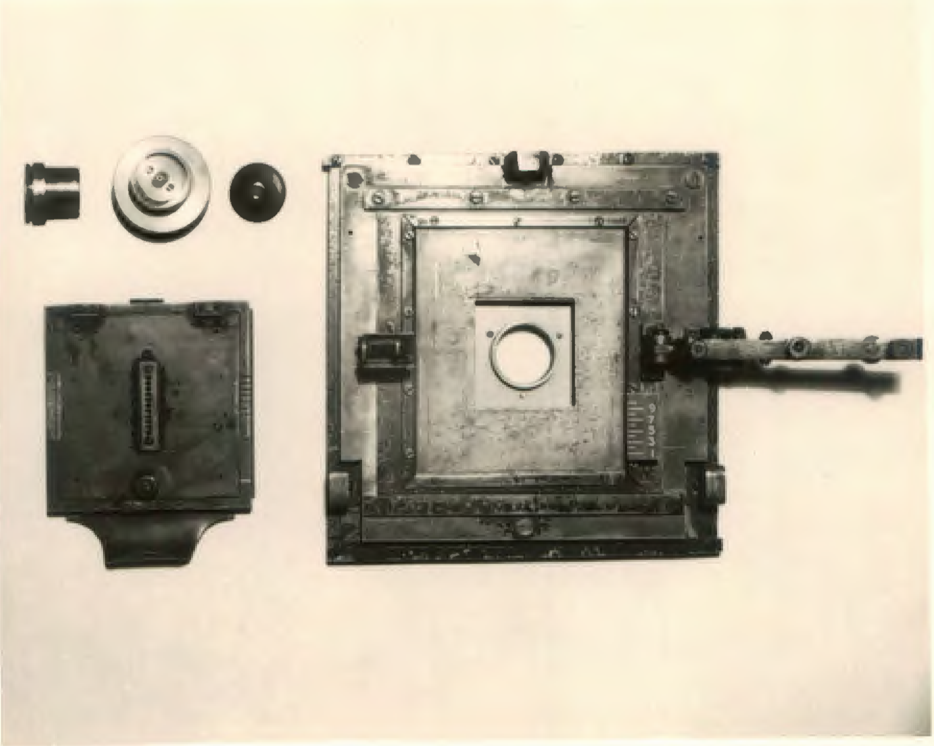
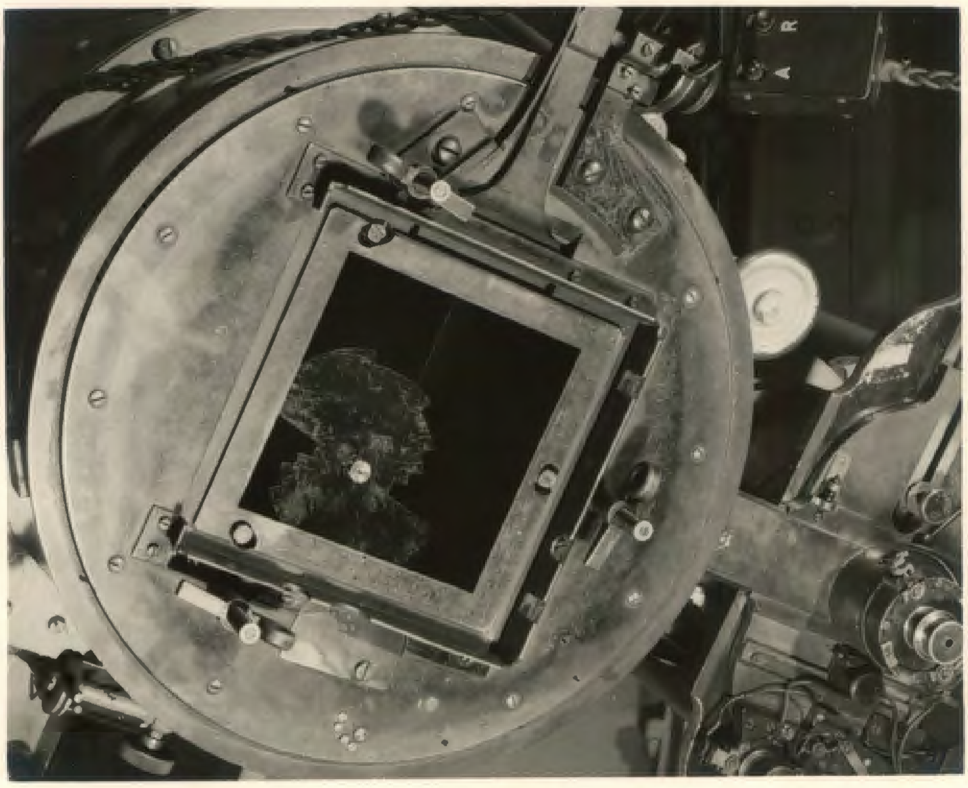
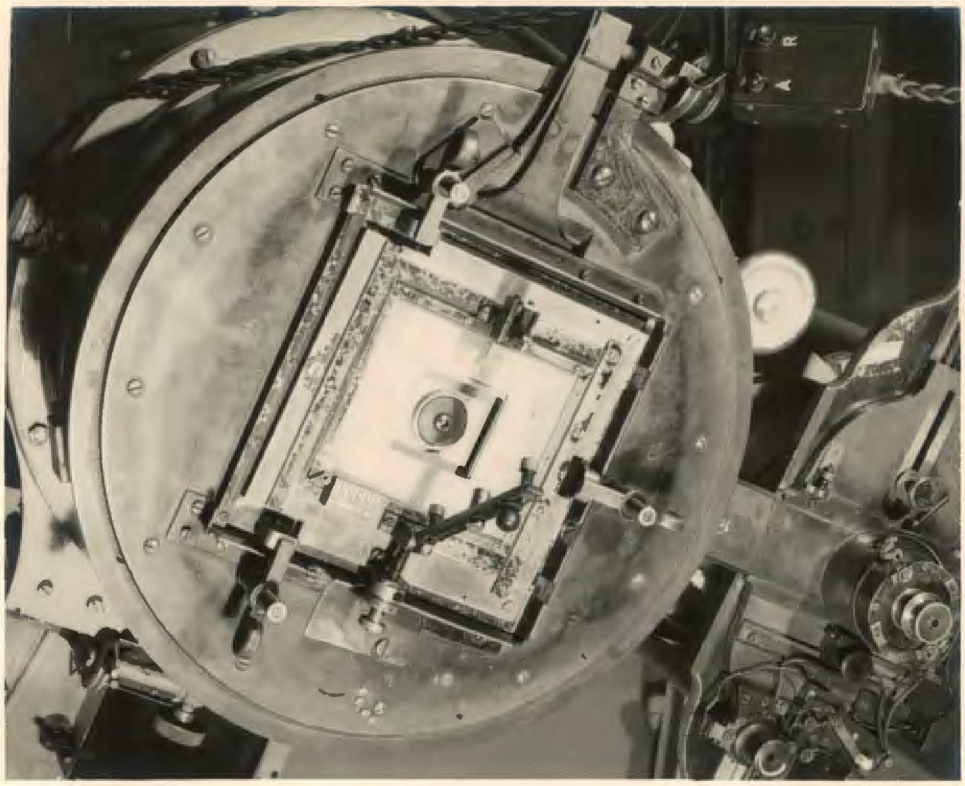


PLATE II

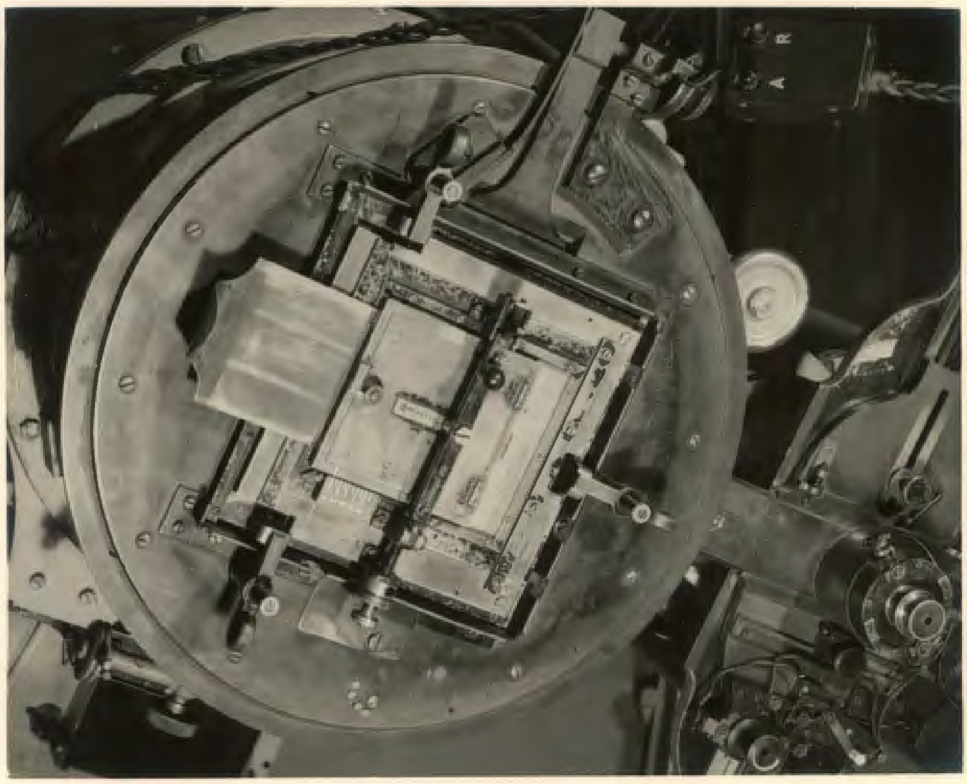

A


B

A



B



SECTION II

THE FABRY METHOD OF STELLAR PHOTOMETRY

I. GENERAL

The photographic method of photometry named after the French physicist Ch. Fabry was devised by him for measuring the light of the night sky (1) (2). The optical system consists of a telescope objective that serves as a condenser and a lens of short focal length that acts as a field lens. The objective focuses the light from a star or a portion of the sky to pass through the field or 'Fabry' lens and the latter images the objective on the surface of a photographic plate. The Fabry photometer has the advantage that the final images do not vary in shape whatever the distribution of light in the original source.

Several workers have taken advantage of this property. Fabry (1) (2), Struve and Elvey (3), and Henyey and Greenstein (4) all used the method for measuring the light of the sky. Barbier and Chalonge observed the brightness of the moon during a total eclipse (5), P. Bacchus measured the brightness of the coma of Comet Bester (6), C. Fehrenbach used the method for determining the integrated magnitudes of globular clusters (7), and J. Bigay did the same for some of the brighter galaxies (8).

The first reported use of the Fabry method specifically for stellar photometry was by H. Grouiller at the Lyons Observatory (9). Shortly afterwards it was used by E. G. Williams (10) and R. O. Redman (11) at the Radcliffe Observatory, Pretoria, by A. W. J. Cousins (12) at Durban and by R. H. Stoy and H. C. Davies (13) at the Cape. The technical aspects of the method have been discussed at some length by Grouiller (9), Redman (11) and Fabry (14).

In all the earlier work the 'scale' was fixed by means of sensitometer calibrations. The range of magnitudes that can be observed depends on the optical components, the filters and the plates used, and the exposure time. If none of these are changed the useful range is scarcely three magnitudes, and that only with some loss of accuracy at both ends of the range. As the result of investigations into the behaviour of rotating sectors in connection with photographic photometry at the Cape (15) (16) and Radcliffe (17) (18) Observatories sectors were introduced to reduce the light from the brighter stars to approximate

Fabry Observations with the Cape Astrographic Telescope

CZC	Q	Pg	Pv	CI
		E 1		
500†	61	4.03	3.32	+0.71
510	37	5.13	5.36s	-0.23
515†	47	6.93	6.99	-0.06
577	36	5.30	5.01	+0.29
582	30	7.65	6.50	+1.15
589	46	7.49		
604	34	8.16	6.61	+1.55
632	4	7.58s	7.54	+0.04
638	43	7.11	7.13	-0.02
652	38	6.31	5.38	+0.93
655	41	7.26	6.20	+1.06
676	32	8.35	6.81	+1.54
677	1	7.55		
680	62	4.91	3.28	+1.63
691	39	7.81*	5.95*	+1.86
703	63	4.76	3.92	+0.84
705	6	8.01		
707†	40	5.99	6.32	-0.33
738†	21	7.62	6.89	+0.73
764	31	8.00	6.91	+1.09
768	42	6.77s	6.76s	+0.01
795	64	6.53	6.79	-0.26
		E 2		
1890	52	7.30	7.46	-0.16
1896	26	7.72s	6.89s	+0.83
1902	8	8.16		
1912	39	6.76	6.78	-0.02
1928	40	7.05	5.82	+1.23
1935	41	6.83	7.02	-0.19
1947	30		7.42	
1948	14	8.43		
1968	10	8.26		
1977	27	7.80	6.75	+1.05
1997	28	8.09	7.16	+0.93
2007	4	8.09		
2023	2	7.60		
2026	42	6.61s	6.72	-0.11
2040	5	7.58		
2058	48	7.36s	6.53s	+0.83
2061	6	8.40		
2074	43	6.72	6.63	+0.09
2092	64	5.03	5.00s	+0.03
2104	29	8.10	6.51	+1.59
2120	65	4.82	3.77	+1.05
2125	44	7.14	6.78	+0.36
2147	69	4.33	4.34	-0.01
2157	53	7.97	7.54	+0.43
2168	45	6.26	5.24	+1.02

CZC	Q	Pg	Pv	CI
		E 3		
3572†	45	5.43s	5.87s	-0.44
3644	35	7.50	6.59	+0.91
3660	37	8.07	7.07	+1.00
3676	5	7.93		
3736	85	6.41	6.98	-0.57
3738	1	7.70		
3740	2	7.92		
3742	86	2.79	3.30	-0.51
3746	4	7.41		
3758	6	8.11		
3763	3	7.25	7.69	-0.44
3768	7	8.14		
3770*	87	5.59	4.86	+0.73
3783	88	6.96	7.50	-0.54
3806	50	6.23	6.76	-0.53
3840	13	8.18		
3862	89	6.77	7.32	-0.55
3904	15	7.32	7.49	-0.17
3912	46	6.94	7.44	-0.50
3926	53	6.82	7.21	-0.39
3931*	36	7.94	6.29	+1.65
3933	47	5.35	5.16	+0.19
3973	48	6.70s	6.53	+0.17
3978	49	6.08	6.57	-0.49
4067	51	6.51	6.93	-0.42
4077	52	5.95	6.32	-0.37
		E 4		
7019†	81	6.44	6.87	-0.43
7024	76	3.81	2.01	+1.80
7070	91	6.43	6.98	-0.55
7091	92	4.92	5.03	-0.11
7103	93	5.26	5.93	-0.67
7115	39	6.84s	6.69s	+0.15
7119†	40	5.16	5.69	-0.53
7132	94	5.60	6.05*	-0.45
7142	78	5.42	5.99	-0.57
7145*	79	4.80	5.37	-0.57
7171†	41	5.89	6.39	-0.50
7184	95	6.04	6.09	-0.05
7191	42	6.71	4.88*	+1.83
7203	96	6.46	6.86	-0.40
7232	6	8.18		
7236	30		7.10	
7262	43	6.87	7.41	-0.54
7265	29	7.78	6.57	+1.21
7269	12	7.85		
7280	11	7.47		

Fabry Observations with the Cape Astrographic Telescope

CZC	Q	Pg	Pv	CI
		E 4		
7292	10	7.34	7.55	-0.21
7302	4	7.86		
7303	44	6.45	5.68	+0.77
7315	3	7.73		
7318	15	8.12		
7327	97	5.80	6.42	-0.62
7333	98	5.81	6.35	-0.54
7336	5	7.92		
7380	13	7.91s		
7385	51	7.23	7.60	-0.37
7418	99	6.73		
7421	100	7.19		
7434	45	6.84	6.62s	+0.22
7435	101	7.30	7.03	+0.27
7439	102	7.25	7.02	+0.23
7453	25	7.80	7.59	+0.21
7462	28	7.68	6.53	+1.15
7471	20	8.01		
7474	14	7.95		
7475	46	6.54	6.60	-0.06
7609	47	6.34	5.48	+0.86
		E 5		
9812	51	4.88	5.40	-0.52
9850	36	7.25	7.24	+0.01
9872	52	7.82		
9884	76	5.65	4.31	+1.34
9887	77	6.36	6.70	-0.34
9922	53	8.10	7.13	+0.97
9968	37	6.45s	6.29s	+0.16
9978*	3	7.99		
9980	38	7.08	6.76	+0.32
9994	70	6.03	6.47	-0.44
10001	39	7.02	6.65	+0.37
10013	16	8.19		
10046	71	6.64	6.67	-0.03
10051	40	5.34	5.17	+0.17
10097	54	7.40	7.23	+0.17
10100	41	7.10	7.40	-0.30
10111	78	5.10	5.45	-0.35
10118	2	7.78		
10121	42	5.78	5.83	-0.05
10153	20	7.87	7.52	+0.35
10156†	27	7.54	6.52	+1.02
10160	50	6.83s	6.60s	+0.23
10197††	55	6.66	5.12	+1.54
10207	28		7.43	
10248	1	7.61		

CZC	Q	Pg	Pv	CI
		E 5		
10282	79	7.16	7.19	-0.03
10284	43	6.64	6.95	-0.31
		E 6		
12297	78	4.09	4.72	-0.63
12300†	79	4.55	4.40	+0.15
12309*	80	5.91	5.91	0.00
12331*	81	6.03	6.56*	-0.53
12353	39	5.17	5.65s	-0.48
12386	21	8.15		
12436	82	6.63	7.01	-0.38
12445	83	1.87	2.51	-0.64
12451	84	7.59	6.72	+0.87
12460	40	6.93	5.35	+1.58
12471	85	6.21	5.33	+0.88
12472	86			
12485	87	6.38	6.78	-0.40
12492	33	7.89	6.73	+1.16
12505	41	6.36s	6.10s	+0.26
12516	4	7.84		
12525	88	6.26	6.76	-0.50
12549	89	1.82	2.47	-0.65
12553	51	7.10	7.49	-0.39
12599	28	8.31	7.48	+0.83
12613	42	6.73	7.05	-0.32
12618	43	5.59	5.89	-0.30
12628	44	7.24	6.21	+1.03
12633	2	7.81		
12699	90	6.75	6.98	-0.23
12713	91	3.93*	4.48	-0.55
12725	52	7.54	7.22	+0.32
12728	38		6.63	
12733	5	8.03		
12740	14	8.20*		
12766	27	8.14	7.25	+0.89
12768	13	8.03		
12776	12	7.84		
12780††	92	5.35	5.79	-0.44
12783	45	6.59	6.92	-0.33
12784	53	7.46	7.11	+0.35
12813	93	2.16	2.86	-0.70
12828	94	2.64	3.30	-0.66
12831	46	7.18	7.11	+0.07
12833	95	6.52	6.10	+0.42
12838	47	6.84s	6.62s*	+0.22
12915††	96	3.50	4.05	-0.55

Fabry Observations with the Cape Astrographic Telescope

CZC	Q	Pg	Pv	CI
		E 7		
15844	43	5.76	5.03	+0.73
15868	61	3.52	3.39	+0.13
15938†	81	6.68	6.89	-0.21
15949	82	6.45	6.55	-0.10
15986	23	7.64s	7.20	+0.44
15993†	44	6.09	5.43	+0.66
15997	80	5.49	5.90s	-0.41
16008†	45	6.63	6.74	-0.11
16035	46	7.11	7.35	-0.24
16087	83	4.83	5.33	-0.50
16121	47	4.80	5.26	-0.46
16133	48	6.82	6.71s	+0.11
16157	16	8.12		
16158	32		7.50	
16185	2	7.57*		
16195	84	4.98	5.41	-0.43
16211	22	7.47s	7.29	+0.18
16213	85	6.39	6.73	-0.34
16236)* 16237)	86	5.92	6.31	-0.39
16260	50	7.24	7.65	-0.41
16348	4	8.01		
16364*	1	7.92		
16407	87	4.33	4.72	-0.39
16433	3	7.86		
16435	39		7.19	
16458	88	2.07	1.93	+0.14
16476	89	5.80	6.23	-0.43
16540	49	5.55	5.91s	-0.36
16605	90	6.67	7.08	-0.41
		E 8		
18469	69	5.06	4.04	+1.02
18476	70	6.84	7.32	-0.48
18508	20	7.73	7.51	+0.22
18533	42	5.85s	5.86s	-0.01
18536	13	7.88		
18541†	43	7.08	7.04	+0.04
18555	2	7.62		
18557	28	7.66	6.46	+1.20
18565	12	7.71	7.61	+0.10
18582	9	7.88		
18588	30	8.36	6.76	+1.60
18643	29	7.80	6.88	+0.92
18654	8	7.86		
18656	11	7.69		
18657	26	7.26	6.50	+0.76
		E 8		
18679	1	7.53		
18691	5	8.13		
18719	10	7.09	7.11	-0.02
18724	25	7.84	7.46	+0.38
18726	31	8.31*	7.48	+0.83
18728	44	6.36s	6.17s	+0.19
18747*	14	7.62	7.34	+0.28
18762	45	5.32*	5.70	-0.38
18771†	71	5.60	5.73	-0.13
18789	72	6.79	6.82	-0.03
		E 9		
19748	70		1.92	
19814	71	6.95	6.05	+0.90
19883*	72	5.76	5.69	+0.07
19888	73	6.76	7.06	-0.30
19939	74	4.84	3.93	+0.91
19946	75	5.73	3.93	+1.80
19953	48	6.65	7.08	-0.43
19956	40	6.80	7.07	-0.27
19970	41	7.47s	7.29	+0.18
19976	24	7.74	6.87	+0.87
19984	29	7.58	6.75	+0.83
19992	76	7.91		
20015	42	7.08	6.79s	+0.29
20028	77	7.89		
20067†	63	6.36	6.01	+0.35
20068	78	3.66	1.89*	+1.77
20070	43	6.92	6.02	+0.90
20077	79	5.75	4.79	+0.96
20092	44	6.72	5.39	+1.33
20106*	80	6.66	6.65	+0.01
20117	49	8.01	6.72	+1.29
20119	17	7.61	7.25	+0.36
20129	25	7.91	7.03	+0.88
20142	1	7.89		
20160	31		7.06	
20167	30	7.85	6.77	+1.08
20186	7	7.68s	7.58	+0.10
20191	45	7.19	7.37	-0.18
20202	5	7.86		
20214	46	7.21	7.41	-0.20

The first column in the table gives the serial number in the Cape Zone Catalogue for stars between -40° and -52°; the second column the "Q" number; the third and fourth the photographic and photovisual magnitudes and the fifth the deduced colour index. A dagga (†) indicates a close double star, d <5", Δm <5.

NOTES

The errors quoted are the m.s.e. of an observation of unit weight. The weight is the normal weight of the mean magnitude.

691 Observations discordant Pg: m.s.e. ±0.032, wt. 9½. Pv observations on 5 nights between October 1947 and January 1949 do not show any abnormality (m.s.e. ±0.017, wt. 3½) but 4 consistent observations on 1949 September 21 gave 5^{m}.99. This is not included in Pv. This star is almost certainly variable.

1968 Observations discordant: m.s.e. ±0^{m}.020; wt. 6.

3770 Companion, 13", included.

3931 Companion, 7", included

7070, 7132, 7191 and 7475. Magnitudes obtained with Zeiss filter do not agree well with these and are not included. The differences (Z - O) after applying colour corrections being -0^{m}.05, -0^{m}.05, -0^{m}.05 and +0^{m}.04 respectively.

7145 Companion, 5", included but contributes little light.

7302 Observations discordant, m.s.e. ±0^{m}.027, wt. 5.

9978 Companion, 19", included but contributes little light.

12309 Companion at 27", not noted, but probably too faint to affect result.

12331 Companion at 67", excluded but troublesome for Pv observations; m.s.e. ±0^{m}.021, wt. 10½.

12445 Spectrum composite and variable.

12471/2 Companion, 20", included.

12713 Observations discordant; m.s.e. ±0^{m}.026, wt. 4.

12740 Observations discordant; m.s.e. ±0^{m}.021, wt. 7.

12838 Magnitude obtained with Zeiss filter 0^{m}.04 brighter.

15868 Observations discordant; m.s.e. ±0^{m}.023, wt. 7½.

16185 Companion, 28", excluded. Combined Pg magnitude = 7.56.

16236/7 Companion, 14", included.

16364 Observations discordant, m.s.e. ±0^{m}.026, wt. 7.

18726 Observations discordant, m.s.e. ±0^{m}.026, wt. 8.

18747 Companion, 11", included.

18762 Observations discordant, m.s.e. ±0^{m}.020, wt. 8.

19883 π^2 Gruis. π^1 Gruis, Spec. S, is irregular variable.

20068 β Gruis. Pv observations discordant, m.s.e. ±0^{m}.07, wt. 9.

20106 (= 20105 + 20107), 10", both included.

The essentially new feature introduced in connection with photometry by the Fabry method at the Cape is the use of rotating sectors to reduce the light from each star to a standard intensity.* This intensity can be chosen so that the photographic images have a density falling on the steep portion of the characteristic curve where errors of photographic origin are relatively small. By limiting the range of densities the magnitudes are made less dependent on the calibration curve and systematic errors due to differences in image size, differences between the colours of the stars and the calibrating light source, and possible latent image effects are no longer of any consequence. The characteristic curve is, in effect, used for interpolation only, except at the extreme ends of the magnitude range.

Two other practical points contributed to the success of this series. The one is the close grouping of the images on the plate which undoubtedly helps to keep the 'local errors' small. The other detail, not in any way peculiar to the Fabry method, is the importance of repeated observations of selected 'standard stars', especially in the early series of observations, to ensure that all stars in a region have the same zero point.

In view of the importance of the sector constants in fixing the magnitude scale some further details of their measurement may be justified.

The geometrical measurements were made by mounting the sector centrally on the rotating stage of a Hilger measuring machine. The angles were read to 0°.1 at several radii. In most cases the variation over the working range was sufficiently small, and mean values of the angles were adopted for computing the reduction ratios. These were then converted into magnitudes.

Photoelectric measurements were made later with a photometer consisting of an RCA 1P21 photomultiplier tube and galvanometer. The potentials for the tube were supplied from a tapped H.T. battery. The tube was enclosed in a metal housing with a small opening opposite the cathode for admitting light. The opening had a shutter and the sectors were run (by the usual motor) immediately in front of this. A circular opal glass screen provided a secondary light source whose intensity could be varied by moving a primary source to various distances. This part of the set-up was essentially that used for earlier tests by a photographic method (16). The moveable primary light source was a 6 volt lamp fed from a storage battery. The lamp was in an enclosure with

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*A similar technique was adopted by Redman at Pretoria at about the same time.

an opening immediately in front of the filament and when used without a diffuser the distance was measured between the filament and the screen. The objection to this arrangement is that refraction and absorption (due to foreign material) at the glass envelope may interfere with the uniform distribution of light implicit in applications of the inverse square law. To obviate this difficulty the opening was later covered with an opal glass window and distances were then measured from this surface. The accuracy was improved but with so considerable a loss of light that it could not be used with some of the sectors. As a compromise a coarse ground glass window was used for some of the tests. In this case the illumination varied as if most of the light came directly from the filament.

From an analysis of the measures, assuming the geometrically determined constants as a first approximation when a change of sector was involved, it was possible to determine small empirical corrections to the intensities computed from the inverse square law. The corrections were negligible when the opal glass window was used but slightly exceeded $0\overset{m}{.}01$ with a bare lamp.

Most measures were made alternately with and without a sector and in all cases one particular position was adopted as standard so as to eliminate the effect of any slow variations in the intensity of the light source.

Three quantities are involved in most of the measurements: (1) variations in the illumination of the opal screen due to changes in the lamp position, (2) the amount of light cut off by the rotating sectors, and (3) the amount of light measured by the photometer.

Electrical tests showed that the galvanometer scale was almost linear. This was confirmed by an analysis of the tests themselves, showing that no additional non-linearity had been introduced by the phototube. Small empirical corrections were applied to the intensities computed according to the inverse square law where these had been shown to be necessary. The corrected measures were used to obtain values for the sector constants.

The measured constants are given in Table I, on page 539 of the paper. In no cases do the photoelectrical and geometrical determinations differ by as much as $0\overset{m}{.}01$. The 'constant' of the 5 magnitude sector depends slightly on the radius used.

The same photometer and light source were used to determine the approximate transmissions of the three colour filters used in connection with the Fabry programmes.

A Hilger constant deviation spectrometer was used as a monochromator. The filters were interposed, one at a time, between the lamp and the first slit and the deflexions (with and without the filters) were noted.

To reduce errors due to stray light (which was bad in this instrument) two filters were sometimes used in series, one of which remained in position to restrict the light to a limited range of wave-lengths.

To obtain sufficient light the slits were opened to about 1 mm. The error of the micrometer reading was determined for the middle of the analysing slit with a neon (and helium) lamp. This is not the mean wavelength of the light admitted because of the varying dispersion of the prism. Fortunately the filter transmissions do not vary rapidly in the longer wavelength region where the error is greatest.* An approximate allowance was made for the effect.

To supplement the data on the transmission of the blue filter, especially for the shorter wavelengths, use was made of some spectrograms obtained with another (single prism) spectrograph. In this case the spectra with and without the filter were not obtained with identical slit illumination and an unknown factor is therefore needed to give the true transmission of the filter. This was obtained by fitting the photographic curve to that measured photoelectrically.

In view of the deficiencies of the instruments and the approximations involved the transmission curves are only approximate but they give a fair idea of the spectral ranges passed by the filters. The results are given in the following table:

Transmissions of Colour Filters

λ	Blue	Zeiss Ikon II	Omag 301	λ	Blue	Zeiss Ikon II	Omag 301
Å	%	%	%	Å	%	%	%
3500	58			5100	6	88	82
600	62			200	4	89	85
700	66			300	2	90	87
800	69			400	2	91	88
900	71			500	3	91	89
4000	72			600	4	91	89
100	72			700	3	91	90
200	70	1		800	2	91	90

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*The blue filter passes light beyond $H\alpha$ but the phototube has little sensitivity there.

Transmissions of Colour Filters - continued

λ	Blue	Zeiss Ikon II	Omag 301	λ	Blue	Zeiss Ikon II	Omag 301
Å	%	%	%	Å	%	%	%
4300	66	2		5900	1	91	90
400	60	4		6000		91	90
500	53	12		100		91	90
600	45	32	2	200		91	90
700	36	56	20	300		91	90
800	26	72	50	400		91	90
900	16	81	70	500		91	90
5000	10	85	78	600		91	90

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SECTION III

PHOTOELECTRIC PHOTOMETRY

PLATE IV

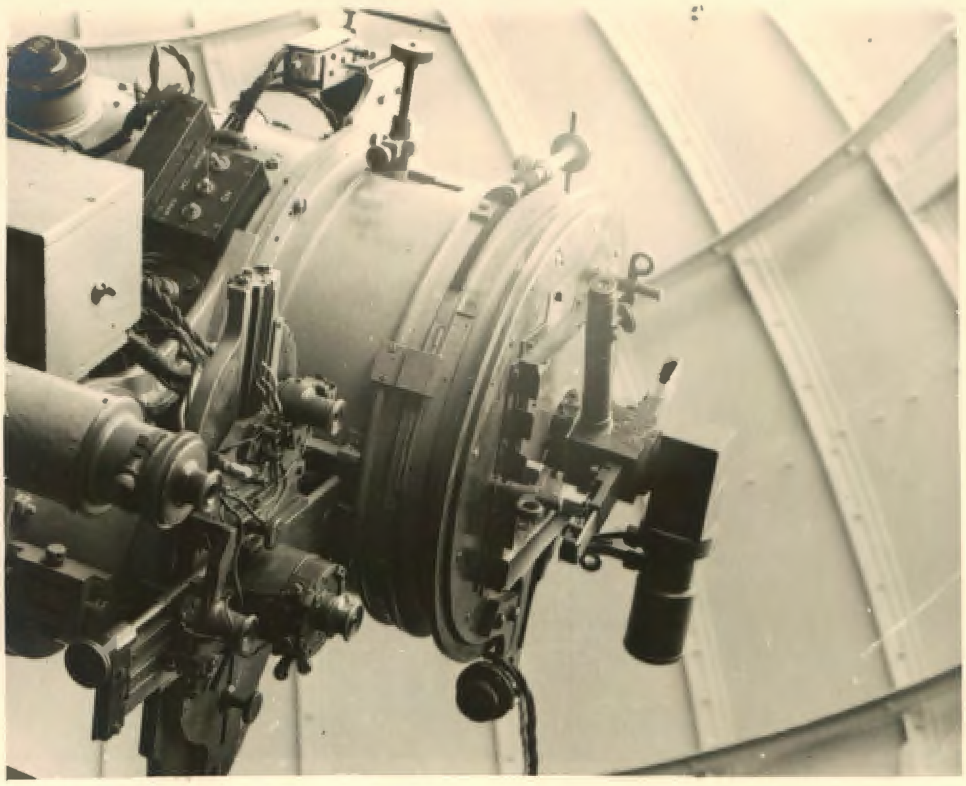
A. The original photoelectric photometer, attached to the Astrographic Telescope.

The viewing eyepiece is pointing upwards, the cell housing is to the right and pointing downwards, and between them is the filter slide.

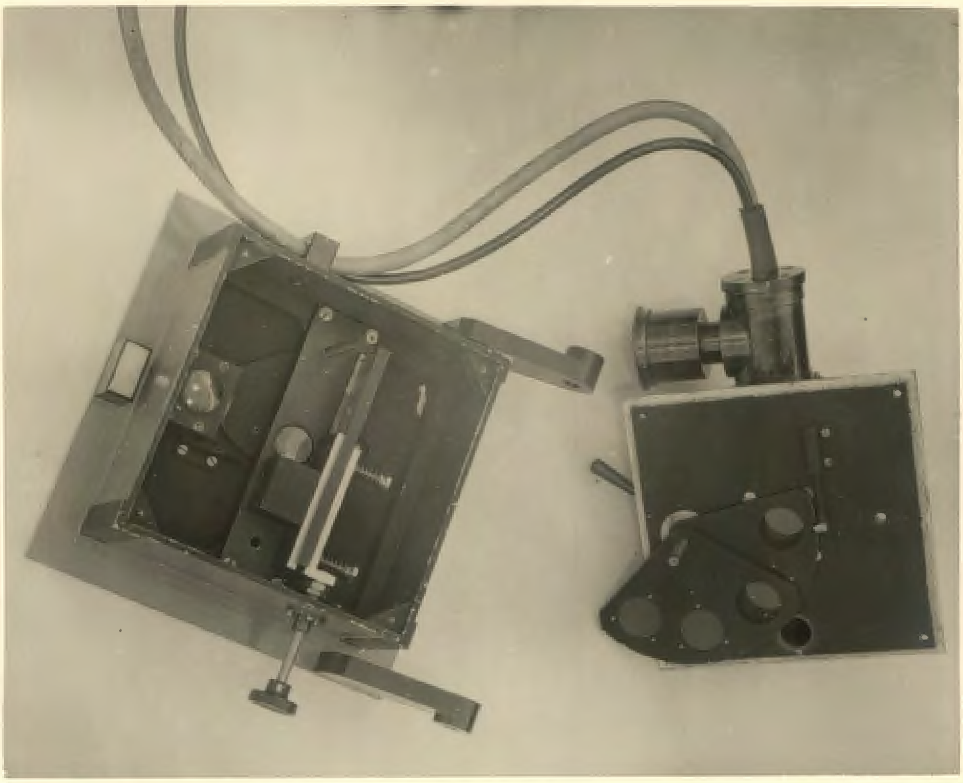
B. The new photometer, opened to show the internal arrangements.

On the left is the base plate (arranged for mounting on the Victoria Telescope) and on the right the cover and cell housing. The Fabry lens is visible in the centre of the former and behind it is the diaphragm plate. To the left is a prism, with lens attached, for projecting an image of the diaphragm down the tube of the viewing eyepiece (shown at the bottom of the cover portion). The rectangular box below the Fabry lens carries a second reflecting prism and serves the dual purpose of deflecting the beam and acting as a shutter. The operating knob projects through the side of the photometer box. The sector-shaped filter holders are attached to the cover plate. One hole in each is left vacant , allowing for the use of four different filters. The projection to the left of the cell housing contains a drying agent (silica gel).

A



B



SECTION III

PHOTOELECTRIC PHOTOMETRY

I. EXPERIENCE WITH THE PHOTOMETER ON THE SEVEN-INCH TELESCOPE

Prior to the introduction of the RCA photomultiplier tube the use of photoelectric methods for stellar photometry was practically confined to a few specialists. The difficulty of measuring extremely small photo-currents discouraged its more general use and restricted its application to comparatively bright stars. With improvements in amplifiers these restrictions no longer apply, but the electron multiplier tube, with an internal amplification of about 10^6, has greatly simplified the problem. Early tubes of this type were not very sensitive but the introduction of the antimony-caesium cathode made them very attractive for astronomical applications.

The first attempts to use a photoelectric photometer at the Cape Observatory were made during 1948 when a simple type of photometer employing an RCA type 931-A photomultiplier tube was fitted to the 7-inch Refractor. The potentials for the tube were supplied direct from a H.T. battery at 90 volts per stage and the output was measured with a galvanometer and scale. Blue and yellow filters were added for colour measurements.

Tests with this equipment for measuring stellar magnitudes were not encouraging. It proved less sensitive and less accurate than the Fabry photometer and the observations took longer to make. When used for measuring colours the results were more promising and showed that a reasonable return might be expected if the sensitivity could be increased. This was achieved by fitting a more sensitive movement to the galvanometer and increasing the potentials on the tube to about 110 volts per stage.

This photometer was put into regular use in 1949 for measuring the colours of the "Bright Stars" whose magnitudes (in photographic light) were being measured by the Fabry method. Instead of measuring photovisual magnitudes directly, as was originally intended, these will now be obtained from the photographic magnitudes by subtracting a linear function of the observed colours.

Various changes were made to the equipment while these observations were in progress. The most important was in April, 1951, when an amplifier and recording milliammeter were substituted for the galvanometer and scale. The decision to build an amplifier was the result of experience with a photometer belonging to the Kirkwood Observatory of the University of Indiana that was temporarily installed on the 24-inch Victoria Telescope towards the end of 1950 and demonstrated the speed and accuracy with which observations could be made with a well-designed equipment employing a recorder.

Preliminary tests were made with a duplicate amplifier connected to the 7-inch photometer, but neither these nor the later measures with the new amplifier were as accurate as those made with the Victoria Telescope. The complete equipment was later tested on both the 24-inch and 13-inch telescopes and gave much better results, leaving little doubt that the size of telescope is an important factor. Apparently the 'sample' of light collected by a 7-inch objective is not large enough to smooth out seeing fluctuations adequately. Nevertheless the new equipment considerably increased the accuracy of measurement and speeded up the observing. The observations were now worth reducing to obtain magnitudes as well as colours and it was possible for one observer to work alone.

A considerable amount of trouble was experienced with the H.T. batteries used with this installation. The amplification of the RCA photomultiplier tube depends not only on the accelerating voltage but also on the correct focusing of electrons from dynode to dynode. This depends on having equal voltage differences for all stages (except the last) so that when a tapped battery is used the partial failure of one element has a serious effect on the performance of the tube. The tapped battery was, therefore, replaced by a voltage divider supplied from the battery as a whole. This has the additional advantage that the voltage per stage can be changed simply by altering the overall voltage. Notwithstanding the extra drain on the battery, this arrangement proved better than the simple tapped battery, but battery failures continued to be a source of trouble, especially during damp weather. It was for this reason that it was decided to substitute a H.T. power supply operated from the supply mains before starting on a new programme.

Experience with the 7-inch programme showed clearly the advantages of measuring colours directly if colour indices are required rather than magnitudes in two colours. The scattering of light by a perfectly clear sky is known to follow Rayleigh's law quite closely for the wavelengths used for photometry at the Cape. The additional absorption due to haze and smoke, on the other hand, is apparently less selective. The result is that while the total extinction varies with time and place in a largely unpredictable way, the selective effect remains relatively constant from day to day. Magnitude measures are affected by the total extinction. Direct colour measures are concerned only with differential effects. For this reason colours can be measured successfully even when the sky is unsuitable for observing magnitudes. Furthermore, there is less need for standard stars as a control on atmospheric changes. On the other hand colour measures depend on a ratio of two deflexions and not on one, and this has a tendency to increase the accidental errors.

At this point it may be well to mention some similarities and differences between the Fabry and photoelectric methods. Optically the two photometers are almost identical. The main difference is in the nature of the sensitive surface used as a receiver. In the first case reliance is put on the uniformity of sensitivity of the photographic emulsion. Measurements are made of the same part of every image but on different parts of the plate and reduced to a magnitude scale by comparison with sensitometer spots on still other parts of the plate. The photocathode of the 931-A phototube is notoriously non-uniform in its response (1) so it is essential that the light should be distributed in the same manner from each and every star. This would present no difficulties if the Fabry image could be sharply focused on an unobstructed surface, but this is not so. The cathode is an inclined and curved surface partly obstructed by a grid, and the cathode and grid cannot both be in focus at the same time. With a small diaphragm and large focal ratio the effect of movements of the stellar image is not great, but if the photometer is to be used for the photometry of extended objects special care would have to be taken to see that the sensitivity is sufficiently uniform over the area of the diaphragm. This difficulty is not experienced with the Fabry method if a suitable lens is used. It has also to be remembered that the phototube responds to and integrates all light reaching the cathode, including that scattered from the walls of the telescope tube or sky light passing the secondary mirror of a Cassegrain reflector. This is not of great importance for stellar photometry but would have to be considered in making quantitative measures of sky light.

As already mentioned, the operation of the RCA electron multiplier tube depends on the correct focusing of electrons at each stage. This can be influenced by both electrostatic and electromagnetic fields. The earth's magnetic field can appreciably affect the amplification of some tubes, giving rise to zero point errors when observations are made in different parts of the sky. Spots of luminous paint have been used to measure the effect and magnetic screening to eliminate it. Photographic photometry is not affected in this way.

One other aspect of the comparison is important. The relation between the density of a photographic image and the intensity of the light producing it is a complicated function involving many variables. A sensitometer calibration as applied to the Fabry plates at the Cape seems to be a reasonably accurate method of determining this function empirically for each plate, but it is doubtful whether this would be sufficient if it were desired to extend the magnitude scale over a range of several magnitudes using different exposure times and observing stars of different colours. The use of rotating sectors has, fortunately, provided a solution. The photomultiplier, on the other hand, has a sensibly linear response to light over a large range of intensities and, provided no non-linearity is introduced in the amplifier and recording instruments, a normal magnitude scale will result simply from the application of Pogson's relation. This linearity of response is a feature that commends itself to many workers but the excellent agreement between the photoelectrically and photographically determined magnitude scales (See Section IV) is enough to show that the Fabry method is at no great disadvantage in this respect. For extended objects it is indeed possible that the Fabry method would prove the more reliable.

II. PHOTOELECTRIC OBSERVATIONS OF BRIGHT STARS IN THE E REGIONS

Programmes

In December 1951 the photometer built for use on the 7-inch telescope was tried on the 13-inch Astrographic Telescope. The results were so encouraging that it was decided to transfer the instrument permanently when the Fabry "Bright Star Programme" was completed.

It was planned to use this photometer for four observational programmes:

(1) to compare four selected standard stars in each E region with similar stars in the two following regions so as to determine corrections to the adopted zero points,

(2) to tie the selected stars to the main body of stars in each region,

(3) to compare the selected standard stars with suitable standard sequences north of the equator,

and (4) to continue with the Bright Star Colour Programme (commenced with the 7-inch Telescope) as opportunity arose.

Programmes (1), (2) and (3) have been completed and are described here. Some work was done on programme (4) but this is not included.

Programmes such as (1) and (3) are needed to ensure that all regions have a common zero point. The precision aimed at was to fix the relative zero points between each and every region involved with a standard error of ± $0^{m}.005$ or less. If the value of these programmes is to be fully realised it is important to see that the zero point defined by the four selected stars is representative of the region as a whole. Furthermore, a large number of stars is needed to define the colour system and transfer it from one group of stars to another. This is the primary purpose of programme (2) and similar observations were made in connection with (3). Advantage was taken of the opportunity to re-observe most of the stars previously observed by the Fabry method (see Section II) and a few other fainter stars within the range of the photometer. It will be recalled that many of these stars could not be observed photovisually in the earlier series. None were too faint to be observed in both colours photoelectrically.

This second series of observations serves as a check on the earlier results and by providing photovisual magnitudes for fainter stars provides additional material where the data are still rather weak. With the results from both series available for most of the stars it is possible to make a comparison between the two methods of observation.

The Photometer

The photometer itself was built in the observatory workshops. The design is far from perfect but the photometer is simple to use and the defects are not important when observing comparatively bright stars. An improved model has since been constructed to replace it. It differs little in principle from the older model but various changes in the design make it a more convenient and efficient instrument. The actual photometer used will be described, with comments on its defects.

The optical arrangements are shown in Fig. 1.

The telescope objective L_1 focuses the light from a star to pass through a circular hole in the diaphragm D. The field or Fabry lens L_2 produces an image of L_1 in approximately the position of the photocathode K. On its way the light passes through one or other of two colour filters F and a clear glass window W that serves merely to isolate the cell housing.

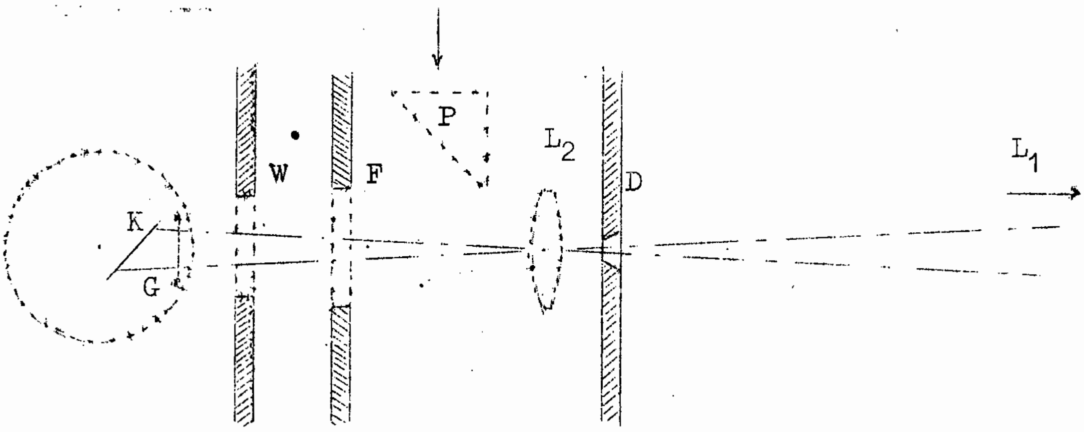


Figure 1. Optical Arrangements of Photoelectric Photometer

The filters are mounted in a slide which also serves as a shutter to cut off the light. The reflecting prism P can be moved in the direction of the arrow to intercept the beam and allow the diaphragm and star image to be viewed with a low-powered microscope (not shown) to check the centering. The focal length of L_2 is about 10 cm.. This produced an image 7.0 mm in diameter when used with the 7-inch Telescope. With the 13-inch it was 9.5 mm. The projected width of the photo-cathode is only 8 mm with the result that not all the light was used. The variation in sensitivity over the surface of the cathode of this type of tube is such that there is an advantage in using a spot appreciably smaller than 8 mm and searching for a sensitive area. It was not easy to make changes to the old photometer nor was it possible at the time to build a new one so the photometer continued to be used as it was for the whole programme.

The arrangements for inserting the prism P are slow in action and awkward to use. The viewing microscope is, therefore, used only to check the collimation of the crosswires in the guiding telescope. This can be most easily done with a bright star before dark while the edge of the diaphragm is still visible against the sky.

The filters used were a blue glass of unknown origin and a yellow glass Omag 301. These are the same (but not identical) filters as were used for the Fabry photometry, the transmissions of which are given in Section II (P. 32).

Mechanically the photometer consists of three principal parts:

(a) an aluminium plate made to fit the breech of the telescope in place of a plate holder, with a collar into which the rest of the photometer is screwed,

(b) an aluminium body carrying the optical parts, the lens L_2, the prism P with viewing microscope and the slide with the colour filters, and

(c) the tube housing with the window W.

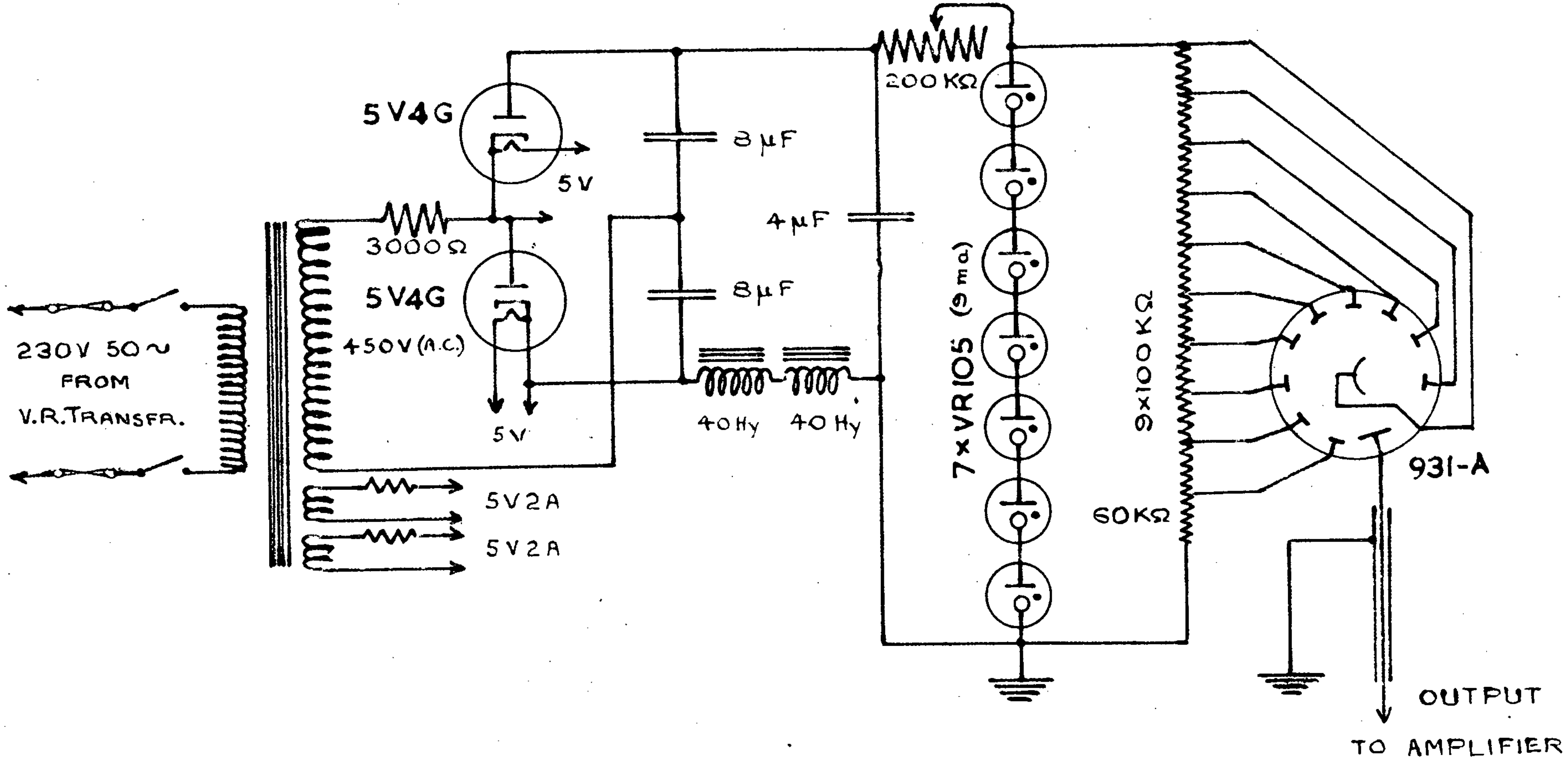


FIG. 2. — H.T. SUPPLY FOR PHOTOMULTIPLIER

Between the plate and the collar of part (a) is a circular disc through which are drilled a number of sharp-edged diaphragm openings. The one used was approximately 1.0 mm in diameter. The multicore cable supplying potentials to the multiplier tube and the screened anode connection enter through sealing glands, and a container filled with silica gel ensures that the interior is kept dry. This is essential as the cathode and anode pins are adjacent to one another - a bad feature of the RCA design.

The Phototube

The 931-A photomultiplier tube used for all the observations made with the 7-inch and Astrographic Telescopes is one of the earlier type with a black plastic base. It has a fairly high sensitivity but also a large dark current and it was found best to operate it with the comparatively low potential of 80 volts per stage. The dark current was usually between 1×10^{-8} and 2×10^{-8} amperes. The semi-amplitude of the noise with an apparatus time constant of one second was less than 10^{-11} amperes.

H.T. Power Supply.

The H.T. supply for the photomultiplier tube is taken from a mains-operated power pack. A diagram of connections is given in Fig. 2. This design was adopted instead of a more flexible and stable arrangement used for another model because of its relative simplicity. Used, as it has been, with a voltage regulating transformer between the mains and the input terminals, the voltage stability has proved quite satisfactory for the rather exacting use to which it has been put. The output from the power pack goes to a potential divider from which a multicore cable leads to the phototube.

This power supply was tested for voltage stability and it was found that a 10 per cent variation in the supply voltage gave rise to a 0.1 per cent variation in the output voltage. Theoretically the amplification of the 931-A multiplier tube (with 9 dynodes) should vary as the ninth power of the applied voltage, but tests indicate that in practice the dependence is less than the seventh power. A 10 per cent voltage variation in the mains (which does occur) would then affect the sensitivity by 0.007 magnitudes. Slow changes of this amount, while not desirable, could be tolerated. Quick changes of this size would be objectionable, not only because of the effect on the amplification, which would introduce errors comparable with the seeing errors, but also

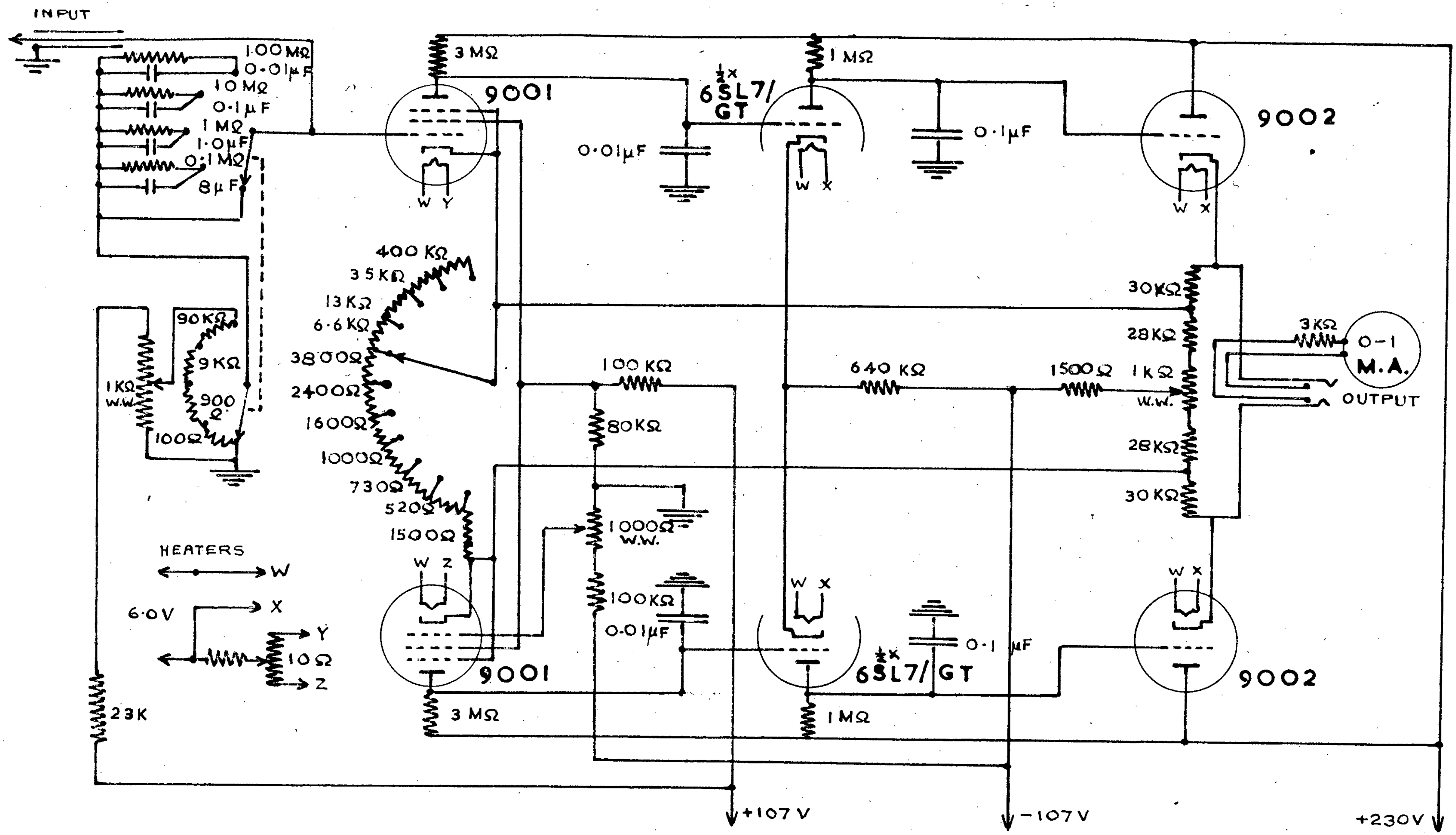


FIG. 3. — NEGATIVE FEED-BACK D.C. AMPLIFIER.

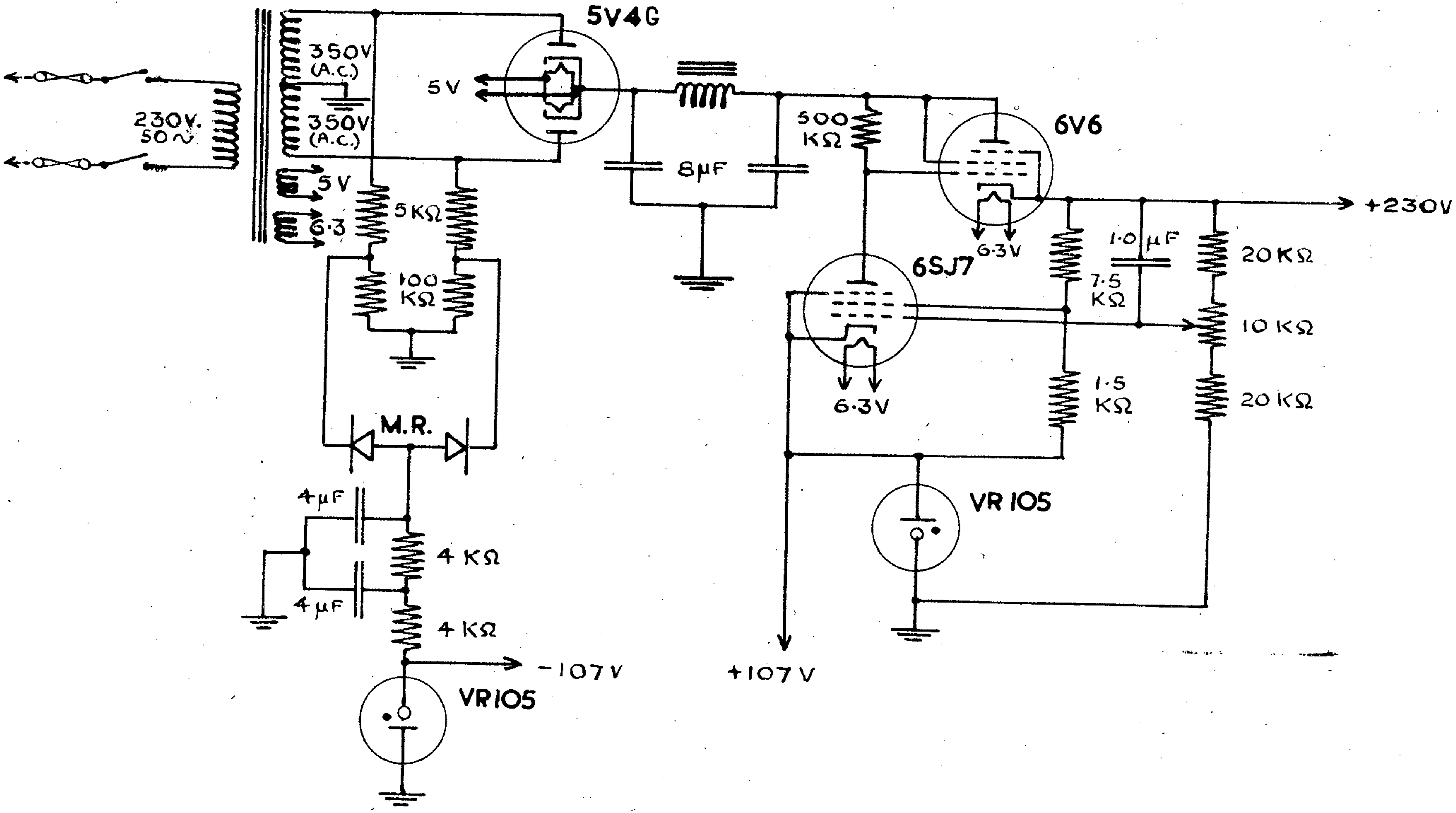


FIG. 4.—— POWER SUPPLY FOR AMPLIFIER.

because of the variations in the dark current when using high sensitivities. By introducing a voltage regulating transformer the input variations are reduced to one or two per cent and the output voltage is then sufficiently insensitive to mains variations.

The VR-105 tubes used for this unit are liable to flickering which is accompanied by voltage changes of several tenths of a volt. This is large enough to produce a detectable noise in the dark current trace but has little effect on the accuracy of the observations. It could be avoided by using a different type of regulating tube.

The Amplifier and Recorder

The output from the phototube is taken by a screened (concentric) cable to an amplifier generally similar to that designed by G. E. Kron (2). Circuit diagrams are shown in Figs. 3 and 4. It is a double-sided degenerative (negative feed-back) D.C. amplifier with a built-in power supply. It was originally built entirely with components available locally - and not all new. The high value resistors giving the 'coarse' sensitivity control were changed for precision components before the present programme was commenced. The resistors forming the feed-back network and the 'fine' sensitivity control were, however, ordinary carbon resistors of commercial quality. They have recently been replaced with high stability resistors.

With an amplifier of the negative feed-back type it is usually arranged that the internal amplification (without feed-back) is reasonably high. In the present case it can be assumed that the output current can vary over a considerable range with very little change in the grid-to-cathode potential of the first stage. The current will in fact change by the amount required for the feed-back to neutralise any change in the input voltage. The voltage amplification is determined by the resistances in the feed-back network, and the performance can be understood with the help of the simplified diagram, Fig. 5.

Assuming that the amplifier has been balanced so that $\frac{R_{2a}}{R_{2b}} = \frac{R_{1a}}{R_{1b}}$, it follows (neglecting current from Va and Vb) that $v_i = 0$ when $v_o = 0$.

For any other values $\frac{v_o}{v_i} = \frac{R_{1a} + R_{1b}}{R_3} + \frac{R_1 + R_2}{R_2}$ .... (1)

(See Appendix I)

Since the grid potential of Vb is referred to earth, a change in the input potential applied to the grid of Va will demand an equal change in v_i to restore equilibrium. To achieve this v_o will have to change by an amount defined by equation (1). Provided, therefore, that R_m is not so low as to overload the output stage, the voltage sensitivity of the amplifier is fixed by the resistances in the feed-back network and R_3 may be changed to alter the sensitivity.

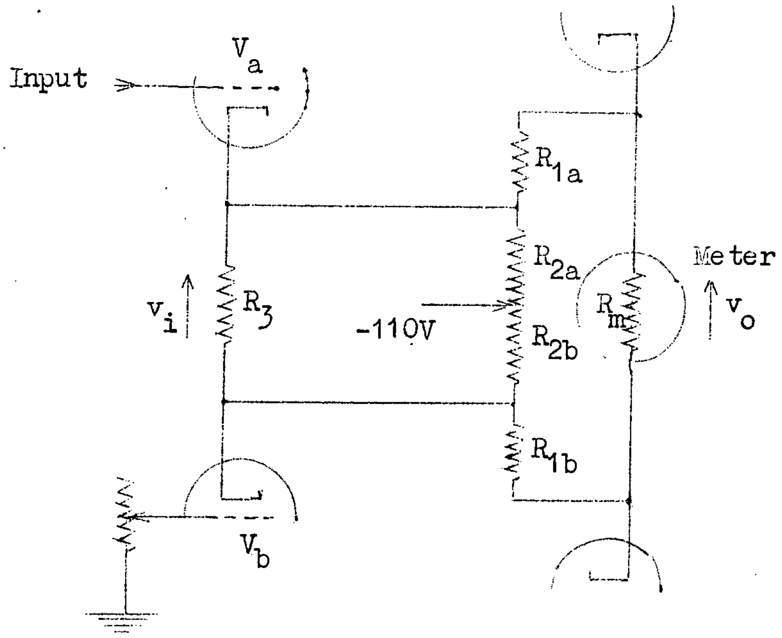


Figure 5. Feed-back Network

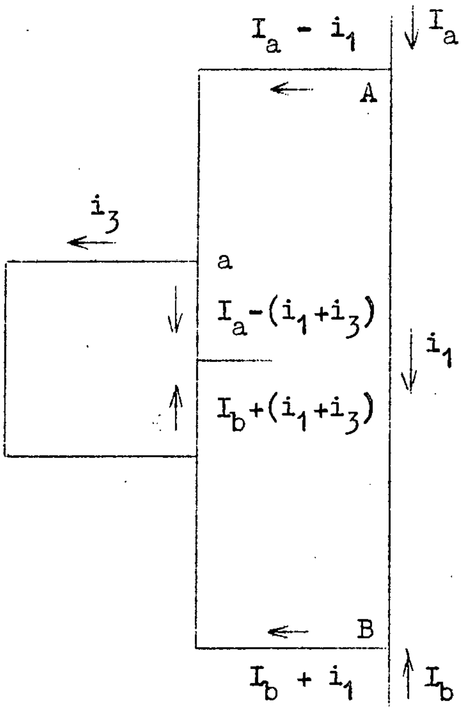


Figure 6. Currents in Feed-back Network

The output current from the photomultiplier tube is converted into potential by grid resistances connected to one of the input valves. A selector switch gives a coarse sensitivity control with steps in factors of ten (2.5 magnitudes).

The observations were recorded partly with an Evershed and Vignoles recording milliammeter registering 0 - 2 milliamperes and having a resistance of 3000 ohms and partly with a Brown "Electronik" recording potentiometer registering 0 - 10 millivolts. The milliammeter was in effect used as a voltmeter with a range of 0 - 6 volts. The Brown Recorder was used with a potential divider, 3000/5 ohms, so that a change from one to the other did not involve a change in sensitivity. A full-scale reading required an input voltage of 150 millivolts on step 10 and 3.0 volts on step 0.

The linearity of the amplifier and associated recorders and the step values of the fine sensitivity control of the amplifier were calibrated with potentiometers connected to the input. These were of the dial type, one with a linear and the other with a logarithmic scale. Both have been standardised and the former is known to be accurate to $0^{m}.001$ on all steps. The linear scale potentiometer is best for scale calibrations but the other has advantages for sensitivity measurements since its steps correspond roughly with the sensitivity steps of the amplifier. Both have been used and give consistent results.

The calibrations have been repeated at monthly intervals. When the milliammeter is used the scale is not linear but there is no evidence of any appreciable change with time. A constant correction curve for all sensitivities and for the whole series has therefore been used. The Brown Recorder combination is sensibly linear within 0.2% of full scale.

The sensitivity steps have shown small but not negligible variations. These appeared to be mainly random and mean values were used for the reductions. It was supposed that these variations resulted from the use of commercial quality resistors. More recent tests have shown that the changes are not entirely random but are correlated with the time the amplifier has been switched on. They appear to be due to temperature changes in the resistors R_1 and R_2 (Fig. 5). The ratio R_1/R_2 scarcely changes; the change is principally in the ratio R_1/R_3. For large values of v_o/v_i (see equation 1) the ratio is principally dependent on the term 2 R_1/R_3, and changes in R_1 affect adjacent steps by nearly the same amount. The largest relative change occurs between steps 0 and 1 and for most purposes changes beyond step 3 can be ignored. The great majority of the observations were made with these higher sensitivities, but those made with lower sensitivities and late at night may have been affected systematically.

The linearity corrections and sensitivity constants are given in the following table.

Table 1

Non-linearity of Recording Milliammeter

Reading	0	6	12	24	41	53	64	73	80	82	88	94	96	97	99	100
Error	- 0.2	0.0	+ 0.2	+ 0.4	+ 0.2	0.0	- 0.2	- 0.4	- 0.4	- 0.2	- 0.1	- 0.2	- 0.4	- 0.6	- 0.8	- 1.0

Fine Sensitivity Constants
(Magnitude Differences)

Position	0	1	2	3	4	5	6	7	8	9	10
Gain	0.00	0.30	0.62	0.93	1.27	1.60	2.00	2.30	2.62	2.94	3.26

Coarse Sensitivity Constants

Position	A	B	C	D
Nominal resistance (Megohms)	0.1	1	10	100
Gain (Magnitudes)	0.00	2.51	5.03	7.35 to 7.46

The sensitivity ratios between the coarse sensitivity steps depend on the effective values of the load resistances. In parallel with each resistor there are three possible leakage paths: (1) a condenser (giving a time constant of about one second), (2) the switch, connectors and cable connection to the phototube and (3) the grid of the valve. The only safe way to determine the sensitivity steps is to do so when the amplifier is in use. This was done by observing suitable stars twice over, compensating for a change in the 'coarse' sensitivity by an approximately equal and opposite change in the 'fine' sensitivity. It was hoped that the ratios would remain constant but this has not been the case. The ratio between the two highest values varied from night to night by a small but appreciable amount and apparently in an erratic manner. Changes during a night were usually progressive and there seems good reason for attributing them to a small residual grid current. The changes are too large to be accounted for by the temperature change in the fine sensitivity calibration (which is also involved). When observations were made with C and D sensitivities and insufficient data was available to fix the C/D ratio those made with C sensitivity had to be rejected. The B/C ratio has remained nearly constant at a value close to that computed from the resistances themselves. The A range was not required. Only Sirius is bright enough to need so low a sensitivity and it was observed (in another programme) with reduced voltage to avoid the risk of fatigue of the phototube.

The Observations

The observing routine resembles that used with the Fabry method except that the dark current of the phototube has to be measured with each observation. One observation consists of four exposures to a star or the sky and three measures of the dark current in the order: dark - blue - yellow - dark - yellow - blue - dark. The exposures and dark current readings were of 30 seconds duration, this being the minimum time that could be used with safety with a meter as sluggish as the Evershed and Vignoles recorder*. The lively action of the Brown Recorder, on the other hand, encouraged the observer to give full exposures because of the seeing 'noise'. All sky measures were made with the highest sensitivity.

When observing stars in one region (e.g. programme (2)) the stars were observed in the same sequence as by the Fabry method, viz. a standard star before (and after) every two other stars. As a rule a measure of the sky was associated with each standard star. About 12 observations of stars and 4 of the sky were made per hour.

When intercomparing two regions by the Fabry method it had been found effective to observe all four selected stars in one region before reversing the telescope to observe the other region. Each region took about 15 minutes and four 'ties' between two regions were possible on one night. An attempt to follow the same routine photoelectrically proved useless. Each region (with 4 stars and 2 'skies') took 25 minutes and only two 'ties' were possible per night. This was not sufficient to compensate for changes in the atmospheric transparancy. The

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*Not only was it necessary to reduce the weight of the pen on the paper to such an extent that a guard was necessary to prevent it leaving the paper entirely, but the dashpot was emptied and a rubber-faced electromagnetically operated hammer was installed to 'tap' the meter continually. This introduced complications on windy nights because the 'tapper' could not be operated with the meter case closed and an extemporised partial case had to be added.

alternative of observing one star in each region alternately , with a sky measure after every second star per region, was adopted. There was a further reduction in the number of observations made but the results were much more satisfactory.

Reduction of Observations

Different methods had to be used for reducing the observations made with the two recorders.

The Brown Recorder charts had a straight and uniform scale and required no corrections for instrumental non-linearity. The nett deflexion could, therefore, be measured directly from the traces. This was actually done by ruling lines between the dark current traces (thus interpolating graphically for any changes in the dark current) and drawing parallel lines through the blue and yellow traces. The lines were drawn to represent the mean deflexion as nearly as possible. The nett deflexions were scaled off between the lines using a piece cut from the chart, but any convenient scale could have been used.

The Evershed and Vignoles recorder also has a straight scale but it was neither linear nor free from scale errors. The position of each part of the trace was therefore read directly from the chart at a point about ten seconds before the end of an exposure, the reader using judgement when the trace was irregular. The means of the three readings of dark current and two each of blue and yellow light were taken, differenced, and corrected for scale error. No ruling in of the traces was done but the extra computing and checking necessary with this recorder considerably increased the amount of office work involved.

Beyond this stage the reductions (see Appendix II) were the same in both cases. The sky measures were plotted separately for each region observed and read for the time of each stellar observation. Tables were used to convert these measures (made with the highest sensitivity) to the sensitivity used for the individual stars. A simple subtraction then gave the deflexion for star light only. The nett deflexions were converted into magnitude differences by means of tables.

The corrections for extinction were then applied.

Many photoelectric observers make a practice of determining the extinction coefficients each night. Attempts were made to do this at the Cape Observatory by noting the change in zero point with change in sec z but the results were quite unreliable. As an alternative an approximate value was assumed and the programme was planned in such a way that the final results were almost independent of the values used. All stars that were being compared were compared at nearly the same altitude (or mean altitude in the case of 'ties'). Different values of the extinction coefficient were adopted at different times, ranging for blue magnitudes from 0.50 to 0.35, for yellow magnitudes from 0.30 to 0.15 and for colours from 0.20 to 0.15. The observations were reduced (nominally) to the zenith.

This procedure was not adequate for the low altitude comparisons with the northern clusters (see page 60).

The amplifier sensitivity constants, determined from the potentiometer calibrations and expressed as magnitude differences, were next applied.

Under ideal conditions only a fixed zero point correction would now be required to reduce the magnitudes to an adopted (natural) system. This was rarely the case in practice. The transparency of the atmosphere nearly always changed in the course of a night and for this if for no other reason the adopted extinction coefficient did not correctly reduce the observations even to the zenith. Changes in the H.T. voltage supplied to the multiplier tube or changes in the grid current of the amplifier also tended to produce changes in the required zero point corrections and there was no simple way of separating the effects. The standard stars were observed to determine such drifts of zero point.

It was not always possible to determine the relative magnitudes and colours of several standard stars with sufficient accuracy from a single night's observations but there was rarely much difficulty in doing so from a longer series. They could then be used to determine the zero point drift on all the nights when they were observed. If the night was reasonably good it was easy to interpolate zero points for the remaining stars.

Magnitudes and colours reduced in this manner were tabulated and means were taken to reduce accidental errors. These provisional values were then used, together with those for the standard stars, to revise the zero points. This was done by taking running means of the differences for five stars at a time. The final residuals served to determine the weight to be assigned to the observations. As with the Fabry observations unit weight was given to a series with an average residual of $0\overset{m}{.}01$.

Until zero point corrections were applied a difference between the two magnitudes (blue and yellow) was identical with the measure of colour. Only two independent quantities were involved. In determining zero points and weights the three (when used) were treated independently so that the final mean values do not necessarily form identities.

Table 2

Photoelectric Observations with the Cape Astrographic Telescope (1952)

Q	B	Y	C	Q	B	Y	C	Q	B	Y	C
	E 1				E 3				E 4 (contd.)		
1	7.56	7.69	-0.13	1	7.71	8.01	-0.30	29	7.79	6.80	+0.99
4	7.58	7.46	+0.12	2	7.94	8.22	-0.28	30	8.15	7.29	+0.86
6	8.03	7.88	+0.15	3	7.28	7.53	-0.25	38	9.52:	8.13:	+1.39:
21	7.62	6.98	+0.64	4	7.44	7.67	-0.23	39	6.87	6.70	+0.17
30	7.63	6.66	+0.97	5	7.94	8.04	-0.10	40	5.19	5.53	-0.34
31	7.99	7.07	+0.92	6	8.13	8.17	-0.04	41	5.93	6.21	-0.28
32	8.33	7.08	+1.25	7	8.16	8.36	-0.20	42	6.71	5.28	+1.43
34	(8.12)	(6.88)	+1.24	13	8.20	8.24	-0.04	43	6.90	7.24	-0.34
36	5.31	5.00	+0.31	15	7.35	7.40	-0.05	44	6.47	5.80	+0.67
37	5.14	5.21	-0.07	31	8.82	8.11	+0.71	45	6.85	6.63	+0.22
38	6.30	5.50	+0.80	32	8.96	8.23	+0.73	46	6.56	6.54	+0.02
40	6.00	6.16	-0.16	35	7.52	6.76	+0.76	47	6.33	5.57	+0.76
41	7.24	6.34	+0.90	36	7.95	6.68	+1.27	51	7.27	7.46	-0.19
42	6.77	6.68	+0.09	37	8.09	7.24	+0.85	78	5.45	5.80	-0.35
43	7.11	7.03	+0.08	38	9.36	8.10	+1.26	79	4.83	5.20	-0.37
46	7.50	7.81	-0.31	45	5.45	5.73	-0.28	81	6.49	6.77	-0.28
47	6.95	6.90	+0.05	46	6.97	7.30	-0.33	91	6.45	6.81	-0.36
61	4.01	3.35	+0.66	47	5.36	5.15	+0.21	92	4.95	5.01	-0.06
62	4.87	3.58	+1.29	48	6.71	6.53	+0.18	93	5.29	5.74	-0.45
63	4.76	4.02	+0.74	49	6.11	6.42	-0.31	94	5.62	5.89	-0.27
64	6.54	6.64	-0.10	50	6.24	6.60	-0.36	95	6.08	6.06	+0.02
				51	6.52	6.80	-0.28	96	6.50	6.72	-0.22
				52	5.98	6.19	-0.21	97	5.87	6.24	-0.37
				53	6.85	7.08	-0.23	98	5.86	6.18	-0.32
	E 2			85	6.44	6.82	-0.38	99	6.75	7.11	-0.36
2	7.59	7.64	-0.05	86	2.79	3.12	-0.33	100	7.22	7.60	-0.38
4	8.08	8.18	-0.10	87	5.61	4.98	+0.63	101	7.33	7.05	+0.28
5	7.58	7.57	+0.01	88	6.99	7.36	-0.37	102	7.26	7.01	+0.25
6	8.39	8.30	+0.09	89	6.78	7.17	-0.39				
8	8.16	8.01	+0.15						E 5		
10	8.25	8.03	+0.22					1	7.60	7.92	-0.32
14	8.42	8.19	+0.23					2	7.78	8.03	-0.25
26	7.70	7.00	+0.70					3	7.99	7.99	0.00
27	7.77	6.92	+0.85					16	8.19	7.90	+0.29
28	8.08	7.32	+0.76		E 4			20	7.86	7.57	+0.29
29	8.07	6.84	+1.23	3	7.76	7.93	-0.17	27	7.53	6.70	+0.83
30	(8.61)	(7.26)	(+1.35)	4	7.93	8.13	-0.20	28	8.50	7.64	+0.86
39	6.75	6.71	+0.04	5	7.96	8.18	-0.22	36	7.24	7.19	+0.05
40	7.03	6.04	+0.99	6	8.22	8.35	-0.13	37	6.44	6.28	+0.16
41	6.84	6.91	-0.07	10	7.37	7.47	-0.10	38	7.07	6.79	+0.28
42	6.60	6.63	-0.03	11	7.50	7.63	-0.13	39	7.00	6.70	+0.30
43	6.73	6.60	+0.13	12	7.89	8.01	-0.12	40	5.33	5.16	+0.17
44	7.13	6.81	+0.32	13	7.95	8.00	-0.05	41	7.08	7.29	-0.21
45	6.26	5.43	+0.83	14	8.00	8.14	-0.14	42	5.77	5.75	+0.02
48	7.34	6.65	+0.69	15	8.18	8.40	-0.22	43	6.64	6.81	-0.17
52	7.29	7.35	-0.06	20	8.04	7.98	+0.06	50	6.81	6.60	+0.21
53	7.96	7.58	+0.38	23	8.40	8.16	+0.24	51	4.88	5.22	-0.34
64	5.02	4.93	+0.09	25	7.83	7.60	+0.23	52	7.83	7.68	+0.15
65	4.79	3.93	+0.86	27	8.50	7.76	+0.74	53	8.09	7.31	+0.78
69	4.31	4.25	+0.06	28	7.67	6.71	+0.96	54	7.40	7.23	+0.17

Table 2 - continued

Photoelectric Observations with the Cape Astrographic Telescope (1952)

Q	B	Y	C
	E 5 (contd.)		
55	6.62	5.44	+1.18
70	6.02	6.31	-0.29
71	6.63	6.62	+0.01
76	5.63	4.56	+1.07
77	6.35	6.58	-0.23
78	5.08	5.31	-0.23
79	7.14	7.12	+0.02
	E 6		
2	7.80	8.06	-0.26
4	7.85	8.06	-0.21
5	8.02	8.18	-0.16
12	7.82	7.88	-0.06
13	8.00	7.99	+0.01
14	8.15	8.14	+0.01
20	8.40	8.17	+0.23
21	8.13	7.88	+0.25
22	8.48	8.16	+0.32
27	8.11	7.38	+0.73
28	8.29	7.60	+0.69
29	8.66	8.21	+0.45
33	7.84	6.92	+0.92
38	8.40	7.01	+1.39
39	5.16	5.46	-0.30
40	6.92	5.68	+1.24
41	6.35	6.10	+0.25
42	6.72	6.89	-0.17
43	5.58	5.73	-0.15
44	7.21	6.39	+0.82
45	6.58	6.74	-0.16
46	7.17	7.06	+0.11
47	6.83	6.61	+0.22
51	7.10	7.34	-0.24
52	7.51	7.23	+0.28
53	7.47	7.15	+0.32
66	8.22	8.04	+0.18
78	4.10	4.50	-0.40
79	4.54	4.36	+0.18
80	5.91	5.83	+0.08
81	6.02	6.34	-0.32
82	6.62	6.86	-0.24
84	7.56	6.85	+0.71
85) 86)	6.20	5.45	+0.75
87	6.37	6.62	-0.25
88	6.24	6.58	-0.34
90	6.75	6.83	-0.08
92	5.35	5.60	-0.25
93	2.16	2.62	-0.46
	E 6 (contd.)		
94	2.65:	3.08:	-0.43
95	6.48	6.14	+0.34
96	3.47:	3.84:	-0.37
	E 7		
2	7.51	7.79	-0.28
3	7.83	8.08	-0.25
4	8.00	8.22	-0.22
16	8.11	8.09	+0.02
22	7.46	7.27	+0.19
23	7.61	7.27	+0.34
28	8.65	8.20	+0.45
32	8.73	7.73	+1.00
33	8.89	7.96	+0.93
39	8.67	7.50	+1.17
40	9.32:	8.06:	+1.26
43	5.75	5.13	+0.62
44	6.08	5.53	+0.55
45	6.60	6.65	-0.05
46	7.11	7.23	-0.12
47	4.79	5.08	-0.29
48	6.80	6.67	+0.13
49	5.53	5.77	-0.24
50	7.23	7.51	-0.28
61	3.51	3.36	+0.15
66	7.74	7.28	+0.46
80	5.46	5.73	-0.27
81	6.66	6.82	-0.16
82	6.43	6.49	-0.06
83	4.83	5.18	-0.35
84	4.95	5.24	-0.29
85	6.38	6.63	-0.25
86	5.91	6.15	-0.24
87	4.30	4.56	-0.26
88	2.03	1.88	+0.15
89	5.78	6.06	-0.28
90	6.65	6.91	-0.26
	E 8		
1	7.53	7.77	-0.24
2	7.63	7.88	-0.25
5	8.16	8.16	0.00
8	7.87	7.83	+0.04
9	7.90	7.84	+0.06
10	7.11	7.04	+0.07
11	7.70	7.70	0.00
12	7.73	7.61	+0.12
13	7.87	7.68	+0.19
14	7.62	7.37	+0.25
	E 8 (contd.)		
15	8.31	8.09	+0.22
20	7.74	7.51	+0.23
25	7.83	7.49	+0.34
26	7.25	6.62	+0.63
28	7.65	6.67	+0.98
29	7.79	7.01	+0.78
30	8.34	7.08	+1.26
32	8.62	7.85	+0.77
33	8.82	7.95	+0.87
34	8.89	7.95	+0.94
42	5.86	5.81	+0.05
43	7.09	6.97	+0.12
44	6.37	6.15	+0.22
45	5.35	5.56	-0.21
61	9.27	8.13	+1.14
69	5.03	4.19	+0.84
70	6.85	7.14	-0.29
71	5.61	5.65	-0.04
72	6.79	6.75	+0.04
	E 9		
1	7.87	8.03	-0.16
5	7.85	7.73	+0.12
7	7.68	7.55	+0.13
10	8.17	8.04	+0.13
17	7.63	7.27	+0.36
24	7.72	6.97	+0.75
25	7.88	7.14	+0.74
29	7.56	6.85	+0.71
30	7.81	6.93	+0.88
31	8.58	7.38	+1.20
32	9.05	8.04	+1.01
40	6.77	6.91	-0.14
41	7.47	7.26	+0.21
42	7.06	6.79	+0.27
43	6.88	6.16	+0.73
44	6.70	5.61	+1.09
45	7.19	7.26	-0.07
46	7.21	7.29	-0.08
48	6.63	6.89	-0.26
49	7.98	6.94	+1.04
63	6.33	6.01	+0.32
69	8.30	7.81	+0.49
70	1.32	1.67	-0.35
71	6.94	6.15	+0.79
72	5.75	5.62	+0.13
73	6.75	6.90	-0.15
74	4.82	4.01	+0.81
75	5.62	4.28	+1.34
76	7.91	7.80	+0.11
77	7.89	7.71	+0.18
79	5.69	4.91	+0.78
80	6.64	6.57	+0.07

Most of the observations were actually reduced as blue magnitudes and colours because it was expected that the colours would be more accurate than the magnitudes. This did not prove to be the case, but the precision of the yellow magnitudes computed from the difference is not much below that obtainable from an independent reduction. A trial computation using the stars in E1 gave an average difference of $0\overset{m}{.}003$ and a maximum difference of $0\overset{m}{.}015$. The yellow magnitudes for all regions have therefore been computed from the blue magnitudes and observed colours.

The following table gives an idea of the relative accuracy of the observations :-

Average weight of observations:	7-inch	0.6
	13-inch	0.8

Average number of observations used per star:

For blue magnitudes	7.3
For colours	8.4

The average weight does not include observations that were rejected. The difference between the two instruments would have appeared greater if this had been done. There is no doubt about the advantage of using the larger aperture. The difference between the numbers of observations used shows that some not worth using for magnitudes could still be used as colour measures.

The mean magnitudes and colours derived from this series of observations are given in Table 2 . The stars are identified by their numbers in the Cape Observatory list ("Q" numbers). A key list (Cape Mimeogram, No. 2) is attached. The zero points have been adjusted by an integral number of hundredths of a magnitude to conform (approximately) with the finally adopted zero points.

Reduction of E Region Ties

These reductions followed the same method as that employed for the sequences up to the point when zero point corrections had to be determined. At this stage the magnitudes were transferred to a ledger for further analysis.

The selected stars were (with one or two exceptions) very well observed and there was no difficulty in determining reliable mean values from the observations. It would have been better to have used the values determined from the sequence observations (Programme 2) but

Table 3

Observed - Adopted Zero Points

(Magnitude and colour differences are in units of $0^m.001$)

1952	Mag. Diff.	wt.	C Diff.	wt.		1952	Mag. Diff.	wt.	C Diff.	wt.
E 1 - E 2						E 1 - E 3				
Sept. 4	+20	6	- 7	5		Jan. 7	+ 8	6	+12	4
15	+19	5	+20	2½		8	- 2	2	+13	6
18	+ 9	4	+ 7	5		Sept. 18	- 9	1½	- 9	4
Oct. 1	+27	1	+21	6		Oct. 13	+12	2	+11	10
13	+21	9	+12	5		18	+ 1	3	+ 5	10
14	+ 6	8	+16	8		Nov. 25	+19	3	+12	2
15	+13	5	+ 2	9		27	+18	2	- 9	3
						28	- 7	4	- 2	3
						Dec. 4	+ 8	4	+ 7	6½
Aver.	+16·	7	+10	7		Aver.	+ 5·	9	+ 4·	9
Mean I	+15	38	+ 9·	40½		Mean I	+ 5·	27½	+ 6	47
Mean II	+15·	22	+10	14½		Mean II	+ 5·	12	+ 5	17½
E 2 - E 3						E 2 - E 4				
Jan. 7	- 8	4	+ 8	3		Jan. 7	- 8	3	+ 4	3
8	- 1	3	+19	1		8	- 9	5	+ 1	1½
10	-23	5	-20	4		24	+ 4	3½	- 6	5
24	+14	4	+11	5		27	- 5	6	-11	10
27	- 6	7	+ 6	3		31	- 8	2	- 3	9
31			-20	2		Feb. 3	+ 1	2½	- 3	10
Feb. 3	- 6	7	-10	1½		24	- 1	8	- 7	10
Aver.	- 5	6	- 1	7		Aver.	- 3·	7	- 3·	7
Mean I	- 6	30	- 1	19½		Mean I	- 3·	30	- 5	48½
Mean II	- 5·	19	- 1·	10½		Mean II	- 3·	10½	- 4·	14½
E 3 - E 4						E 3 - E 5				
Jan. 7	+ 2	5	+10	2		Feb. 24	- 7	1½	-18	6
27	- 1	5	- 7	4		25	-15	3	-11	2
31	+10	3	+ 2	9		Mar. 13	- 3	3½	+ 8	10
Feb. 3	- 6	6	-17	10		27	+10	2½	+ 8	10
11	+ 1	2	+ 4	3		28	+ 1	2	+ 4	3
13	+26	1	- 6	1½		31	-13	5	+ 4	3
24	- 5	3	- 9	4		Apr. 10	- 8	1½	-19	5½
Mar. 13	- 5	1	- 9	3						
Aver.	+ 4	7	- 4	8		Aver.	- 5	7	- 3·	7
Mean I	0	26	- 6	36½		Mean I	- 6	19	- 1	39½
Mean II	+ 1	17	- 4·	14½		Mean II	- 6	8½	- 2·	13½

Table 3 - continued

1952	Mag.		C	
	Diff.	wt.	Diff.	wt.
E 4 - E 5				
Feb. 26	-3	10	+5	5
Mar. 14	-20	2	+2	8
16	+30	½	+5	6
27	+5	6	+8	9
28	+20	5	-2	9
31	-4	2	-13	6
Apr. 9	-4	4	-6	7
10	-2	3	+20	3
Aver.	-1	7	+2•	8
Mean I	+1•	32½	+1	53
Mean II	+1	20	+1•	17½
E 5 - E 6				
Feb. 26	+5	2	+22	1
Mar. 27	+2	3	-3	6
Apr. 8	+2	2	-15	3½
17	-1	2	+2	5
22	+9	3	-3	10
24	+28	½	+2	8
25	+18	3	-8	10
June 10	+12	1	-6	3½
27	+10	2	-20	1
Aver.	+7	8	-3	9
Mean I	+8	18½	-3•	48
Mean II	+8	13½	-4	17½
E 6 - E 7				
Apr. 25	0	3	0	4
May 28	+10	6	+10	5
June 10	+37	2	+19	1½
27	+1	3	-4	4
July 1	+5	4	-3	9
21	-6	½	+13	2
28			-6	8
Aug. 1	+16	2	+3	6
Aver.	+11•	6	+4	8
Mean I	+9	20½	+1	39½
Mean II	+9	14	+2	15½

1952	Mag.		C	
	Diff.	wt.	Diff.	wt.
E 4 - E 6				
Feb. 26	+2	2	0	4
Mar. 14	-19	½	+2	1½
27	+11	10	+5	10
Apr. 8	0	5	+1	7
17	0	3	-7	2
24			+10	1
May 19	+18	1	+8	4
27	-14	1	-2	4
29	+15	7	-16	3
Aver.	+4•	7	0	9
Mean I	+7	29½	+1	36½
Mean II	+5	9½	+0•	16
E 5 - E 7				
Apr. 8	+11	3	-2	3½
17	+8	4	-8	3
22	-6	4	-11	4
24	+6	½	-6	4
25	+10	3	-7	9
May 23	+11	5	0	9
27	-10	3	-14	3
June 2	-5	4	-16	4
10	+1	½	-9	1½
27	+17	5½	-5	3
July 1	-14	1½	-14	9
Aver.	+2•	9	-8•	11
Mean I	+4•	34	-7•	57
Mean II	+3•	14½	-8	21
E 6 - E 8				
July 1	-28	½	-13	3
20	-8	5	-1	7
21	+3	10	-1	10
28			-16	2½
Aug. 13	+33	½	0	1
20	+7	3	-7	1
25	-10	4	-11	7
Aver.	-2	4	-7	7
Mean I	-1	23	-6	31½
Mean II	-1	7½	-6•	12½

Table 3 - continued

1952	Mag.		C			1952	Mag.		C	
	Diff.	wt.	Diff.	wt.			Diff.	wt.	Diff.	wt.
	E 7 - E 8						E 7 - E 9			
July 20	- 6	1	+10	6		July 20	- 2	9	- 1	9
21	- 1	1½	+12	10		21	+ 3	2	+13	5
28	- 5	1½	- 6	3		28	-17	2½	- 6	2
Aug. 13	- 3	2	+ 1	7		Aug. 20	+ 1	1½	+ 4	2
20	- 3	5	-27	9		25	-10	5	- 1	2½
Sept. 2	- 1	2	- 4	4		Sept. 2	- 5	5	- 7	3
16	-17	5	- 2	3½		18	-15	5	- 1	3
Aver.	- 5	7	- 2	7		Aver.	- 6•	7	0	7
Mean I	- 7	18	- 2•	42½		Mean I	- 7	34	+ 1	26½
Mean II	- 6•	12	- 2•	15		Mean II	- 6•	9½	+ 0•	12
	E 8 - E 9						E 8 - E 1			
July 21	+12	5	+ 8	9		July 28	+19	1½	+14	4
28	+35	1	- 9	3		Aug. 20	+21	8	+11	3
Aug. 20	+ 2	9	- 9	10		Sept. 15	+ 4	5½	- 2	4
Sept. 2	+ 6	3	+ 1	1½		16	+33	4	+13	2½
15	+ 9	5	-18	1		17	+30	4	- 2	5
16	+10	10	+ 1	5		18	+17	3	+ 2	3
18	+ 4	3	- 2	10		Oct. 1	+15	5	+ 3	6
						6	+14	½	+ 4	2½
Aver.	+11	7	- 4	7		Aver.	+20	7	+ 5•	8
Mean I	+ 8	36	- 2	39½		Mean I	+19	31½	+ 4•	30
Mean II	+ 8•	20½	- 3	13		Mean II	+19	11½	+ 5	14
	E 9 - E 1						E 9 - E 2			
July 28	+43	1	- 1	3		July 28	+78	1	+ 9	3
Aug. 20	+17	1	-14	2		Sept. 4	+23	4	+ 4	5
Sept. 4	+38	1	+10	6		15	+27	10	+ 1	3
15	+18	4	- 7	1		17	+40	4	+10	1
16	+14	3	- 6	5		18	+29	3	+12	1½
17	+22	4	-11	3		Oct. 1	+31	2½	+11	3
18	+23	5	+ 9	4		Nov. 21	+21	1½	+16	6
Oct. 1	+33	1	+ 8	1		28	+15	3	+13	4
						Dec. 2	+16	5	+22	5
Aver.	+26	8	- 1•	8		Aver.	+31	9	+11	9
Mean I	+22•	20	0	25		Mean I	+27	34	+11•	31½
Mean II	+23	15	- 1	12½		Mean II	+27	12	+11	14½

these were not available until later and it was desirable to keep the analysis of the tie observations up to date to ensure sufficient observations without unnecessary repetitions. The actual differences for individual stars as observed in the two programmes rarely differ from the mean for a region by as much as $0^{\mathrm{m}}.01$. The mean values can therefore be accepted without fear of significant errors arising from any particular grouping. There is no justification for repeating the whole analysis with the new values.

The differences between the observed blue magnitude and colour and the adopted mean values were computed for every observation. Any systematic difference between two regions implied an error in the adopted zero points. Second differences were accordingly computed with due regard to the order in which the two regions had been observed. One such difference results from every change of region. The mean of these from one night's observations on a pair of regions constituted one zero point tie. A weight was assigned to this according to the number of differences and the internal agreement on the basis that unit weight corresponds to a s.e. of $\pm 0^{\mathrm{m}}.01$. These mean values are collected in Table 3.

It is at once apparent that the assigned weights are too high, indicating the existence of 'night errors'. Means were taken (a) unweighted, but ignoring observations of weights less than 1 - "Aver." - and (b) using the assigned weights - "Mean I". In most cases there is little difference and as a first approximation the average of the two was adopted.

The residuals for all ties were then collected according to weight and the following values of the average differences were found:

Series	Regions	Assigned weight	A.D.	Night Error
			(unit $0^{\mathrm{m}}.01$)	
Magnitudes	Adjacent	> 4	0.50	0.40
	Alternate	> 3	0.70	0.62
Colours	Adjacent	> 4	0.70	0.63
	Alternate	> 4	0.60	0.52

The following revised weights were adopted. They are not strictly in accord with the above night errors but, as it has already been shown, the mean values are not very dependent on the weighting system adopted.

Assigned Weight	Revised Weight		
	Magnitudes		Colours
	Adjacent Regions	Alternate Regions	
½	½	½	½
1	1	1	1
2	1½	1½	1½
3	2	1½	1½
4	3	1½	2
5	3	1½	2
6	3½	2	2
7	4	2	2½
8	4	2	2½
9	4½	2	2½
10	5		2½

Using the revised weights new means were computed and are given as "Mean II".

Summing these means right round the sky gives the following results :

Magnitudes	Adjacent	regions	$+0^m.054$	$\pm 0^m.010$	(s.e.)
	Alternate	"	$+0.043$	± 0.011	
Colours	Adjacent	"	-0.003	± 0.011	
	Alternate	"	$+0.001$	± 0.008	

The closing errors for the colours are well below their standard errors, but this is not so for the magnitudes. The physical explanation might be a small systematic difference in transparency between the eastern and western parts of the sky* or a magnetic effect on the electron multiplier tube. Either is possible but the fact that the two revolutions of

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*The western sky has long been considered inferior to the eastern for photometric purposes, and Mr T. Houck has recently shown conclusively that this is so, especially at the lower altitudes. The extinction increases more rapidly than sec z.

the sky involved in tying alternate regions together do not give a larger closing error than the other series makes the second explanation the more probable.

To examine the possibility of an orientation effect a fluorescent spot (excited by radioactive carbon) was fixed in front of the photometer and deflexions were recorded as the telescope was moved. These indicated a small difference of the expected sign and the right order of magnitude when the telescope was reversed. There was little change with declination. (When the telescope was in the meridian the axis of the phototube pointed east and west). There was, however, a difference of $0^m.01$ between the deflexions in the meridian and at an hour angle of 90°. The effect of this will be considered later. Such effects have been reported elsewhere (4) (5). In the present case the error is not large and has been divided equally between the comparisons.

The relative zero point corrections for all the regions could now be derived from the two series by solving the appropriate normal equations but this method involves very heavy computing. ~~It~~ They could also be obtained by a method of successive approximations but this method is only slowly converging. A first approximation was therefore derived by a more direct method.

Taking E1 as standard a correction to every other zero point can be derived by taking weighted means of the various intercomparisons. Thus E2 has been tied directly with E1 and also indirectly via E9 and via E3. E3 has been tied directly with E1 and also via E2. E4 has been tied, via E2 and E3 and also (with lower weight) by completing the circuit. The same applies to E5 and E6 but with nearly equal weights, and so on.

Using these values as a starting point new values were derived for each region by applying the observed corrections (Mean II) to the four nearest regions and taking the mean of the five values thus assembled.

This was repeated several times with very little change from the first approximate values. The first approximation and adopted values are given in Table 4.

This table also gives the mean differences between the magnitudes and colours adopted for the analysis of the tie observations and those derived from the sequence observations. The combined corrections have to be applied to all magnitudes and colours observed in the sequences to reduce them to a common zero point.

Table 4

Zero Point Corrections to Observed Photoelectric Magnitudes and Colours
(Unit $0^m.001$)

E Region No.	1	2	3	4	5	6	7	8	9
Pg (Blue) Magnitudes									
First Approximation	0	- 9	+ 1	+ 4	+11	+ 9	+ 5·	+17	+14·
Adopted	+ 0·	- 8·	+ 0·	+ 5	+ 9·	+ 8	+ 6	+17	+16
Reduction to Standards	+11	+22	+29	+22	0	+ 2	-22	- 2	-14
Combined Correction	+11·	+13·	+29·	+27	+ 9·	+10	-16	+15	+ 2
Colours									
First Approximation	0	- 9·	- 7	- 3·	- 5·	- 1·	+ 1	+ 0·	+ 2
Adopted	0	- 9	- 7	- 3	- 5·	- 1·	0	+ 2·	+ 1·
Reduction to Standards	-32	-30	-20	0	+ 2	+10	+10	+22	+15
Combined Correction	-32	-39	-27	- 3	- 2·	+ 8·	+10	+24·	+16·

Note:

The above corrections apply to the observed magnitudes and colours and were used to reduce the magnitudes to the SPg system, and to derive SPv magnitudes from the Pg magnitudes and colours. Colour corrections and additional zero point corrections common to all regions were also required. The corrections were computed to the third decimal place and the final magnitudes were rounded off to the second place. The 'observed' magnitudes in Table 2 are not the original magnitudes but have had zero point corrections, rounded off to the nearest $0^m.01$, applied region by region to reduce them (approximately) to a common zero point. The above corrections do not apply to them without removing these corrections.

An analysis has been made of the individual observed ties, using the revised weights, to determine the accuracy of the zero points, and the results of this analysis are given in the following table:

	Magnitudes		Colours	
Regions compared	Adjacent	Alternate	Adjacent	Alternate
S.d. for unit weight	$\pm 0^{m}.014$	$\pm 0^{m}.012$	$\pm 0^{m}.014$	$\pm 0^{m}.010$
Average weight per night	2.3	1.3	1.9	1.8
Average no. nights per tie	7	8	8	8
Average weight per tie	17	11	14	15
S.e. of tie	$\pm 0^{m}.0034$	$\pm 0^{m}.0037$	$\pm 0^{m}.0028$	$\pm 0^{m}.0026$

As a check on these values the zero point differences obtained when comparing alternate regions can be compared with the corresponding differences via the intermediate region. The standard deviations have been compared with values computed from the above standard errors with the following results :

	From Comparison	Computed
Magnitudes	$\pm 0^{m}.0050$	$\pm 0^{m}.0061$
Colours	$\pm 0^{m}.0053$	$\pm 0^{m}.0052$

The zero point of any one region depends on four ties to nearby regions. The s.e. of a zero point is therefore $1/\sqrt{3}$ x s.e. of one tie.

Hence s.e. of magnitude zero point = $\pm 0^{m}.0021$

and s.e. of colour zero point = $\pm 0^{m}.0016$

Small additional errors are involved in relating the adopted magnitudes of the standards to the values obtained from the sequence observations and in 'rounding off' the magnitudes. Allowing for these, $\pm 0^{m}.003$ may be accepted as the s.e. of the zero points of the E region sequences relative to their mean zero point.

Northern Clusters

Much the same methods have been used to derive the zero points for three northern hemisphere galactic clusters: the Pleiades, the Hyades and Praesepe.

In each case a selection was made from the brighter stars to define the system more definitely than can be done with three or four standard stars. (Three were selected for Praesepe, four for the others). These stars were observed in essentially the same way as were the E region sequences. The same is true of the ties. The Pleiades could be tied to E9 and E4, the Hyades to E9, E1 and E4 and Praesepe to E2, E5 and E6. The latter two clusters contain stars of spectral type F and for these the usual E region selected standards were used. The Pleiades stars are of type A and to avoid possible differential colour effects special standards of similar colour were selected in E9 and E4 for this tie programme.

Special care was needed to allow for atmospheric extinction since these clusters have to be observed at zenith distances of 50° and over when the rate of change of sec z for the E region is rapid. Not only is it difficult to ensure that the average value of sec z is the same for the two regions but progressive changes in the extinction coefficient can disturb the balance.

Once the relative zero points of the E regions are accurately known a comparison between a region at 50° or 60° zenith distance and another at high altitude gives a nearly instantaneous correction to the adopted coefficients. On a night of good transparency the coefficients are about 0.35 for blue and 0.20 for yellow light. The difference, 0.15, applicable to colours, is in close agreement with that computed from Rayleigh's law. On some nights when no determination by this method was available it was possible to obtain a sufficiently accurate value by assuming that the absolute sensitivity of the photometer had remained constant from night to night. (With sec $z \simeq 2$, a variation of $0\overset{m}{.}1$ would lead to an error of 0.05 in the coefficient, which could be tolerated).

Once the extinction is known the magnitudes can be reduced to outside the atmosphere. Any change in the extinction from the time when it is measured will produce a change in zero point and this change can be used to adjust the measured value.Such changes (usually increases in the extinction) are common at the Cape and on several occasions they had to be allowed for when reducing the cluster region tie observations.

In other respects these ties were reduced in the same way as the E region ties but using magnitudes taken from the E region and cluster sequence observations, not values based on the ties. The mean values were then reduced to the revised E region system by applying the zero point corrections already found for these regions.

A further correction is required for these low-altitude observations. The colour system of the E regions is appropriate for sec z = 1.1. The clusters were observed under conditions where sec z was between 1.6 and 2.0. The zero point is appropriate for the colour of the standards but the natural colour system is slightly redder than that of the E region magnitudes.

Several series of observations were made to determine the reddening effect of the atmosphere. These consisted of observations made of selected red and blue stars alternately, as a region was rising or setting. The seeing noise increases so rapidly with increasing zenith distance that the observations were not extended much beyond 60°. The results confirm the effect qualitatively but cannot be considered of much quantitative value.

As an alternative the effect has been computed assuming Rayleigh's Law and the dependence of the effective wavelength (λ_e) on the gradients (G) of the stars.

The equivalent wavelengths (λ_ϵ) of the blue and yellow magnitudes are approximately 4300 Å and 5300 Å and the radii of gyration (μ_ϵ) of the areas under the sensitivity curves are approximately 335 Å and 370 Å respectively.

$$\Delta\lambda_e \quad = \quad \Delta G \times \left(\frac{\mu_\epsilon}{\lambda_\epsilon}\right)^2 \qquad \text{(approximately, see Appendix III)}$$

Hence, $\Delta\lambda_e / \Delta G$ is 61 Å for blue magnitudes and 49 Å for yellow magnitudes.

Assuming the above equivalent wavelengths the Cape photoelectric colours should vary with spectral type more slowly than gradients by a factor 0.48. (A comparison between Cape colours and Canberra gradients (on the Greenwich System) indicates a factor 0.54 if stars with strong hydrogen lines are omitted. The difference presumably arises from line absorption).

At λ4300 Rayleigh's law indicates a change in the extinction of $0^{m}.00029$/Å at the zenith. At λ 5300 the corresponding value is $0^{m}.00011$/Å (6). Hence the change for unit change in the photoelectric colour is 0.037 for blue and 0.011 for yellow light. These colour coefficients

Table 5

Corrections Required to bring Magnitudes of Cluster Stars into Conformity with Revised S System. Observed Differences for Selected Standard Stars.

The Hyades

	Blue Magnitudes			Yellow Magnitudes		
	E 9	E 4	E 1	E 9	E 4	E 1
1952 Nov. 28		+0.013	+0.010		+0.026	-0.006
Dec. 12	-0.014		-0.007	+0.030		-0.023
Dec. 13	+0.010	-0.010		+0.052	+0.032	
Dec. 14	+0.035			+0.070		
Dec. 19	+0.028	-0.008	-0.004	+0.064	+0.019	-0.012
Dec. 24		+0.001			+0.020	
Mean	+0.015	-0.001	0.000	+0.054	+0.024	-0.014
Corrn. to E region	-0.087	-0.062	-0.078	-0.104	-0.059	-0.046
Total Corrn.	-0.072	-0.063	-0.078	-0.050	-0.035	-0.060

Mean (all regions) Blue magnitudes: $-0\overset{m}{.}071$ Yellow magnitudes: $-0\overset{m}{.}048$

The Pleiades

E 9	Magnitudes		E 4	Magnitudes	
	Blue	Yellow		Blue	Yellow
1952 Dec. 6	-0.044	+0.074	1952 Dec. 9	-0.047:	+0.031:
Dec. 7	-0.034	+0.071	Dec. 10	-0.067	+0.022
Dec. 20	-0.026	+0.089	1953 Jan. 2	-0.029:	+0.060:
Dec. 24	-0.032	+0.069	Jan. 4	-0.075	+0.024
Dec. 25	-0.049	+0.056	Jan. 5	-0.086	+0.011
Mean	-0.037	+0.072		-0.067	+0.025
Corrn. to E region	-0.087	-0.104		-0.062	-0.059
Total Corrn.	-0.124	-0.032		-0.129	-0.034

Mean (both regions) Blue magnitudes: $-0\overset{m}{.}127$ Yellow magnitudes: $-0\overset{m}{.}033$

Praesepe

	Blue Magnitudes			Colours		
	E 5	E 2	E 6	E 5	E 2	E 6
1952 Feb. 17	-0.010	-0.012:	+0.011	+0.050	+0.070:	+0.039
Feb. 18	-0.016	+0.014:	+0.042	+0.053	+0.095	+0.058
Feb. 23	-0.004	-0.015	+0.002	+0.067	+0.073	+0.034
1953 Jan. 16	-0.032:			+0.075:		
Jan. 20		-0.009	+0.016		+0.081	+0.051
Jan. 23	-0.031			+0.041		
Mean	-0.017	-0.008	+0.018	+0.055	+0.081	+0.046
Corrn. to E region	-0.080	-0.075	-0.080	-0.002	-0.039	+0.008
Total Corrn.	-0.097	-0.083	-0.062	+0.053	+0.042	+0.054

Mean (all regions) Blue magnitudes: $-0\overset{m}{.}081$ Colours: $+0\overset{m}{.}050$

have to be multiplied by the change in the mean value of sec z. For blue light the corrections are +0.03 for the Pleiades, +0.02 for the Hyades and +0.02 for Praesepe. For yellow light +0.01 is applicable to all three.

Unless the selected standard stars have zero colour indices any change in colour equation will change the zero point (for zero colour index). Corrections of +0.006, -0.006 and -0.003 magnitudes have been applied to the observed Pg zero point differences on this account. The corrections to the yellow magnitudes are only one-third as large.

The zero point corrections derived from the tie observations and given in Table 5 . The mean value is entered at the foot of each column and followed by the further correction required to reduce the individual E regions to the adopted zero point of the system. The last line gives the zero point correction to be applied to the observed cluster magnitudes to reduce them to the zero point of the E region system for stars of the same colour as the selected standards. The magnitudes also require the differential colour corrections discussed in the previous two paragraphs to reduce them to the E region system, and the same corrections as the latter to reduce them to the S System.

The magnitudes of the stars observed in the cluster regions are given in Table 6*. The first two columns give the number of the star in one or more published lists as indicated at the end of the table. The remaining columns give the magnitudes and colours on the "S" (Southern) system.

The orientation tests with the luminous spot indicated that stars observed at an hour angle of 90° would be measured about $0^m.01$ too bright. The E regions were observed at large hour angles (over 74°). The clusters were comparatively near the meridian. There is, therefore, reason to think that the magnitudes of the cluster stars need a correction of about $-0^m.007$, but this correction is somewhat uncertain and has not been applied.

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* Cape Mimeogram No. 3, Table II.

Table ~~II~~ 6

Magnitudes of stars in the Pleiades, Preasepe and the Hyades

The Pleiades

E	H	SPg	SPv	SCI
10	117	5.19	5.57	-0.38
16	150	5.38	5.76	-0.38
22	216	7.14	7.30	-0.16
27	255	5.52	5.87	-0.35
28	265	6.20	6.53	-0.33
40	436	6.62•	6.92	-0.29•
43	510	6.81•	7.08	-0.26•
45	520	7.06	7.27	-0.21
47	540	6.68	6.92	-0.24
54	722	5.16	5.55	-0.39
56	742	6.88•	7.05	-0.16•
67	977	5.90•	6.27	-0.36•
		The Hyades		
	10	7.33	7.01	+0.32
	15	5.73	5.70	+0.03
	36	8.00	7.63	+0.37
	38	7.20	7.00•	+0.19•
	66	6.73	6.49	+0.24
	72	7.67	7.59	+0.08
	82	7.85	7.53	+0.32
	90	4.54	4.56•	-0.02•
	112	8.20	6.81	+1.39
	144	7.74	7.45•	+0.28•
	177	6.01	5.95	+0.06
	193	8.07	8.04	+0.03
	199	6.90	6.61•	+0.28•
	236	5.68	5.63	+0.05
	244	4.75	4.86	-0.11
	252	5.52	5.54	-0.02
	261	6.72	6.55•	+0.16•
	274	7.89	6.27	+1.62
	280	8.08	7.93	+0.15
	296	6.12	6.07	+0.05
	353	4.69	4.71•	-0.02•

Praesepe

KW	R	SPg	SPv	SCI
	57	7.08	6.61	+0.47
	73	7.43	7.56•	-0.13•
	100	7.40	7.56	-0.16
40	193	7.75	7.83•	-0.08•
50	206	6.72	6.80••	-0.08•
94	257	8.11	7.88	+0.23
114	279	8.17	8.23	-0.06
143	314	8.35	8.37•	-0.02•
150	322	7.50•	7.50•	-0.00•
203	379	7.77	7.81	-0.04
204	381	6.71	6.73	-0.02
207	387	7.66	7.73	-0.07
212	390	7.39	6.57•	+0.81•
224	402	7.31	7.38	-0.07
229	405	7.58	7.57	+0.01
253	427	7.21	6.37	+0.84
265	438	6.40	6.68•	-0.28•
276	448	7.48	7.59	-0.11
279	452	7.66	7.73	-0.07
284	454	6.83	6.83•	-0.00•
283	456	7.26	6.38	+0.88
286	457	8.00	8.08•	-0.08•
292	462	8.28	8.27	+0.01
300	469	6.26	6.37	-0.11
323	491	7.82	7.87•	-0.05•
328	496	6.84	6.91	-0.07
348	514	6.74	6.85	-0.11
377	540	6.64	6.81	-0.17
385	544	7.97	7.99•	-0.02•
428	587	7.73	6.91	+0.82
445	609	7.97	8.04	-0.07
	823	8.07	8.08	-0.01
	825	7.88	7.63	+0.25
	844	7.82	7.61	+0.21

In the case of the Pleiades, the stars are identified by their number in Eggen's list (Ap.J 111, 81, 1950) and by their Hertzsprung number (Mem. Danish Acad. No. 4, 1923); for the Hyades and Preasepe, the R number given is from Ramberg's catalogues (Stok. Obs. An., 13, No. 9, 1941). The KW number for Preasepe is from Klein-Wassink's list (Groningen Pub., No. 41, 1927).

The magnitudes given for E 45 in the Pleiades are significantly different from Johnson's and were not used in finding the zero correction.

References

(1) e.g. M. J. Smyth, M.N., 112, 90, 1952.
(2) G. E. Kron, Electronics, August 1948.
(3) O. J. Eggen, Ap.J., 114, 141, 1951.
(4) S. C. B. Gascoigne, M.N. 110, 21, 1950.
(5) M. J. Smyth, loc. cit. p. 93.
(6) H. Grouiller, Annales d'Astrophysique, 2, 397, 1939.

Appendix I

Feed-back Network of Amplifier

Applying Kirchoff's Law to the feed-back network (see Figs. 5 and 6) and summing potentials:

Left loop: $i_3R_3 + (I_b+i_1+i_3)\,R_{2b} - (I_a-i_1-i_3)\,R_{2a} = 0$

Right loop: $i_1R_m + (I_b+i_1)\,R_{1b} + (I_b+i_1+i_3)\,R_{2b} - (I_a-i_1-i_3)\,R_{2a} - (I_a-i_1)\,R_{1a} = 0$

$$\therefore \quad I_aR_{2a} - I_bR_{2b} = (i_1+i_3)(R_{2a}+R_{2b}) + i_3R_3 \quad \ldots\ldots\ldots\ldots \quad (1)$$

and
$$I_a\,(R_{1a}+R_{2a}) - I_b\,(R_{1b}+R_{2b}) = i_1R_m + i_1\,(R_{1a}+R_{1b}) + (i_1+i_3)(R_{2a}+R_{2b}) \ldots\ldots (2)$$

Now the amplifier has been balanced so that $\dfrac{R_{2a}}{R_{2b}} = \dfrac{R_{1a}}{R_{1b}}$

$$\therefore \quad \frac{R_{1a}+R_{2a}}{R_{2a}} = \frac{R_{1b}+R_{2b}}{R_{2b}} = \rho \quad \text{(say)}$$

Eliminating I_a and I_b from equations (1) and (2)

$$i_1R_m = i_3R_3\left[\frac{(\rho-1)(R_{2a}+R_{2b})}{R_3} + \rho\right]$$

$$\therefore \quad \frac{v_o}{v_i} = \frac{i_1R_m}{i_3R_3} = \frac{R_{1a}+R_{1b}}{R_3} + \frac{R_1+R_2}{R_2}$$

(The last term is unaffected whether suffix a or b is used)

Appendix II

Sample Reduction of One Observation

(This illustrates the process but not the lay-out of the reductions).

Star		E9,41			
Local Sidereal time		$1^h\ 22^m$	From observing book		
Sec z		1.22			
Amplifier sensitivity		D - 8			
Average deflexion	blue	45.6	yellow	59.6	
Sky (D-10)		5.3		5.2	
Sky reduced to D-8		2.9		2.9	
Nett. deflexion (star only)		42.7		56.7	Colour
Equivalent magnitude		0.92		0.62	+0.30
Extinction coefficient		0.35		0.20	
Extinction correction		- 0.08		- 0.04	-0.04
Corrected magnitude		0.84		0.58	+0.26
Amplifier gain + 4.00 *			6.62		
Deduced magnitude		7.46		7.20	
Provisional value		7.55		7.32	+0.24
Difference		+ 0.09		+ 0.12	-0.02
Running mean		+ 0.09		+ 0.13	-0.02
Adopted observed magnitudes and colour		7.55		7.33	+0.24
Final residual		0.00		+ 0.01	0.00

The individual readings and linearity corrections (when required) were recorded next to the trace on the strip chart. Corrected means were transferred to the reduction book.

* Arbitrary zero point adjustment to give magnitudes of right order of size.

Appendix III

If $S(\lambda)$ is the sensitivity of a photometer to radiation of wavelength λ, including both the sensitivity of the receiver itself and the transmissions of filters and other optical components, then the equivalent wavelength, λ_ϵ

$$= \int_0^\infty S(\lambda)\lambda\, d\lambda \Big/ \int_0^\infty S(\lambda)\, d\lambda$$

The response of that photometer to radiation varying with wavelength, $I(\lambda)$

$$= \int_0^\infty S(\lambda) I(\lambda)\, d\lambda$$

which by Taylor's expansion

$$= \int_0^\infty S(\lambda)\, [I(\lambda_\epsilon) + (\lambda-\lambda_\epsilon)I'(\lambda_\epsilon) + \tfrac{1}{2}(\lambda-\lambda_\epsilon)^2 I''(\lambda_\epsilon) \;\ldots\ldots\;]\, d\lambda$$

Now, from the definition of λ_ϵ, the first-order term vanishes. Hence, to a first-order approximation, integrated magnitudes behave like monochromatic magnitudes of wavelength λ_ϵ. The second-order term introduces some curvature if the band width is large.

Similarly, if the effective wavelength, λ_e is defined

$$\lambda_e = \int_0^\infty S(\lambda) I(\lambda)\lambda\, d\lambda \Big/ \int_0^\infty S(\lambda) I(\lambda)\, d\lambda$$

the effect of absorption varying smoothly with λ will be, to the first order, the same as if the light were monochromatic and of wavelength λ_e. Expanding this equation as before

$$\lambda_e \doteq \frac{\int_0^\infty S(\lambda)\lambda\, [I(\lambda_e) + (\lambda-\lambda_\epsilon)I'(\lambda_e) + \tfrac{1}{2}(\lambda-\lambda_\epsilon)^2 I''(\lambda_e) \;\ldots\ldots\;]\, d\lambda}{\int_0^\infty S(\lambda)\, [I(\lambda_e) + (\lambda-\lambda_\epsilon)I'(\lambda_e) + \tfrac{1}{2}(\lambda-\lambda_\epsilon)^2 I''(\lambda_e) \;\ldots\ldots\;]\, d\lambda}$$

$$\text{Now} \quad \int_0^\infty S(\lambda)\, (\lambda-\lambda_\epsilon)\, d\lambda = 0 \qquad \text{(by definition)}$$

Hence, neglecting second and higher order terms

$$\lambda_e = \frac{\int_0^\infty S(\lambda)\lambda\, [I(\lambda_e) + (\lambda-\lambda_\epsilon)I'(\lambda_e)]\, d\lambda}{\int_0^\infty S(\lambda) I(\lambda_e)\, d\lambda}$$

$$\doteqdot \lambda_\epsilon + \frac{I'(\lambda_e) \int_0^\infty S(\lambda)\, (\lambda-\lambda_\epsilon)^2\, d\lambda}{I(\lambda_e) \int_0^\infty S(\lambda)\, d\lambda}$$

The ratio $\dfrac{\int_0^\infty S(\lambda)\, (\lambda-\lambda_\epsilon)^2\, d\lambda}{\int_0^\infty S(\lambda)\, d\lambda} \doteq \mu_\epsilon^2$, where μ_ϵ is the radius of gyration of the area under the sensitivity curve about $\lambda=\lambda_\epsilon$ as axis.

Assuming Planck's equation (in logarithmic form - see Section I, p. 6)

$$\frac{d}{d\lambda}\log_e I(\lambda) = -\frac{5}{\lambda} + \frac{c_2}{\lambda^2 T}\Big/\left(1-e^{-\frac{c_2}{\lambda T}}\right)$$

But

$$\frac{d}{d\lambda}\log_e I(\lambda) = \frac{I'(\lambda)}{I(\lambda)}$$

and

$$\frac{c_2}{T}\Big/\left(1-e^{-\frac{c_2}{\lambda T}}\right) = \phi \quad , \text{ the absolute gradient.}$$

Hence

$$\frac{I'(\lambda)}{I(\lambda)} = \frac{\phi}{\lambda^2} - \frac{5}{\lambda}$$

and

$$\lambda_e = \lambda_\epsilon + \left(\frac{\phi}{\lambda^2_\epsilon} - \frac{5}{\lambda_\epsilon}\right)\mu_\epsilon^2 \quad \text{(approximately)}$$

or

$$\frac{d\lambda_e}{d\phi} = \frac{\mu_\epsilon^2}{\lambda_\epsilon^2}$$

(See also I. R. King, A.J., 57, 253, 1952 for a different treatment of the same problem).

SECTION IV

MAGNITUDES OF STARS IN THE E REGIONS BASED ON OBSERVATIONS BY THE FABRY AND PHOTOELECTRIC METHODS

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MAGNITUDES OF STARS IN THE E REGIONS BASED ON OBSERVATIONS BY THE FABRY AND PHOTOELECTRIC METHODS

I. SUMMARY OF OBSERVATIONS MADE WITH FABRY AND PHOTOELECTRIC PHOTOMETERS

The primary object of the research programmes described in this thesis has been to produce sequences of standard magnitudes in the nine Harvard Standard Regions at -45° declination. Two such programmes have been described in detail in Sections II and III. A considerable amount of work has been done with other photometers and other telescopes, but it is impossible to give detailed accounts of all these within the compass of this thesis. The equipment has differed in detail but the methods of observation and reduction have been essentially the same for all the series observed by members of the Cape Observatory staff.

In the early stages of the work a limited amount of observing was done with a moving plateholder (schraffirkasette) camera and in-focus with rotating sectors. These methods were discontinued when experience showed that better methods were available but it is probable that both methods would prove of value for work on fainter stars.

In the summary that follows a brief account is given of all series of observations of stars in the E regions made with Fabry and photoelectric photometers that were completed prior to June 1953 and of some other series, only partly completed, of which use has been made in deriving the final magnitudes. To avoid confusion the numbering of the series has been made the same as that adopted in Cape Mimeogram No. 3 (Table I). This is not strictly chronological.

(1) A series of photovisual observations made by R. O. Redman in Pretoria. Redman used the Fabry method with a 12-inch aluminised mirror mounted in the tube of the then unfinished 74-inch reflector. The mirror was tilted and used in the Herschelian manner. Ilford HP3 plates and an Ilford Delta filter were used. The light from the brighter stars was reduced by rotating sectors and exposures were increased beyond the

normal length to reach the fainter stars. Stars from the fifth to the tenth magnitude were observed. Some precision had to be sacrificed in order to observe a maximum number of stars in a limited time and with a telescope that was far from ideal for the purpose.

(2,3,4) Photographic and photovisual observations of stars brighter than $8^{m}.4$ Pg and $7^{m}.6$ Pv observed by the Fabry method at the Cape between 1947 and 1949. A few of the brightest stars were also observed with a blue filter. (See Section II).

(5,6) Photographic magnitudes observed by the Fabry method with the 24-inch Victoria Telescope at the Cape between 1948 and 1950. These observations were made and reduced mainly by R. H. Stoy with the object of investigating a Purkinje effect in the magnitudes determined with the Photometric Cameras. The author made an attempt to reach fainter stars by using fast 103a0 plates. Stars to $11^{m}.0$ were measured but the coarse and somewhat uneven emulsion gave rise to large accidental errors and the observations were discontinued. The main programme included a large number of stars, mostly brighter than the 10th magnitude, in all the E regions. The fainter stars were observed in E5 only.

(7) A few photovisual observations were made with a duplicate photometer on the 18-inch telescope. (The 18-inch objective was in England being repolished during most of the time that the photographic observations were being made). Photovisual and photographic exposures were made simultaneously.

The same sensitometers were used for all the Fabry programmes at the Cape. The rotating sectors used for the series of observations with the Victoria Telescope are small in size and are driven by compressed air. The photometric constants of these sectors were measured on photographic enlargements and later checked with a photoelectric photometer, at the same time and in the same manner as the sectors used for the Astrographic programme.

(8) Photoelectric observations made by I. R. King at Harvard Observatory, Bloemfontein, mostly with the 60-inch Reflector. (Doctoral Thesis, Harvard University, 1952).

(9) Photoelectric observations in blue and yellow light made by J. B. Irwin and A. N. Cox at the Radcliffe Observatory, Pretoria, in 1950 and reduced at the Cape. Harvard sequence stars were observed in E1 (bright stars only), and in E4, E7 and E9 (to beyond magnitude 13). The accidental

errors are rather large, except for the E9 sequence, and the scale is not beyond suspicion at the faint end.

(10) Photoelectric observations made at the Cape Observatory in December 1950 and January 1951. The photometer used for (9) was attached to the 24-inch telescope. The diaphragm employed was 1.1 mm in diameter. The colour filters were Corning Glass 9780, for the yellow and 3850 cemented to 5850 for the blue magnitudes. The amplifier was similar to (but not identical with) the unit described in Section III. It was used with an Esterline Angus 0 - 1 ma recorder. The 1P-21 photomultiplier tube had a high sensitivity and good stability and was supplied from a tapped battery. The exposures were of 20 seconds duration and were made in the same sequence as was later adopted for the Astrographic programme.

Observations were made in E1, E2, E3, E4 and E5, mainly between the seventh and the twelfth magnitudes. A number of brighter stars were also observed to tie the results to other work being done at the Cape.

Further details of the equipment are given by Cox in a paper describing another series of observations made by himself. (See Ap.J. 117, 83, 1953).

(11) Observations made on two nights in 1951 by D. S. Evans and J. C. Churms with a photoelectric photometer belonging to the Leiden Observatory and fitted at the Newtonian focus of the 74-inch Radcliffe Reflector in Pretoria. Although the observations (in two colours) were mostly made once only, the accidental errors are small. The measures were reduced using instrumental constants supplied by T. H. Walraven. The stars are all comparatively faint.

(12) Photoelectric observations of bright stars made at the Cape in 1951 and 1952. (See Section III). The stars are mostly brighter than magnitude 8.5.

(13) Photoelectric observations made at the Radcliffe Observatory in 1952 mainly of stars between the ninth and thirteenth magnitudes.

A special photometer designed for use at the Cassegrain focus of the reflector had been constructed for the Radcliffe Observatory in the Leiden Observatory instrument shop. The amplifier supplied with the photometer proved unsuitable and all observations were made using one of the amplifiers belonging to the Cape Observatory. A Brown Recorder was available.

The 931-A photomultiplier tube used for the observations was not particularly sensitive but had an unusually small dark current. It was operated at about 105 volts per stage from a potential divider and high tension battery. The dark current was then less than 10^{-9} amps.

A number of "teething troubles" were experienced and during the ten weeks the photometer was in operation there was a progressive and unaccountable loss of sensitivity. This, combined with poor weather and limited opportunities for observing, restricted the work. The observations are, however, a useful check on earlier work by Irwin and Cox and King.

The filters used were Corning Glass 5551 for the blue and Jena GG5 for the yellow. The primary mirror was silvered, the secondary and flat were aluminised, and an appreciable amount of ultraviolet light entered into the blue magnitudes. King (Series 8) had used a similar blue filter with silvered mirrors and a comparison between the two series of magnitudes showed a nearly linear colour equation. King's series includes a better selection of early type stars than does the Pretoria series and shows a markedly non-linear colour equation compared with the Cape magnitudes observed with refractors. The non-linear term thus found has been adopted for reducing the Pretoria results to the "S" system.

In any future work with this photometer it is intended to interpose a Jena GG 13 filter to cut out ultraviolet light.

(14) Photoelectric observations made with an improved photometer attached to the 24-inch telescope at the Cape, These observations extend to the eleventh magnitude and were planned to provide a link between the Pretoria observations (Series 13) and the observations of brighter stars previously made at the Cape. These observations were made during September, October and November 1952 while the telescope was temporarily in commission during reconstruction.

The amplifier was the one used in Pretoria but fitted with new high-stability resistances in the feed-back network. The mains-operated power supply for the amplifier and photomultiplier tube was used without a voltage regulating transformer and it was found necessary to replace two VR-105 voltage reference tubes by 85A-1 tubes of higher stability. The readings were recorded with a Brown Recorder coupled with a 3000/10 ohm voltage divider to get increased sensitivity.

The 931-A multiplier tube used for this programme was one having moderate sensitivity and a comparatively small dark current. Dark current noise was the limiting factor on dark nights and it was not found economical to observe much beyond magnitude 11.0. The tube was operated at about 80 volts per stage.

This tube is appreciably more red sensitive than those used for the Pretoria and Astrographic programmes and it was found desirable to use an Omag 302 filter, instead of the 301 filter used previously, in order to keep the blue and yellow deflexions more nearly equal. This results in a useful increase in the "colour base line".

The same method of observation was used as for other similar work at the Cape and partial sequences were observed in E7, E8, E9, E1 and E2. Further work is desirable to complete this programme and if possible to extend it to fainter stars. A new photometer is being constructed to work with the more sensitive E.M.I. type 5659 photomultiplier tubes.

(15) A new series of photoelectric observations was commenced with the Astrographic Telescope in January 1953. The photometer is the one used in connection with Series 14, with the Omag 302 filter, but the 931-A tube that was used for Series 12. The potentials have been raised to 85 volts per stage to avoid having to use the 'D' sensitivity range (with the attendant uncertainty of the C/D ratio). Measures of E region stars, mostly brighter than $7^{\mathrm{m}}.0$, in E2, E3, E4 and E5 have been used.

(16) A series of observations made with a photometer belonging to the Washburn Observatory of the University of Wisconsin attached to the 24-inch Victoria Telescope. The observations were made with four filters: Corning Glass 3384 (yellow), Jena BG12 cemented to GG13 (blue), Corning Glass 9863 (ultra-violet) and the Cape blue glass.

The amplifier and power supplies associated with this photometer differ considerably from those used previously. The performance was very satisfactory and it is proposed to build a similar unit for future use. The calibration of the amplifier was checked with the Cape potentiometer.

The observations were made primarily to investigate the effect of admitting or excluding the small amount of ultra-violet light that passes through the Cape blue filter, but some yellow magnitudes of stars in E4 and E5 have been used in conjunction with the other magnitude data.

The investigation of ultra-violet light effects shows that there is an appreciable amount of non-linearity in the colour relation between the Cape and Washburn filter blue magnitudes. If the colour equation is fixed by the sensibly straight line defined by main sequence stars of type A and stars of later type, there is a discrepancy of $0\overset{m}{.}05$ for B0 stars. The departure from linearity appears to be closely related to the measured ultra-violet - blue colour indices and the spectral types, but the effect of absolute magnitude has not yet been fully explored.

Although a number of ultra-violet - blue colour indices were measured this phase of the work is still in the explatory stage and no details are included in the tables. Further work in this direction will be done when a more suitable telescope is available.

II. THE DERIVED MAGNITUDES AND COLOURS

The various series of observations summarised in the preceeding sub-section have been combined to give accurate magnitudes for a large number of stars in the E regions.

A good deal of preliminary work had to be done to determine the relative colour equations and to decide on a standard colour system to which all could be reduced. When this work was commenced the southern "S" system was defined principally by a compilation of magnitudes observed with the Cape Photometric Cameras and the new magnitudes were compared with these. It was known at the time that some of these magnitudes were affected by a photographic equivalent of the well known Purkinje effect, that is to say, a change of colour equation with magnitude. The best that could be done was to make the new colour system agree with the old for the mean of the magnitudes being compared. Since the SPg and SPv systems were thought to be near the corresponding international systems it was hoped that the new magnitudes would be so also.

Every series but two --- the photographic magnitudes observed with the Victoria Telescope (Series 5 and 6)-requires a colour correction, but these corrections are nearly linear for all but two series. The exceptions are the two series of photoelectric blue magnitudes that include a perceptible amount of ultra-violet light viz. 8 and 13. The best that could be done for these was to use a smooth curve drawn through the magnitude differences plotted against the observed colours. It is probable that a plot against accurate spectral types would give a more definite curve, but as many of the stars are too faint for classification this is not practicable.

Table 1

Colour Corrections to Observed Magnitudes

Series	Observers	Colour Coefficient Pg	Colour Coefficient Pv	Source of Colour Index
Fabry				
1	Redman		+0.12	SCI
2	Cousins	-0.03		2 - 3
3	Cousins		+0.075	2 - 3
4	Cousins	-0.16		2 - 3
5	Stoy	0.00		
6	Cousins	0.00		
7	Stoy		+0.03	SCI
Photoelectric				
8	King	(-0.055)	-0.23	8*
9	Irwin & Cox	+0.10	-0.19	9
10	Cape	+0.05	-0.18	10
11	Evans & Churms	+0.04	-0.21	11
12	Cape	-0.02	-0.20	12
13	Cousins	(0.00)	-0.475	13*
14	Cousins	-0.015	-0.07	14
15	Cape	-0.03	-0.09	15
16	Cousins	(-0.065)	-0.135	16

* The Pg colour corrections are non-linear (see below). The non-linearity was removed before using these colour indices to compute SPv magnitudes.

Observed Colour	Correction	Observed Colour	Correction	Observed Colour	Correction
Series 8 Pg (-0.55 x C observed)					
-0.30	+0.04	+0.20	-0.02	+0.90	0.00
-0.20	+0.04	+0.30	-0.01	+1.10	0.00
-0.10	+0.03	+0.40	+0.01	+1.30	-0.01
0.00	0.00	+0.50	+0.02	+1.50	-0.02
+0.10	-0.02	+0.70	+0.01		
Series 13 Pg					
-0.30	+0.02	+0.10	+0.01	+0.80	-0.01
-0.20	0.00	+0.20	+0.02	+1.00	-0.01
-0.10	-0.02	+0.40	+0.01	+1.20	-0.02
0.00	-0.01	+0.60	0.00	+1.40	-0.03

All the photoelectric observations have been made in two colours and colour corrections can be applied on the basis of the measured colours. Many of the brighter stars observed by the Fabry method (Series 2, 3 and 4) were also observed in two colours and could be reduced on this basis. The photographic magnitudes observed with the Victoria Telescope do not require a colour correction. The remaining observations were first reduced to the standard system with the help of the original (SPg - SPv) colours and then revised when more accurate colours became available.

The colour coefficients finally adopted for the reductions are given in Table 1 . The non-linear corrections for the blue magnitudes of Series 8 and 13 are also given.

Accurate zero point corrections are available only for the bright stars observed photoelectrically in Series 12. Constant quantities were added to the corrections deduced from the E region comparisons so that the resulting systems would have as nearly as possible the same mean zero points as the original SPg and SPv systems. This series of magnitudes (12) is the foundation of the whole system, and all other series have to be tied directly or indirectly to them. No difficulty is experienced in doing so when both series are accurate and there is a fair number of stars common to both, but this is by no means always the case.

The observations of bright stars by the Fabry method could always be combined with the basic photoelectric series and this was done first to reduce the accidental errors of the magnitudes. From this point on each E region had to be treated individually, the various series being compared with the bright stars (where possible) and with one another, sometimes in one order and sometimes in another, to obtain a satisfactory reconciliation of all the data. The material is not sufficiently homogeneous to state the standard errors of the zero points over the whole magnitude range. Between 5.0 and 8.0, they can be taken as less than $\pm 0^{m}.005$, and at 10.0 as less than $\pm 0^{m}.010$, for both colours, and relative to the mean of all the regions.

Several other attempts have been made to tie the E regions together.

The zero points adopted for the reduction of the zone plates depend on the original SPg and SPv magnitudes. These were based on intercomparisons made with the Photometric Cameras. Because of the Purkinje effect and changes in the stellar population from one E region to another it is difficult to compare the two systems accurately. It can be said, however, that the zero point differences are not more than about $0^{m}.02$ and that the scale differences are also small.

An independent determination of the zero points was made in connection with the "Bright Star Programme". Three sets of data were available, not usually complete for all regions, but of considerable weight when taken together. Thus, a few regions were weakly tied together during the progress of the photographic programme; more observations of a similar type were made with the blue filter and Ilford Special Rapid plates; and finally, the routine observations of the "Bright Stars" provided additional data, since individual stars were frequently tied to two different E regions and therefore served as common reference points. All these data were combined to give new zero points for the standard stars and as these magnitudes can be reduced to the new standard system it is possible to compare the two series.

A third independent determination of zero points was made by I. R. King at Bloemfontein for the regions observed by him.

The results of these comparisons are as follows: (Unit $0^{m}.001$)

E Region	B.S. - SPg	King - SPg	King - SPv
1	+ 11		
2	- 10		
3	- 10		
4	+ 7		
5	- 11	+ 10	- 251
6	+ 3	- 10	- 246
7	- 9	+ 10	- 246
8	- 17	+ 7	- 226
9	0	+ 37	- 194

The internal agreement and small closing error of the Bright Star Programme zero points is such as would have led one to expect a rather better agreement with this series. It is surmised that part of the disagreement arises from the small number of stars available in some regions and because many of the stars are of early spectral types where any difference in the percentage ultra-violet content of the magnitudes between the two series has the most effect.

The large amount of non-linearity in the colour correction applied to King's blue magnitudes (because of ultra-violet light) may have affected this comparison also. It is to be noted that King relied on only one star in each region when observing zero point differences.

In view of these remarks and the disagreement between King's measures and the Bright Star Programme results it is not thought that the differences need be taken seriously.

The magnitudes of the stars as observed by different workers and with different instruments are given in the tables on pages 26 to 29, 49 to 50 and 85 to 95. Zero point corrections (in units of $0^{m}.01$) have been applied to the observed magnitudes to reduce them approximately to the S system, usually for a mean colour near 0.4. These are on the natural colour systems of the observations and require the corrections given in Table 1 to reduce them to the standard system. The mean magnitudes derived from them are given in the attached Cape Mimeogram No. 3. Unit weight corresponds approximately to an A.D. of $0^{m}.007$. The better series have a weight of one. The number of independent determinations is, therefore, never less than the assigned weight. When the observed magnitudes disagree amongst themselves, the mean magnitude is marked with a colon. Magnitudes between parentheses are even less certain. They are in most cases based on the earlier Photometric Camera measures and have been inserted where no better magnitudes are available. A few stars are noted as variable. None of the magnitudes in parentheses are included in the later discussions.

The colour and zero point corrections were computed to three decimal places to avoid introducing systematic changes in the zero points and were applied to the magnitudes as recorded in the working ledgers. In some cases these had been computed to the nearest $0^{m}.005$. The corrected magnitudes were rounded off to the nearest hundredth of a magnitude and entered in another ledger where they were later combined. Because of the zero point adjustments mentioned in the previous paragraph it is not possible to reproduce these magnitudes rigorously from the present lists.

There would be some justification for expressing the mean magnitudes to three decimal places, but it is doubtful whether the accuracy with which magnitudes can be reproduced warrants this refinement and the considerable increase in labour involved. An increased weight does give more confidence in the long term stability of a star's light.

In the process of combining the observations nearly every possible intercomparison for scale, colour and accidental errors was made. This preliminary analysis is not repeated here but some comparisons between different series of magnitudes reduced to the standard system are given below.

A direct comparison between the two series of observations of bright stars described in Sections II and III gives the following differences after both have been reduced to the standard system (unit $0^{m}.001$):

Colour Range (SCI)	Fabry Pg - Pe Blue	No. of Stars	Fabry Pv - Pe Yellow	No. of Stars
<-0.4	+ 3	28	+ 3	27
-0.4 to -0.2	+ 3	54	+ 3	33
-0.2 to 0.0	0	35	+ 1	19
0.0 to 0.2	- 5	39	- 2	29
0.2 to 0.4	+ 2	27	-12	23
0.4 to 0.7	-10:	5	- 6:	5
0.7 to 1.0	0	30	+ 6	32
1.0 to 1.3	+ 2	12	+ 3	13
>1.3	- 4	7	-40	11

There is no evidence of any appreciable colour difference remaining between the blue magnitudes and only a very slight curvature between the yellow magnitudes, except for the reddest stars (K5 and later). The natural colour systems of the blue magnitudes are very close and a good agreement might have been expected here. The relative colour equation of the natural yellow magnitudes is 0.25 x SCI, indicating that the photovisual magnitudes (observed with the same yellow filter) extend much further towards the red. It is possible that band absorption may produce a greater effect on the photoelectric than on the photovisual magnitudes of late type stars.

The average differences between these magnitudes are $0^{m}.009$ for the blue magnitudes and $0^{m}.012$ for the yellow. The average internal standard errors are approximately $\pm 0^{m}.006$ for the Fabry magnitudes and $\pm 0^{m}.004$ and $\pm 0^{m}.005$ for the photoelectric blue and yellow magnitudes, or $\pm 0^{m}.007$ for the blue and $\pm 0^{m}.008$ for the yellow magnitude differences. As is usually the case, these are appreciably smaller than the errors found by direct comparison.

To show the extent to which the colour corrections have been effective in reducing the various series of observations to a common system, the differences (individual determination - mean magnitude) have been plotted against the colours of the stars (SCI) in Figures 7 and 8. Only the more important of the completed series are shown and no stars are included unless the mean magnitude has at least twice the weight of

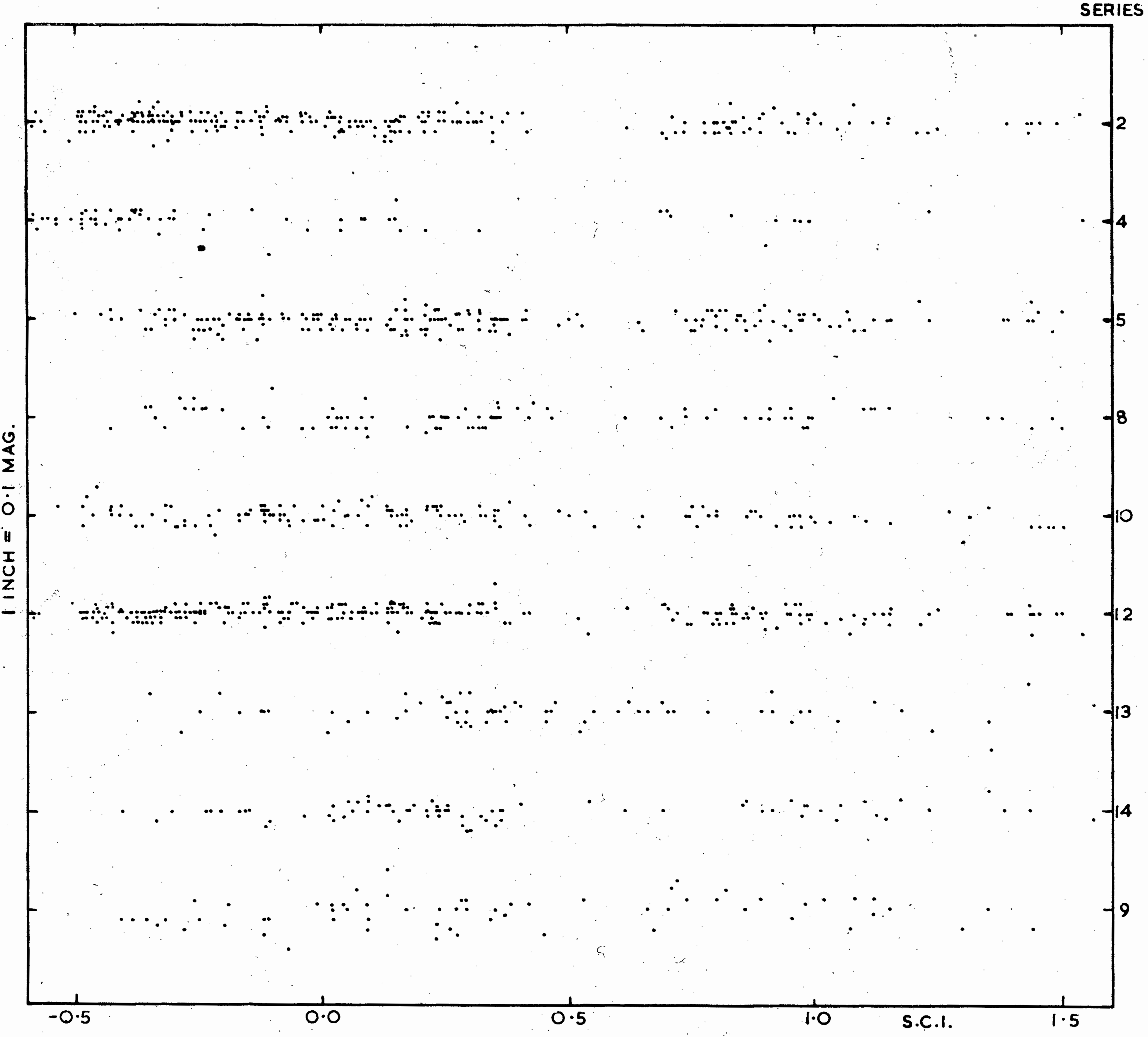

FIG. 7.—RESIDUAL COLOUR DIFFERENCES: SERIES — SP$_g$.

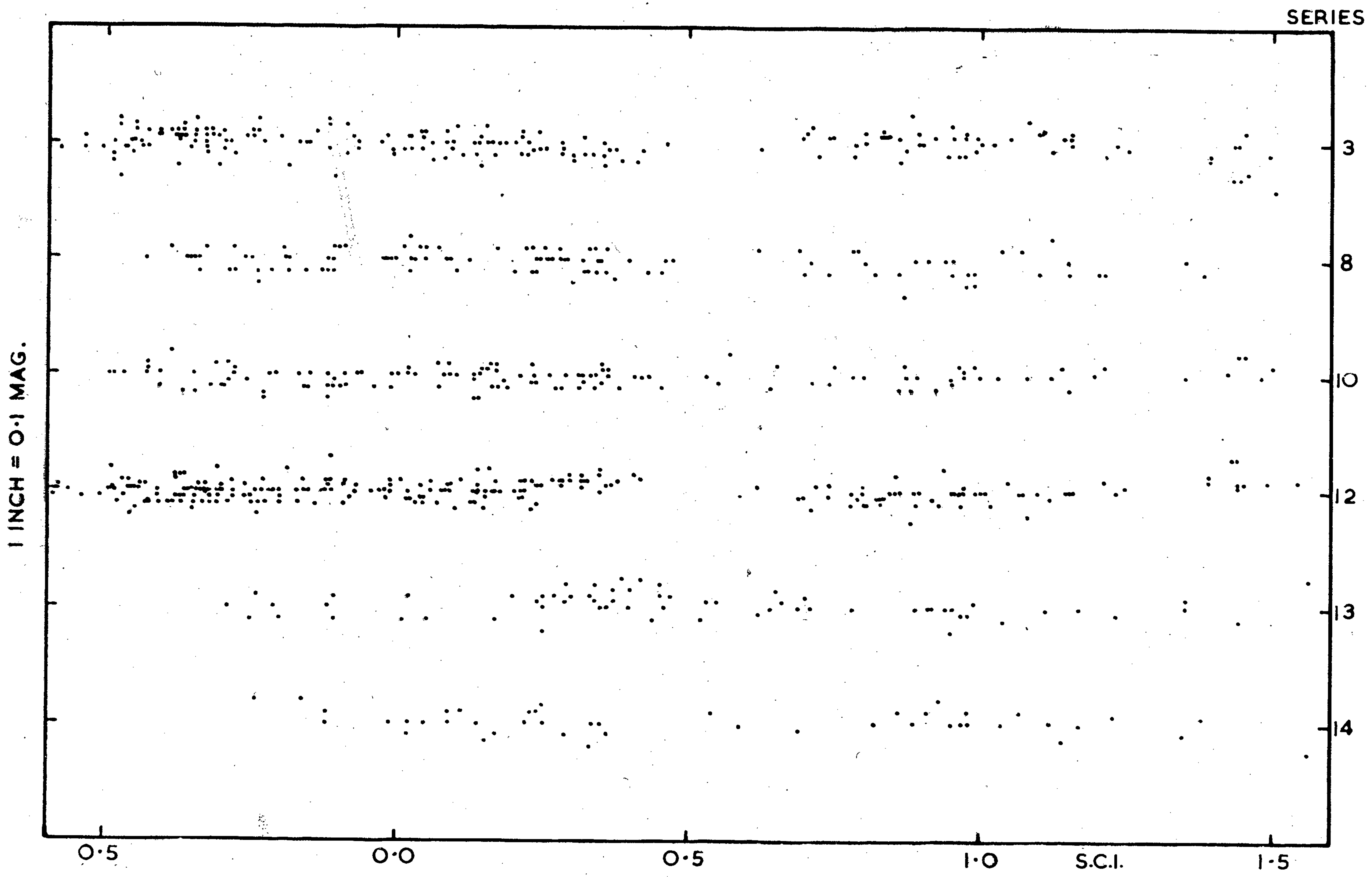

FIG. 8.— RESIDUAL COLOUR DIFFERENCES: SERIES — SPv.

the magnitude being compared with it. The scatter of the points is somewhat less than would be the case if the magnitudes were independent, especially for the fainter stars where fewer measures are available.

The very small amount of non-linearity revealed by these plots shows that linear colour corrections are satisfactory in most cases. If smoothed curves or normal points were used to represent the residual differences they would lie almost wholly within $\pm 0^{m}.01$ of the zero line, and usually well within these limits. Even in the two cases where the corrections were not linear there is no unusual scatter of the plotted points. Some of the series not represented show a greater amount of scatter but the smoothed curves are not significantly less linear than for those shown.

Possible scale errors can be investigated either by comparing the individual series (corrected for colour and zero point differences) with the final mean magnitudes or by comparing the different series (similarly corrected) with one another. The latter method is the more critical because the different series are independant as regards scale, whereas the mean magnitudes may derive half their weight from the magnitudes with which they are compared. (If more than half is involved the comparison is of little value). The results of a number of comparisons of the second type are given in Table 2 . These do not include all possible combinations but only those where there is a fair number of stars in common over a range of at least two magnitudes. The tables give the mean differences in units of $0^{m}.001$ and the numbers of stars in each mean (in parentheses).

Omitting the brightest stars observed photoelectrically (Series 12. They are suspect because of variations in the C/D ratio of the amplifier) and the faintest stars observed in the two Astrographic Fabry series (2 and 4, where the images are weak and the calibration depends entirely on the sensitometer), there are no appreciable scale differences between the various series of Pg magnitudes of stars brighter than 10.0. The few fainter stars observed with the Fabry photometer on the 24-inch telescope with Ilford Zenith plates (Series 5) do not carry much weight, but the disagreement between the photoelectric measures of the faint stars will need further investigation. A detailed discussion of the magnitudes of the faint stars must wait until further observations are available.

The data are less complete for the yellow (or photovisual) magnitudes and the random errors are, on the average, somewhat larger, but between magnitudes 5.0 and 10.0 there is little to suggest that any of

Table 2

Scale Relations of Observed Magnitudes

(Unit $0^{m}.001$)

A. Photographic Magnitudes of Bright Stars

Series	Magnitude Range					
	< 4.0	4.0 to 5.0	5.0 to 6.0	6.0 to 7.0	7.0 to 8.0	8.0 to 9.0
2 - 4	- 4 (10)	+ 4 (13)	0 (31)	+ 8: (6)		
2 - 10			+ 2 (4)	0 (14)	0 (37)	- 4: (15)
2 - 12	+ 7: (3)	+ 2 (12)	+ 1 (32)	+ 3 (66)	- 1 (93)	- 4: (25)
4 - 12	+15: (2)	- 1 (11)	+ 1 (31)	-10: (5)		
5 - 12				0 (3)	- 3 (50)	+ 5 (26)
10 - 12			+ 2 (4)	- 1 (12)	- 1 (37)	- 2 (18)

B. Intermediate Photographic Magnitudes

Series	Magnitude Range				
	< 7.0	7.0 to 8.0	8.0 to 9.0	9.0 to 10.0	> 10.0
5 - 8		- 1 (16)	+ 2 (12)	0 (22)	-10: (3)
5 - 10	0 (2)	- 1 (14)	+ 3 (16)	+ 1 (19)	+ 4: (5)
5 - 14		- 5 (10)		+ 1 (14)	
10 - 8		0 (11)	+10 (4)	+ 7 (6)	-22 (9)
10 - 14		+ 4 (10)	- 2 (18)		-16 (8)
14 - 8		+10: (5)		0 (8)	- 5 (8)

C. Photovisual Magnitudes of Bright Stars

Series	Magnitude Range					
	< 4.0	4.0 to 5.0	5.0 to 6.0	6.0 to 7.0	7.0 to 8.0	8.0 to 9.0
1 - 12			0 (6)	+ 5 (21)	+ 3 (40)	+ 6 (19)
3 - 1			- 3 (6)	-10 (21)	0 (22)	
3 - 10			+ 7 (6)	0 (20)	- 1 (21)	
3 - 12	+20: (7)	+10: (9)	+ 1 (34)	- 2 (80)	- 4 (51)	
8 - 12				- 5 (10)	- 2 (18)	- 4 (10)
10 - 12			- 3 (6)	- 2 (20)	0 (29)	+ 5 (19)

D. Intermediate Photovisual Magnitudes

Series	Magnitude Range				
	< 7.0	7.0 to 8.0	8.0 to 9.0	9.0 to 10.0	10.0 to 11.0
1 - 14		- 3 (7)	- 2 (19)	- 7 (16)	-36: (6)
8 - 9	-20: (3)	+13 (9)	0 (14)	+ 1 (11)	- 1 (11)
10 - 1		+ 4 (8)	- 5 (11)	+ 6 (10)	
10 - 14		- 1 (8)	- 1 (7)	0 (3)	

the series have appreciable scale errors. The agreement between the two series of observations of the brightest stars is again not very satisfactory and this is not to be surprised at as the photoelectric blue and yellow magnitudes are likely to be affected in a similar way. The difference will be investigated further when the present series of observations with the Astrographic Telescope (Series 15) is completed.

There is, therefore, no evidence of any significant scale differences between the series over the range from 5.0 to 10.0 in either colour, and there is no reason to suppose that the mean magnitudes do not reproduce the scales of the constituent series, but that does not prove that the scale is a normal Pogson scale. However, when it is considered that two completely different techniques (Fabry and photoelectric) have been used and that no two series employing the same instrument have covered precisely the same magnitude range, the evidence is overwhelmingly in favour of the correctness of the scales.

The conclusion to be drawn from these comparisons is that the mean magnitudes meet the requirements with regard to uniformity and systematic accuracy considered necessary for present day astronomical research, and that the accidental errors are usually no larger than the uncertainties introduced when converting one system of magnitudes to another.

III. CONCLUSION

The present system of magnitudes grew out of the need for adequate sequences to reduce the observations of stars being made as part of the Cape A.G. Zone Programme. These stars are mostly brighter than the tenth visual and the eleventh photographic magnitudes. The research programmes described in this thesis have ensured that the magnitudes, to these limits of brightness, are systematically accurate and on a homogeneous system, and, in most cases, the accuracy of the individual magnitudes is more than adequate for the purpose. It appears (though this has not been demonstrated here) that the magnitudes measured on the Photometric Camera plates can be reduced to the revised S system by means of linear colour corrections, though these are not independent of the magnitude range. It is concluded, therefore, that the revised S system is sufficiently accurate and in other respects entirely suitable for the purpose for which it was set up.

The number of stars measured in each E region is also sufficient but the range in colour of the stars in different magnitude ranges is not always as good as could be desired. Additional stars are being selected to improve the position and these will be measured when an opportunity can be found. It is then hoped that these sequences will prove adequate for the present and any similar programmes of two-colour photometry in this range of magnitudes.

The most urgent need for the future is to extend the sequences to the faintest limit possible with the 74-inch reflector in Pretoria. Reference has already been made to some preliminary work in this direction. Further observations have recently been made by and under the direction of Dr. A. D. Code and more work is contemplated by the Cape observers in the near future.

Reference has also been made to a possible demand for red and ultra-violet magnitudes (or colour indices involving them). No work is at present planned in the first connection. It may even prove possible to compute red magnitudes from the present two-colour results. Some work has, however, been done on the measurement of ultra-violet - blue colour indices for the brighter stars in the E regions. Further observations are contemplated in the future, as the importance of this information is now recognised, but it is not yet certain how extensively these should be measured. They should certainly be measured for stars of early spectral types but may not be important for later types. This question has still to be investigated.

One other issue arises in connection with future work. While the present SPg system is entirely suitable for work with the Cape refractors it lies intermediate between the natural systems of magnitudes obtained with a reflector using blue sensitive plates and no filter and with a photometer from which all ultra-violet light has been excluded. Recent measures at the Cape have shown that the latter can be reconciled with the SPg system if the ultra-violet - blue colours or the spectral types are known. No significant differences were found for stars between A0 (main sequence) and K0 but B-type stars, and presumably giants of type A, appear noticeably brighter according to the SPg system. On the other hand difficulties have already been encountered when using reflectors without removing the ultra-violet light. It is probably better to remove this light entirely than to try to copy the refractor system and this means that the standard magnitudes should also conform to this condition.

It is not proposed that all the present Pg magnitudes should be abandoned. They are appropriate for their purpose and can be reduced to the proposed system with the necessary accuracy for these brighter stars. This may not be true for the fainter stars whose spectral types are not known and whose colours are often greatly affected by interstellar reddening, and it is here that the change is desirable. For intermediate magnitudes - between the tenth and twelfth - both systems will probably be required and measures may have to be made of the brighter stars to adequately define the colour system.

Addendum (September, 1953).

Sufficient progress has been made with the Astrographic photoelectric observations (Series 15) to justify a preliminary comparison between these magnitudes and those observed in Series 2, 3, 4 and 12. There is very little scale difference between them. The mean differences for stars brighter than magnitude 4.0 observed by the Fabry method are all less than $0\overset{m}{.}005$. The brightest stars observed photoelectrically in Series 12 still appear to be (on the average) too bright but the error is small and scarcely significant. The suggested explanation (see p. 80) appears to be a reasonable one.

1. Photovisual Magnitudes determined by the Fabry Method with a 12-inch mirror at Pretoria

Q \ E	1	5	6	7	8	9
1	7.93	8.12	10.20	8.36	7.95	8.23
2	8.57	8.20	8.28	8.04	8.10	11.02:
3	9.81	8.12	9.86	8.27	8.92	9.45
4	7.53	8.67	8.22	8.39	9.39	9.02
5	9.53	8.75	8.35	8.61	8.32	7.82
6	7.98	8.65	8.68	9.25	8.43	8.99
7	8.70	8.95	8.91	10.13	10.03	7.62
8	8.98	10.06	9.32	10.67	7.97	8.35
9	8.26	8.55	9.20	8.70	7.90	9.31
10	8.45	8.96	10.14	8.97	7.10	8.08
11		9.33	10.24	8.74	7.84	8.20
12	8.23	9.34	8.00	9.37	7.66	8.77
13	9.35	8.72	8.10	9.49	7.73	
14	9.44	9.80	8.25	9.35	7.39	9.46
15	9.59	10.26	9.53	10.11	8.12	9.60
16	9.82	7.86	9.44	8.20	8.55	10.41
17		8.78	9.80	9.23	9.20	7.27
18	9.46	9.81	9.43	8.60	9.35	8.35
19	9.60	9.92	10.02	9.13	9.46	8.53
20		7.52	8.17	9.49	7.49	8.40
21	6.91	8.90	7.91	10.21	9.12	8.89
22	8.00	10.14	8.14	7.33	10.07	10.38
23	8.64	8.37	9.04	7.19	10.18	10.38
24	8.83	8.85	9.39	8.43	10.38	6.88
25		9.29	8.47	8.14	7.51	7.03
26	7.86	9.93	9.35	8.63	6.47	9.18
27	9.30	6.50	7.26	9.94		9.38
28	8.50	7.44	7.43	8.14	6.44	10.27
29	8.54	8.26	8.15	8.48	6.90	6.72
30	6.50	8.32	8.99	8.68	6.77	6.78
31	6.90	9.01	10.01	9.00	7.45	7.09
32	6.80	9.04	9.48	7.52	7.70	7.81
33	7.59	7.79	6.70	7.77	7.80	8.82
34	6.60	8.29	10.09	8.02	7.75	9.30
35	9.30	8.40	8.91	8.66	8.25	10.46
36	5.00		9.03	8.74	8.48	9.60
37	5.39		8.60	9.64	8.95	8.68
38	5.34		6.61	9.50	8.76	9.34
39	5.92			7.16	9.39	8.49
40	6.37			7.71	7.87	7.07
41	6.18			8.55	9.36	7.30
42				10.27	5.89	6.79
43					7.03	5.99
44					6.19	5.39
45					5.79	7.42
46						7.51
47						
48						
49						
50						

4. Fabry Observations of "blue" magnitudes made with the Cape Astrographic Telescope

No.	Pg(b)	C.I.$_{(F)}$
	E 1	
36	5.28	+ 0.29
37	5.06	- 0.23
38	6.35	+ 0.93
40	5.90	- 0.33
61	4.07	+ 0.71
62	5.07	+ 1.63
63	4.83	+ 0.84
	E 2	
45	6.35	+ 1.02
64	4.98	+ 0.03
65	4.90	+ 1.05
69	4.29*	- 0.01
	E 3	
45	5.33	- 0.44
47	5.31	+ 0.19
49	5.96	- 0.49
50	6.10	- 0.53
52	5.86	- 0.37
85	6.29	- 0.57
86	2.69	- 0.51
87	5.66	+ 0.73
	E 4	
40	5.02	- 0.53
41	5.77	- 0.50
76	4.00	+ 1.80
78	5.30	- 0.57
79	4.67	- 0.57
92	4.81	- 0.11
93	5.11	- 0.67
94	5.49	- 0.45
97	5.69	- 0.62
98	5.69	- 0.54
	E 5	
40	5.29	+ 0.17
42	5.71	- 0.05
51	4.77	- 0.52
76	5.79	+ 1.34
78	4.99	- 0.35

No.	Pg(b)	C.I.$_{(F)}$
	E 6	
39	5.06	- 0.48
43	5.49	- 0.30
78	3.97*	- 0.63
79	4.52	+ 0.15
80	5.87	0.00
83	1.73*	- 0.64
89	1.69	- 0.65
91	3.80	- 0.55
92	5.26	- 0.44
93	2.04	- 0.70
94	2.52	- 0.66
96	3.37	- 0.55
	E 7	
43	5.83	+ 0.73
47	4.69	- 0.46
49	5.45	- 0.36
61	3.49	+ 0.13
80	5.37	- 0.41
83	4.71	- 0.50
84	4.87	- 0.43
87	4.20	- 0.39
88	2.05	+ 0.14
89	5.69	- 0.43
	E 8	
42	5.78	- 0.01
45	5.23	- 0.38
69	5.13	+ 1.02
71	5.53	- 0.13
	E 9	
63	6.32*	+ 0.35
72	5.73	+ 0.07
74	4.97*	+ 0.91
75	5.86*	+ 1.80
78	3.86*	+ 1.77
79	5.82	+ 0.96

A description of the observation of these "blue" magnitudes is given by A. W. J. Cousins in M.N. 110, 531, 1950. The "blue" magnitudes given in the second columns can be reduced to the standard S system photographic magnitudes by applying 0.16 (C.I.$_F$ - 0.38).

More recent observations made in connection with the "Bright Star Programme" indicate that the following stars are either variable or suspected of variation. E2 No. 69 (Range $0^{m}.06$); E6 No. 78 (Range $0^{m}.04$), No. 83 (Range $0^{m}.12$); E9 No. 63 (Suspected), No. 74 (Suspected), No. 75 (Range $0^{m}.08$), No. 78 (Range $0^{m}.12$).

5, Photographic Magnitudes determined by the Fabry Method with the Victoria Telescope at the Cape

Q \ E	1	2	3	4	5	6	7	8	9
1	7.55		7.72		7.62	9.94		7.55	7.89
2		7.57	7.96	9.55		7.83			
3	9.50	9.69	7.26	7.74	8.00		7.87		9.39
4		8.10	7.42						
5	9.58		7.93	7.96	8.80	8.03			7.87
6	8.03	8.38		8.20					
7			8.16			8.68	9.82	9.79	
8		8.18		9.42	10.13			7.86	
9	8.47		8.61	9.72				7.90	9.43
10	8.63	8.25	9.19	7.34		9.92	8.60		8.18
11			9.51	7.47		9.96	8.75	7.71	
12			9.57	7.87		7.83		7.71	
13				7.93		8.03			
14	9.72		9.43	7.98	10.06				9.75
15	9.82		7.31	8.18		9.43		8.32	9.95
16	10.14		8.69		8.18	9.44	8.14		
17				9.55		9.86		9.38	7.61
18		9.01	8.62	9.18	9.97	9.52	8.64	9.54	8.71
19	10.26		9.01		10.09	10.21		9.80	
20			8.46		7.88	8.43	9.35	7.72	
21		10.04	9.95	9.61		8.15		9.19	
22	8.86	9.75	8.70	9.47'		8.50	7.48		
23			9.89	8.38		9.34	7.63		
24	9.83		9.18	8.75	9.34	9.69	8.62		
25		9.98		7.83				7.84	7.89
26	8.46		9.76			9.61			10.09
27			8.76	8.48	7.52	8.14	10.31		
28	9.46			7.63	8.50		8.67	7.64	
29		8.07	9.08	7.76					
30	7.61		9.34		9.45	9.94	9.55		
31	7.98		8.81	9.47	9.98	10.26	9.86	8.32	8.62
32			8.94	9.48			8.74	8.64	
33					9.68	7.87	8.95		9.83
34	8.12	9.60		9.79	9.97		9.12		10.32
35		10.27	7.49		9.97	10.15	9.79		
36						10.10		9.52	
37			8.07					9.89	9.56
38			9.32					10.04	
39			9.40	6.83			8.67		
40			9.43				9.34	9.40	
41			9.63				10.02		7.47
42			9.99						
43				6.90					
44					9.93				
45									
46	7.51		6.94						
47									
48			6.68						
49									8.01
50									8.78

5. Photographic Magnitudes determined by the Fabry Method with the Victoria Telescope at the Cape.

Q \ E	1	2	3	4	5	6	7	8	9
51			6.52				8.28		
52	9.31				7.84	7.52			
53		7.98	6.85		8.10			10.13	
54			10.02						
55									
56								9.70	
57									9.91
58	9.79								10.08
59									
60									10.29
61				8.84					9.81
62				9.09					
63				8.85				9.76	
64				8.65					9.88
65						9.44	7.60		
66						8.25	7.77		
67						8.92		9.71	
68					9.51	9.63			
69					9.64	9.83	9.88		8.34
70									
71									
72					9.42	10.26			
73									
74					9.74				
75				7.74	10.03				
76							9.24		
77			9.00	8.36		10.31	9.62		
78									
79									
80				7.84					
81									
82				9.21					
83			10.06						
84				9.08					
85				8.75					

8. Photoelectric Observations made at Bloemfontein by Ivan King in 1950

H	B	Y	C
	E 4		
A	6.49	5.65	+0.84
B	7.28	7.31	-0.03
C	7.74	7.79	-0.05
D	7.70	6.57	+1.13
Q11	7.50	7.44	+0.06
F	7.93	7.85	+0.08
G	8.00	8.00	0.00
H	8.51	8.44	+0.07
I	9.24:	9.11:	+0.13:
K	9.24	9.20	+0.04
L	9.40	9.44	-0.04
M	9.57	9.39	+0.18
N	9.56	7.91	+1.65
O	9.68	8.72	+0.96
P	9.74	9.64	+0.10
R	10.32	9.84	+0.48
S	10.69	9.43	+1.26
T	10.59	10.41	+0.18
U	10.93	10.62	+0.31
V	11.02	10.58	+0.44
W	11.57	11.26	+0.31
X	11.66	11.26	+0.40
Y	11.76	11.31	+0.45
Z	12.35	11.42	+0.93
a	12.57	11.35	+1.22
b	12.56	12.12	+0.44
c	13.06	11.75	+1.31
d	13.08	12.48	+0.60
e	13.75	13.15	+0.60
	E 5		
A	7.07	7.13	-0.06
B	6.97	6.54	+0.43
C	7.56	6.56	+1.00
D	7.53	7.75	-0.22
E	7.74	7.86	-0.12
F	7.83	7.40	+0.43
G	8.15	7.72	+0.43
H	8.48	8.37	+0.11
I	8.79	8.52	+0.27
K	8.93	8.70	+0.23
L	9.39	9.12	+0.27
M	10.00	8.52	+1.48
N	9.92	9.80	+0.12
O	10.15	9.84	+0.31
P	10.70	9.22	+1.48

H	B	Y	C
	E 5 (cont.)		
Q	10.58	10.44	+0.14
R	10.99	9.36	+1.63
S	10.99	10.49	+0.50
T	11.28	10.71	+0.57
U	11.71	10.48	+1.23
V	11.74	10.81	+0.93
W	12.25	11.92	+0.33
X	12.59	11.92	+0.67
Y	12.70	12.70	0.00
Z	12.99	12.24	+0.75
	E 6		
A	6.32	5.94	+0.38
B	6.54	6.79	-0.25
C	6.71	6.74	-0.03
D	7.10	7.19	-0.09
E	7.21	6.24	+0.97
F	7.47	7.07	+0.40
G	7.75	7.89	-0.14
H	8.26	8.31	-0.05
I	8.36	7.99	+0.37
K	8.43	8.00	+0.43
M	9.00	9.04	-0.04
N	9.04	8.93	+0.11
O	9.39	9.24	+0.15
P	9.41	9.22	+0.19
Q	9.55	9.17	+0.38
R	9.83	9.59	+0.24
S	9.84	9.97	-0.13
T	9.92	9.92	0.00
U	10.15	9.83	+0.32
V	10.51	9.56	+0.95
W	10.56	10.39	+0.17
X	10.56	9.55	+1.01
Y	10.75	10.07	+0.68
a	11.22	10.86	+0.36
b	11.63	10.68	+0.95
c	12.11	10.71	+1.40
e	12.29	11.91	+0.38
f	12.55	11.59	+0.96
h	12.77	11.75	+1.02
i	13.05	12.01	+1.04
k	13.09	11.79	+1.30
n	13.46	12.64	+0.82

8. Photoelectric Observations made at Bloemfontein by Ivan King in 1950

E 7

H	B	Y	C
A	6.80	6.52	+0.28
B	7.12	7.09	+0.03
C	7.20	7.34	-0.14
D	7.51	7.69	-0.18
E	7.76	7.91	-0.15
F	7.77	7.98	-0.21
G	7.98	8.03	-0.05
H	8.12	7.93	+0.19
I	8.32	8.31	+0.01
K	8.79	7.60	+1.19
L	8.78	8.91	-0.13
M	8.76	8.50	+0.26
N	8.96	7.84	+1.12
O	9.16	9.04	+0.12
P	9.21	9.20	+0.01
Q	9.27	9.07	+0.20
S	9.80	9.83	-0.03
T	9.89	8.99	+0.90
U	9.97	9.84	+0.13
W	10.51	10.38	+0.13
X	10.52	10.58	-0.06
Y	10.73	10.64	+0.09
Z	10.93	10.13	+0.80
a	11.22	10.82	+0.40
b	11.43	10.86	+0.57
c	11.42	10.36	+1.06
d	11.43	11.02	+0.41
e	11.86	11.78	+0.08
h	12.54	11.76	+0.78
i	12.79	12.35	+0.44
k	13.07	12.75	+0.32
m	13.75	12.41	+1.34

E 8

H	B	Y	C
A	7.86	7.69	+0.17
B	7.58	7.72	-0.14
C	7.26	6.48	+0.78
D	7.70	7.55	+0.15
E	7.69	6.55	+1.14
F	7.91	7.71	+0.20
G	8.30	7.97	+0.33
H	8.29	8.19	+0.10
I	8.54	8.58	-0.04
K	8.68	8.37	+0.31
L	8.84	7.82	+1.02
M	8.93	7.82	+1.11
N	9.30	8.30	+1.00
O	9.46	8.13	+1.33
P	9.53	9.22	+0.31
Q	9.79	9.39	+0.40
R	9.94	9.02	+0.92
S	10.56	9.52	+1.04
T	10.53	10.10	+0.43
U	10.72	9.95	+0.77
W	11.49	10.68	+0.81
X	11.56	11.21	+0.35
Y	11.72	11.37	+0.35
Z	12.21	11.74	+0.47
a	12.51	12.02	+0.49
b	12.44	11.90	+0.54
c	12.68	12.15	+0.53
d	12.82	12.63	+0.19
e	12.87	12.49	+0.38

E 9

H	B	Y	C
A	7.24	7.16	+0.08
B	7.06	6.66	+0.40
C	7.63	6.77	+0.86
D	7.62	7.15	+0.47
E	7.88	7.62	+0.26
F	7.91	7.91	0.00
G	8.39	8.14	+0.25
H	8.40	8.05	+0.35
I	8.97	8.45	+0.52
K	9.00	8.79	+0.21
L	9.07	8.83	+0.24
M	9.42	9.14	+0.28
N	9.43	9.25	+0.18
O	9.61	8.68	+0.93
P	9.87	8.84	+1.03
Q	10.13	9.21	+0.92
R	10.66	9.53	+1.13
S	10.87	9.56	+1.31
T	10.71	10.30	+0.41
U	11.10	10.63	+0.47
V	11.34	10.37	+0.97
W	11.43	9.80	+1.63
X	11.83	11.06	+0.77

9. Photoelectric Observations made at Pretoria by Irwin and Cox in 1950

H	B	Y	C	H	B	Y	C	H	B	Y	C
		E 1				E 7				E 9	
A	7.12	7.07	+0.05	A	6.87	6.74	+0.13	A	7.22	7.34	-0.12
B	7.54	7.88	-0.34	B	7.14	7.28	-0.14	B	7.09	6.86	+0.23
C	7.17	6.40	+0.77	C	7.29	7.54	-0.25	C	7.54	6.92	+0.62
D	7.59	7.03	+0.56	D	7.62	7.90	-0.28	D	7.60	7.30	+0.30
E	7.56	7.49	+0.07	E	7.89	8.14	-0.25	E	7.86	7.78	+0.08
F	8.03:	7.92	+0.11:	F	7.90	8.14	-0.24	F	7.89	8.10	-0.21
G	8.59:	8.41:	+0.18:	G	8.03	8.25	-0.22	G	8.39	8.31	+0.08
H	8.18:	7.08:	+1.10:	H	8.15	8.14	+0.01	H	8.38	8.21	+0.17
I	8.35	8.19	+0.16	I	8.40	8.55	-0.15	I	8.94	8.60	+0.34
K	8.81	8.67	+0.14	K	8.66	7.74	+0.92	K	8.99	8.97	+0.02
				L	8.90	9.15	-0.25	L	9.04	8.99	+0.05
				M	8.78	8.70	+0.08	M	9.41	9.31	+0.10
				N	8.84	7.98	+0.86	N	9.40	9.41	-0.01
				O	9.16	9.26	-0.10	O	9.51	8.84	+0.67
	E 4			P	9.23	9.43	-0.20	P	9.74	8.99	+0.75
A	6.40	5.85	+0.55	Q	9.29	9.28	+0.01	Q	10.01:	9.34:	+0.67:
B	7.29	7.48	-0.19	R	9.39	9.27	+0.12	R	10.48	9.61	+0.87
C	7.77	7.96	-0.19	S	9.85	10.05	-0.20	S	10.68	9.66	+1.02
D	7.56:	6.74:	+0.82:	T	9.83	9.17	+0.66	T	10.67:	10.46:	+0.21:
E	7.68	6.84	+0.84	U	9.98	10.04	-0.06	U	11.04	10.76	+0.28
F	7.90:	8.01:	-0.11:	V	10.32	10.08	+0.24	V	11.19	10.47	+0.72
H	8.44:	8.59:	-0.15:	W	10.53	10.60	-0.07	W	11.14:	9.86:	+1.28:
I	9.14:	9.20:	-0.06:	X	10.62	10.82	-0.20	X	11.75:	11.19:	+0.56:
K	9.25:	9.45:	-0.20:	Y	10.76	10.87	-0.11	Y	11.94	11.65	+0.29
L	9.42:	9.67:	-0.25:	Z	10.88	10.30	+0.58	Z	11.99	11.76	+0.23
N	9.29	8.09	+1.20	a	11.23	11.02	+0.21	a	12.03	11.52	+0.51
Y	11.73	11.52	+0.21	b	11.40	11.05	+0.35	b	12.23	11.82	+0.41
Z	12.16	11.60	+0.56	c	11.31	10.51	+0.80	c	12.54	12.30	+0.24
a	12.33	11.48	+0.85	d	11.42	11.21	+0.21	d	12.77	12.47	+0.30
b	12.42	12.27	+0.15	e	11.89	12.01	-0.12	e	12.81	12.48	+0.33
c	12.80	11.84	+0.96	f	12.04	12.05	-0.01	f	13.20	12.89	+0.31
d	13.00	12.64	+0.36	g	12.27	12.07	+0.20	g	13.35	12.73	+0.62
e	13.55	13.20	+0.35	h	12.47	11.97	+0.50	h	13.51	13.08	+0.43
f	13.70:	13.34:	+0.36:	i	12.79	12.62	+0.17	i	13.88	13.52	+0.36
g	13.85	13.57	+0.28	k	13.02	12.99	+0.03	k	14.24	13.99	+0.25
h	14.05	13.78	+0.27	l	13.47	12.56	+0.91	l	14.52	13.98	+0.54
i	14.30	13.76	+0.54	m	13.58	12.60	+0.98	m	14.72	14.24	+0.48
k	14.77	14.24	+0.53	n	13.95	13.09	+0.86	n	14.99	14.73	+0.26
l	15.06:	14.08:	+0.98:	o	14.14	12.95	+1.19	o	15.07	14.53	+0.54
m	15.13:	14.83:	+0.30:	p	14.09	13.29:	+0.80:	p	15.49:	14.89:	+0.60:
n	15.53:	15.04:	+0.49:	q	14.50	13.21	+1.29	q	15.56	15.22	+0.34
o	16.29	15.13	+1.16	r	14.74:	13.52	+1.22:	r	15.84	15.36	+0.48
				s	14.72:	14.36	+0.36:	s	15.78	15.57	+0.21
				u	15.41	15.13	+0.28				
				v	15.57	14.20	+1.37				
				w	15.80	15.35:	+0.45:				

10. Cape Observations with the Kirkwood Photoelectric Photometer

(1950 - 51)

Q	B	Y	C
	E 1		
1	7.56	7.72	-0.16
4	7.59	7.50	+0.09
6	8.03	7.92	+0.11
7	8.81	8.66	+0.15
10	8.63	8.42	+0.21
12	8.37	8.18	+0.19
16	10.12	9.82	+0.30
19	10.23	9.70	+0.53
20	10.36	9.91	+0.45
24	9.80	9.02	+0.78
33	9.05	7.90	+1.15
35	10.71	9.60	+1.11
44	11.31	10.95	+0.36
46	7.54	7.87	-0.33
	E 2		
1	8.71	8.85	-0.14
2	7.60	7.68	-0.08
3	9.70	9.71	-0.01
4	8.11	8.24	-0.13
5	7.58	7.61	-0.03
6	8.40	8.35	+0.05
7	9.06	8.99	+0.07
8	8.17	8.06	+0.11
9	8.66	8.63	+0.03
12	9.63	9.43	+0.20
13	9.15	9.04	+0.11
14	8.42	8.20	+0.22
15	8.73	8.54	+0.19
16	8.56	8.21	+0.35
17	8.71	8.43	+0.28
18	8.99	8.56	+0.43
19	9.28	9.10	+0.18
20	9.88	9.59	+0.29
21	10.04	9.75	+0.29
22	9.72	9.12	+0.60
25	9.93	9.32	+0.61
26	7.67	7.03	+0.64
27	7.73	6.95	+0.78
28	8.05	7.34	+0.71
29	7.99	6.85	+1.14
30	8.58	7.66	+0.92
33	9.22	8.16	+1.06
34	9.55	8.86	+0.69
35	10.24	9.51	+0.73
36	9.39	8.18	+1.21

Q	B	Y	C
	E 2 (cont)		
37	10.60	10.03	+0.57
38	10.92	9.81	+1.11
39	6.77	6.76	+0.01
40	6.96	6.04	+0.92
41	6.85	6.93	-0.08
42	6.61	6.67	-0.06
43	6.75	6.64	+0.11
44	7.12	6.85	+0.27
45	6.21	5.45	+0.76
46	11.00	10.54	+0.46
47	11.13	10.98	+0.15
48	7.31	6.69	+0.62
49	11.47	11.14	+0.33
50	11.58	11.02	+0.56
51	11.90	11.65	+0.25
52	7.32	7.39	-0.07
53	7.94	7.60	+0.34
54	10.93	10.68	+0.25
55	10.56	10.36	+0.20
56	10.64	10.00	+0.64
57	10.38	10.12	+0.26
58	10.34	9.67	+0.67
63	10.79	10.22	+0.57
64	5.05	4.98	+0.07
66	9.47	9.00	+0.47
67	11.62	10.94	+0.68
68	11.80	11.53	+0.27
	E 3		
1	7.72	8.07	-0.35
2	7.95	8.29	-0.34
3	7.28	7.57	-0.29
4	7.43	7.70	-0.27
5	7.93	8.07	-0.14
6	8.12	8.20	-0.08
7	8.16	8.41	-0.25
11	9.52	9.63	-0.11
12	9.57	9.69	-0.12
13	8.21	8.32	-0.11
15	7.34	7.43	-0.09
16	8.68	8.70	-0.02
17	9.47	9.53	-0.06
19	9.00	9.02	-0.02
20	8.45	8.33	+0.12
21	9.95	9.79	+0.16
25	9.88	9.59	+0.29
26	9.75	9.59	+0.16
28	9.88	9.51	+0.37
30	9.32	9.06	+0.26

Q	B	Y	C
	E 3 (cont)		
33	10.99	10.16	+0.83
34	10.42	9.80	+0.62
35	7.45	6.77	+0.68
37	8.01	7.26	+0.75
38	9.25	8.12	+1.13
39	9.36	8.66	+0.70
42	9.94	9.14	+0.80
44	10.66	9.51	+1.15
45	5.44	5.76	-0.32
46	6.98	7.35	-0.37
47	5.34	5.19	+0.15
48	6.69	6.56	+0.13
49	6.11	6.46	-0.35
50	6.25	6.64	-0.39
51	6.51	6.82	-0.31
52	5.97	6.23	-0.26
54	10.01	10.17	-0.16
55	10.46	10.68	-0.22
56	11.05	10.52	+0.53
57	11.13	10.95	+0.18
58	11.45	11.61	-0.16
59	11.51	11.39	+0.12
60	12.12	11.96	+0.16
61	12.07	11.31	+0.76
62	12.50	12.27	+0.23
63	12.25	11.65	+0.60
65	10.54	9.72	+0.82
66	10.70	10.62	+0.08
67	10.96	10.72	+0.24
68	11.26	11.04	+0.22
69	11.34	11.07	+0.27
70	11.50	11.38	+0.12
71	12.21	10.99	+1.22
72	11.88	10.92	+0.96
73	10.40	10.26	+0.14
75	10.48	10.01	+0.47
76	10.70	10.59	+0.11
77	8.99	8.60	+0.39
78	10.44	9.87	+0.57
82	10.19	10.22	-0.03
83	10.06	10.04	+0.02
84	10.76	10.91	-0.15
85	6.47	6.87	-0.40
88	7.03	7.43	-0.40
89	6.79	7.21	-0.42

10. Cape Observations with the Kirkwood Photoelectric Photometer

(1950 - 51)

Q	B	Y	C	Q	B	Y	C	Q	B	Y	C
	E 4				E 4 (cont.)				E 5 (cont.)		
3	7.74	7.96	-0.22	44	6.42	5.82	+0.60	23	8.82	8.43	+0.39
5	7.95	8.21	-0.26	48	10.54	10.63	-0.09	25	9.97	9.44	+0.53
6	8.19	8.38	-0.19	49	10.90	10.79	+0.11	27	7.49	6.71	+0.78
8	9.44	9.73	-0.29	50	11.00	10.80	+0.20	28	8.46	7.64	+0.82
10	7.35	7.49	-0.14	51	7.27	7.52	-0.25	31	9.92	9.17	+0.75
11	7.50	7.67	-0.17	63	8.84	8.90	-0.06	32	10.57	9.38	+1.19
13	7.93	8.03	-0.10	64	8.64	8.55	+0.09	34	9.88	8.67	+1.21
14	7.99	8.17	-0.18	67	10.86	9.97	+0.89	36	7.24	7.21	+0.03
15	8.19	8.46	-0.27	68	10.25	10.28	-0.03	39	7.00	6.71	+0.29
16	8.49	8.62	-0.13	71	11.22	11.07	+0.15	41	7.11	7.32	-0.21
18	9.17	9.24	-0.07	73	11.28	11.22	+0.06	44	9.95	10.04	-0.09
20	8.05	8.03	+0.02	74	11.52	11.51	+0.01	45	10.51	10.59	-0.08
21	9.61	9.59	+0.02	90	11.34	10.58	+0.76	46	10.97	10.66	+0.31
25	7.82	7.64	+0.18					47	11.25	10.89	+0.36
26	10.29	10.06	+0.23		E 5			49	10.81	9.47	+1.34
28	7.60	6.74	+0.86	1	7.65	7.96	-0.31	52	7.84	7.70	+0.14
29	7.71	6.82	+0.89	2	7.81	8.06	-0.25	53	8.05	7.31	+0.74
30	8.06	7.30	+0.76	6	8.50	8.56	-0.06	54	7.40	7.26	+0.14
31	9.42	8.62	+0.80	8	10.13	10.04	+0.09	61	10.64	9.57	+1.07
32	9.47	8.89	+0.58	10	8.94	8.89	+0.05	69	9.62	8.99	+0.63
33	9.60	8.94	+0.66	12	9.42	9.32	+0.10	72	9.41	9.00	+0.41
34	9.77	9.17	+0.60	16	8.18	7.90	+0.28	74	9.72	9.30	+0.42
36	10.32	9.56	+0.76	18	9.95	9.80	+0.15				
37	10.54	9.60	+0.94	20	7.87	7.58	+0.29				
38	9.35	8.04	+1.31	21	9.24	8.94	+0.30				

1 .Cape Observations made at Pretoria in 1951 with the Leiden Photoelectric Photometer

(Single observations only)

H	B	Y	C	H	B	Y	C	H	B	Y	C
	E 1				E 6				E 8		
S	11.33	10.94	+0.39	W	10.63	10.54	+0.09	S	10.49	9.64	+0.85
V	11.99	11.67	+0.32	a	11.29	11.04	+0.25	T	10.56	10.24	+0.32
Y	12.71	12.44	+0.27	b	11.64	10.85	+0.79	V	10.96	10.67	+0.29
Z	12.88	12.49	+0.39	c	12.08	10.87	+1.21	X	11.57	11.32	+0.25
a	13.07	12.73	+0.34	d	12.10	11.80	+0.30	a	12.51	12.15	+0.36
b	13.47	13.20	+0.27	e	12.38	12.06	+0.32	b	12.45	12.04	+0.41
d	13.99	13.44	+0.55	g	12.55	12.26	+0.29	c	12.66	12.27	+0.39
h	14.37	13.91	+0.46	h	12.74	11.87	+0.87	d	12.84	12.77	+0.07
i	14.53	13.86	+0.67	m	13.55	12.51	+1.04	e	12.78	12.38	+0.40
				o	13.98	12.95	+1.03	f	13.04	12.88	+0.16
				r	15.10	14.33	+0.77	h	13.72	13.37	+0.35
				s	15.27	14.69	+0.58	i	14.10	13.61	+0.49
								k	14.11	13.77	+0.34
								l	14.49	14.03	+0.46
								m	13.08	12.75	+0.33
								n	14.86	14.53	+0.33

13. Photoelectric Observations with the Radcliffe Reflector (1952)

Q	B	Y	C
	E 1		
3	9.56	9.54	+0.02
16	10.12	9.79	+0.33
17	10.19	9.87	+0.32
18	9.97	9.52	+0.45
19	10.25	9.73	+0.52
20	10.38	9.92	+0.46
27	10.07:	9.46:	+0.61:
35	10.72	9.73	+0.99
44	11.30	10.94	+0.36
48	11.85:	11.63:	+0.22:
	E 5		
8	10.12	9.96	+0.16
14	10.01	9.79	+0.22
18	9.96	9.75	+0.21
19	10.05	9.84	+0.21
26	10.31	9.99	+0.32
80	10.34	9.65	+0.69
	E 6		
1	9.88	10.04	−0.16
10	9.91	9.91	0.00
11	9.95:	9.99:	−0.04:
19	10.16	9.97	+0.19
32	10.48:	9.78:	+0.70:
34	10.75	10.25	+0.50
48	10.53	9.78	+0.75
49	10.57	10.48	+0.09
50	10.82	10.69	+0.13
54	11.23:	11.00:	+0.23:
55	11.63	10.91	+0.72
56	12.11	11.00	+1.11
57	12.06	11.79	+0.27
58	10.51	10.39	+0.12
59	10.93	10.13	+0.80
60	10.58	10.39	+0.19
61	11.28:	10.42:	+0.86:
72	10.20:	10.03:	+0.17:
b	12.25:	11.96:	+0.29:
f	12.48:	11.77:	+0.71:
g	12.51:	12.24:	+0.27:
h	12.69:	11.92:	+0.77:
i	13.00:	12.21:	+0.79:
[illegible]	13.01:	12.02:	+0.99:

Q	B	Y	C
	E 7		
7	9.81	9.89	−0.08
8	10.51	10.47	+0.04
15	9.96	9.91	+0.05
21	10.33	10.12	+0.21
27	10.31	10.05	+0.26
	10.24	9.97	+0.27
37	10.76	9.97	+0.79
38	10.75	9.94	+0.81
42	10.89	10.33	+0.56
52	10.52	10.64	−0.12
53	10.73	10.73	0.00
54	11.19	10.94	+0.25
55	11.41	11.04	+0.37
56	11.37	10.60	+0.77
57	11.42	11.16	+0.26
58	11.82:	11.86:	−0.04:
59	12.08:	12.00:	+0.08:
60	12.23:	11.97:	+0.26:
62	10.98	10.88	+0.10
63	11.49	11.26	+0.23
64	9.15:	8.61:	+0.54:
72	10.83	10.49	+0.34
h	12.50:	12.01:	+0.49:
i	12.80:	12.49:	+0.31:
k	13.06:	12.86:	+0.20:
	E 8		
23	10.52	10.22	+0.30
37		9.21:	
38	10.00	9.12	+0.88
39	10.49	9.71	+0.78
41	10.59	9.75	+0.84
46	10.70	10.11	+0.59
47	10.92	10.65	+0.27
48	11.46	10.85	+0.61
49	11.56	11.32	+0.24
50	11.74	11.49	+0.25
51	12.19:	11.88	+0.31
55	10.69	10.51	+0.18
57	11.29	10.13	+1.16
58	11.60	10.76	+0.84
59	11.49	10.75	+0.74
60	11.01	10.27	+0.74
68	10.95	10.55	+0.40
a	12.50	12.15	+0.35
b	12.44	12.05	+0.39
c	12.65	12.28	+0.37

Q	B	Y	C
	E 8 (contd.)		
d	12.81	12.70	+0.11
e	12.87	12.63	+0.24
f	13.00:	12.80:	+0.20:
	E 9		
2	10.59	10.69::	−0.10::
16	10.66	10.40	+0.26
22	10.62	10.35	+0.27
23	10.66::	10.40	+0.26
26	10.06	9.37	+0.69
27	10.58	9.70	+0.88
28	11.26	10.53	+0.73
34	10.29	9.52	+0.77
35	11.06	10.55	+0.51
36	11.37:	10.13:	+1.24:
38	10.77	9.77	+1.00
47	11.06	10.72	+0.34
51	11.77::	11.02::	+0.75
52	11.78	11.20	+0.58
53	11.96	11.60	+0.36
54	11.99	11.70	+0.29
55	11.34:	11.15	+0.19
a	12.07	11.52	+0.55
b	12.23	11.79	+0.44
c	12.58	12.27	+0.31
d	12.79	12.45	+0.34
e	12.86	12.48	+0.38
f	13.25:	12.87	+0.38:

14. Photoelectric Observations with the Victoria Telescope (1952)

Q	B	Y	C
	E 1		
1	7.56	7.73	-0.17
2	8.42	8.47	-0.05
3	9.49	9.66	-0.17
4	7.58	7.48	+0.10
6	8.03	7.89	+0.14
7	8.82	8.63	+0.19
8	9.10:	8.94:	+0.16:
9	8.47	8.20	+0.27
10	8.63	8.39	+0.24
12	8.38	8.15	+0.23
16	10.14	9.76	+0.38
17	10.22	9.88:	+0.34:
18	10.01:	9.48:	+0.53:
19	10.30	9.66	+0.64
20	10.43	9.85	+0.58
30	7.65	6.57	+1.08
31	7.99:	6.95	+1.04:
33	9.18	7.77	+1.41
34	8.14	6.74	+1.40
35	10.83	9.46	+1.37
42	6.77	6.70	+0.07
43	7.12	7.04	+0.08
46	7.50	7.89	-0.39
47	6.94	6.91	+0.03
53	8.98:	8.78	+0.20:
54	9.32	9.09	+0.23
	E 2		
2	7.58	7.68	-0.10
4	8.09	8.24	-0.15
5	7.57	7.60	-0.03
6	8.40	8.34	+0.06
8	8.15	8.03	+0.12
10	8.26	8.04	+0.22
11	9.55:	9.31:	+0.24:
15	8.73	8.49	+0.24
17	8.73:	8.40:	+0.33:
20	9.87:	9.52:	+0.35:
23	9.35:	8.71:	+0.64:
24	9.95:	9.13:	+0.82:
30	8.66	7.55	+1.11
31	8.80	7.61	+1.19
37	10.65:	9.98:	+0.67:
6	10.97:	10.43:	+0.54:
7	11.17:	10.98:	+0.19:
	10.96:	10.66:	+0.30:
	9.38:	8.63:	+0.75:
	E 7		
12	9.14	9.23	-0.09
13	9.19:	9.40:	-0.21:
14	9.24	9.25	-0.01
17	9.34	9.13	+0.21
21	10.31:	10.14:	+0.17:
31	9.86	9.08	+0.78
33	8.93	7.89:	+1.04:
38	10.71:	9.66:	+1.05:
	E 8		
1	7.53:	7.86:	-0.33:
2	7.62:	7.95:	-0.33:
4	9.09	9.28	-0.19
7	9.78	9.94	-0.16
15	8.34	8.11	+0.23
17	9.37	9.17	+0.20
18	9.54	9.35	+0.19
19	9.79	9.50	+0.29
21	9.18	8.85	+0.33
23	(10.54)	(10.22)	+0.32
35	9.29	8.37	+0.92
36	9.52	8.59	+0.93
37	9.92	9.09	+0.83
38	10.04	8.94	+1.10
39	10.50	9.55	+0.95
40	9.41	8.13	+1.28
41	10.62	9.55	+1.07
46	10.71	10.02	+0.69
47	10.92	10.64:	+0.28:
55	10.71	10.54	+0.17
56	9.71	8.93	+0.78
57	11.28:	9.79	+1.49:
60	11.06:	10.15:	+0.91:
	E 9		
1	7.88	8.10	-0.22
2	10.56	10.90	-0.34
3	9.36	9.36	0.00
4	9.03	8.95	+0.08
5	7.86	7.75	+0.11
	E 9 (contd.)		
6	8.96	8.92	+0.04
7	7.69	7.56	+0.13
8	8.38	8.27	+0.11
9	9.39	9.24	+0.15
10	8.17	8.05	+0.12
11	8.37	8.16	+0.21
12	8.90	8.72	+0.18
14	9.73	9.44	+0.29
16	10.67	10.43	+0.24
22	10.66	10.40	+0.26
23	10.67	10.39	+0.28
26	10.08	9.23	+0.85
27	10.59	9.50	+1.09
28	11.30	10.39	+0.91
32	9.04	7.92	+1.12
33	9.83	8.87	+0.96
34	10.30	9.37	+0.93
35	11.08	10.49	+0.59
36	(11.38)	(9.73)	+1.65
37	9.57	8.72	+0.85
38	10.82	9.51	+1.31
45	7.17:	7.30:	-0.13:
46	7.21:	7.34:	-0.13:
47	11.08	10.71	+0.37
50	8.75	8.48	+0.27
56	9.28	8.36	+0.92
59	10.59	9.39	+1.20
60	10.25	10.01	+0.24
61	9.79	9.64	+0.15
64	9.83	9.67	+0.16
69	8.33	7.80	+0.53

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MAGNITUDES OF BRIGHT STARS IN THE E REGIONS OBSERVED BY THE FABRY METHOD

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Summary

This paper describes the Fabry photometer attached to the Cape Astrographic Telescope and its use to determine photographic, photovisual and " blue " magnitudes of the brighter stars in the Harvard E Regions. 258 Pg, 209 Pv and 66 blue magnitudes have been determined with a standard error that does not normally exceed $\pm 0^{m}{\cdot}007$. The scale was fixed by means of rotating sectors. Most of the stars are brighter than 8·3 Pg or 7·5 Pv. The systematic errors affecting the method are carefully discussed and their effect found to be less than 0·01 mag. The accidental errors are analysed and the standard error of a single observation is found to be $\pm 0^{m}{\cdot}01$, excluding the effect of the sky. This is closely approached on the best nights.

The Fabry magnitudes have been compared with one another (Pg and blue) and with magnitudes obtained with the Cape Photometric Cameras. The Fabry colours have been compared with colours measured photoelectrically. The colour corrections are linear. The standard deviations are $\pm 0^{m}{\cdot}013$, $\pm 0^{m}{\cdot}025$ and $\pm 0^{m}{\cdot}033$ for the magnitudes and $\pm 0^{m}{\cdot}028$ for the colours. The corresponding external errors are $\pm 0^{m}{\cdot}009$, $\pm 0^{m}{\cdot}017$, $\pm 0^{m}{\cdot}024$ and $\pm 0^{m}{\cdot}024$. It is concluded that standard magnitudes should be determined with a precision of at least $\pm 0^{m}{\cdot}02$ but that there is not much to be gained by pressing the accuracy beyond $\pm 0^{m}{\cdot}01$. A final section discusses the relative merits of the photoelectric and Fabry methods.

Introduction.—The potentialities of the Fabry method for stellar photometry had already been demonstrated* when it was decided to adopt the method at the Cape Observatory, where the method has been made more effective by the introduction of rotating sectors. These serve as neutral filters to reduce the light of the stars by accurately known amounts and so limit the range in photographic density without any change in exposure time. The magnitude scale is no longer primarily dependent on the plate calibration curve, but on the constants of the rotating sectors.

The use of rotating sectors in photographic photometry has been questioned because of the well-known reciprocity failure of photographic emulsions, but experience has shown that rotating sectors give reliable results provided the speed of rotation is sufficiently high.

The Fabry method has several advantages over in-focus methods of stellar photometry. The images are large and uniform and their structure is virtually unaffected by seeing conditions, by small guiding errors or by the colours of the stars. The plates can be calibrated with a sensitometer, and if the light from the brighter stars is reduced by means of rotating sectors, the density of the

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* H. Grouiller, *Annales d'Astrophysique*, **2**, 418, 1939. E. G. Williams and H. Knox-Shaw, *M.N.*, **102**, 226, 1942. R. O. Redman, *M.N.*, **105**, 212, 1945. A. W. J. Cousins, *M.N.*, **103**, 154, 1943.

photographic images can be kept within a limited range on the steep part of the calibration curve.

The Fabry method is very suitable for setting up a magnitude scale because the latter is fixed by the constants of the rotating sectors and the sensitometer, both of which are dependent on geometrical measurements alone. The images vary so little in structure and density that there should be no risk of a change of colour equation with magnitude. Moreover, as the stars are observed individually, there are no complications due to distance corrections.

This paper gives an account of the observations that have been made with a Fabry photometer attached to the 13-inch Astrographic Refractor to determine the magnitudes of the brighter stars in the Harvard Standard (E) Regions at −45° declination. Three programmes provide photographic, photovisual and "blue" magnitudes. These latter are on the colour system of the Cape Bright Star* Programme which was started in 1945 and aims at providing accurate photographic magnitudes for all stars south of the Equator whose H.R. magnitudes are brighter than 5·0.

The photographic programme was commenced in 1947 to provide magnitudes for a sufficient number of stars to define the scale above the eighth magnitude and to include all stars brighter than 7·0 in an area 6° by 6° centred on each E region. Stars above $6^{\mathrm{m}}\cdot 8$ are too bright to be measured satisfactorily on the short-exposure plates taken with the photometric cameras as a separate part of the Cape E-region programme, but are needed to provide a link with the Bright Star observations.

The photovisual programme was started a few months later. It includes most of the stars in the photographic programme whose photovisual magnitudes are brighter than 7·6 and a few additional late-type stars too faint to be included in the photographic list. These magnitudes serve to fix the scale above magnitude 7·5. In conjunction with the photographic magnitudes, they provide the colour indices needed to convert one system of magnitudes to another.

The third programme is designed to provide standard stars for the Bright Star Programme. The original plan had been to observe these stars in series at equal altitudes, both east and west of the meridian, and build up a homogeneous system of magnitudes by means of stars common to several plates. This method did not prove satisfactory in practice because there is nearly always a progressive change in the atmospheric transparency during the night and frequently a difference from one azimuth to another. An obvious solution was to use standard stars located at intervals of R.A. round the sky, and the brighter stars in the E regions were chosen for the purpose because they would also provide a link with the fainter stars. As the Bright Stars are being observed with a blue filter these magnitudes differ from ordinary photographic magnitudes and colour corrections are needed to convert the one system to the other. The brightest stars in the E regions have been re-observed with the blue filter and a few selected from these serve as standards for the Bright Star Programme.

The Fabry method is now being used in conjunction with the Victoria Telescope to observe fainter stars. The practical limits with one-minute exposures are about 10·8 Pg and 9·3 Pv. Observations are being made to obtain magnitudes for stars whose parallax has been measured at the Cape, and to check the magnitude scales in the E regions to the limits given above.

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* Capital letters are used hereafter to differentiate between stars observed in this particular programme and bright stars in general.

Equipment and observing procedure.—The Fabry unit is constructed to take the place of a standard plate holder on the Astrographic Refractor and can be removed or replaced at will without interfering with the adjustments. The unit carries the Fabry lens, a simple plano-convex lens of about 8 mm. focus, adjusted to give a sharp image of the objective on the plate. Immediately in front of the lens is a diaphragm located in the focal plane of the telescope objective.

The small plate holder used with the unit is provided with cross motions. This permits a maximum of 216 images arranged in 9 rows of 24 in an area 20 mm. by 23 mm. In practice it is found preferable to leave a space between every pair of images, thus reducing the maximum number by one-third. Fig. 1, which is approximately to scale, shows the arrangement of the images on a photographic plate.

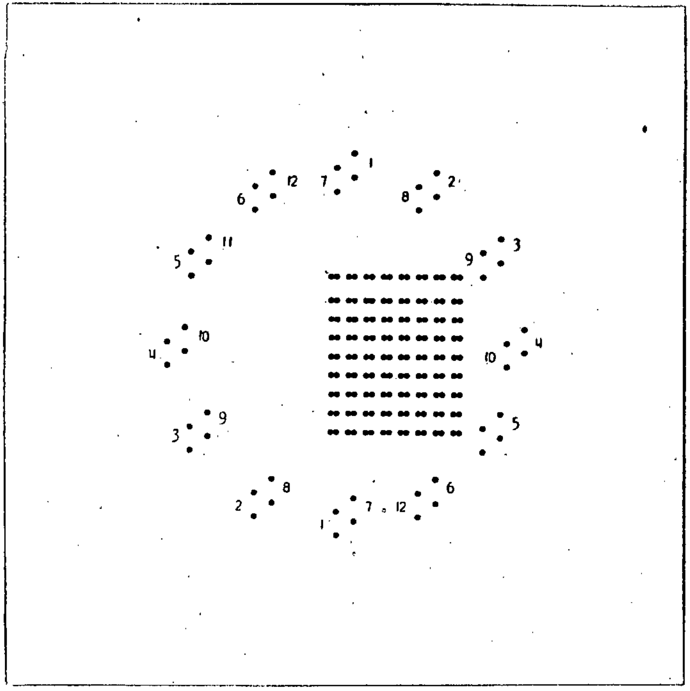

FIG. 1.—*Arrangement of images on* $3\frac{1}{4}\times 3\frac{1}{4}$ *inch photographic plate.*

A stepped rotating sector (see Fig. 2) driven by a small electric motor is mounted inside the telescope tube. It can be moved in and out to the desired position without disturbing the Fabry unit, and takes only a few seconds to change from one step to another. In earlier work a series of interchangeable sectors had been used and an appreciable time was spent in changing these between exposures. The stepped sector is designed with half-magnitude steps from 0 to 2·5. When very bright stars are observed, the original sectors with constants of 3, $3\frac{1}{2}$, 4 and 5 magnitudes still have to be used. The actual values of the constants have been computed from measurements made with a Hilger measuring machine. The 4 and 5 magnitude sectors have only one opening, but the others interrupt the light twice every revolution. The speed of the motor normally exceeds 3000 r.p.m.

Each plate was calibrated in a sensitometer, two exposures of one-minute duration being given before and two after the star observations.

In each region two (or sometimes three) stars, usually of spectral type F, were chosen as local standards and used as comparison stars. If these stars are designated A and B and the remainder a, b, c, d, e, etc., then the observing sequence would be: A a b B c d A e, etc.; every two observations of other stars being preceded and followed by an observation of one of the standards. This serves as a check on any drift in the zero point due to variations in the atmospheric transparency or unevenness of the plate. It was often necessary to use different standards for the stars of the different programmes.

Except for some of the fainter stars in the photovisual programme, each star was given two exposures of one-minute duration. This appears to be the most economical number of images per star with this equipment. From 15 to 20 stars, including the standards, could be observed per hour. Observations were restricted to one region at a time, but several regions were often observed on the same night.

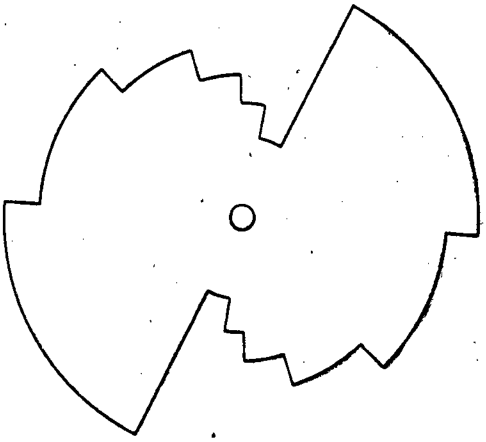

FIG. 2.—*Stepped sector.*

Routine observations were limited to the time during which a region was within 35° of the zenith. The risk of trouble from clouds, smoke, local haze and the loom from city lights increases rapidly at lower altitudes. The differential extinction between individual stars was in consequence always small and rarely exceeded $0^{\mathrm{m}}{\cdot}02$. The telescope was, however, fitted with a clinometer graduated to give the relative air-mass (sec z) directly and the reading was recorded for each star at the time of observation.

All plates were developed in M.Q. developer (ID—2 formula) without rocking or agitation of any kind. The Eberhard effect is easily seen, but there is little unevenness over the plate.

Sky light.—The diaphragm in front of the Fabry lens admits light from the sky as well as from the star being observed and from any other stars that happen to be sufficiently close. When companions were seen and could not be avoided by setting out of centre, the fact was recorded. Such stars are not suitable for standards, as the measured magnitude will depend on the photometric procedure. The effect of the sky light can and should be allowed for.

Since 1947 June routine observations of the brightness of the sky have been included in the photographic and photovisual programmes. This is not necessary for the Bright-Star observations as the effect is negligible. In order to obtain images of suitable density with an exposure of one minute, and so avoid complications due to different exposure times, a lens working near $f/1$ is required. For some months a common aspherical "bulls-eye" lens was used, but this was later replaced by a microscope condenser mounted so that it could be quickly interchanged with the regular Fabry lens. The effective relative speeds of the sky lens and the regular Fabry lens, with their respective diaphragms, were determined empirically with the help of rotating sectors and the inverse-square-law apparatus previously used for sector tests.*

Tests show that, for moderately small zenith distances, the brightness of the sky increases approximately as $\sec z$. It is therefore possible to reduce the results to the zenith. The mean photographic brightness was $12^{m}\cdot0$ per square minute of arc compared with a star reduced to the zenith. Values above $12^{m}\cdot2$ were rare; below $11^{m}\cdot8$ they were usually associated with a hazy sky. Observations made at the same time, but of different areas of the sky, usually agree within a few hundredths of a magnitude, indicating that the sampling error is small. Only in the case of the Milky Way region E7 (centre: $\lambda=312^{\circ}$, $\beta=-7^{\circ}$) were the measures systematically brighter by about $0^{m}\cdot1$. The Moon increases the brightness 45° away by about 1 magnitude at First Quarter and 3 magnitudes at Full Moon.

The photovisual brightness of the night sky is both brighter and more variable than the photographic. Values brighter than $11^{m}\cdot4$ and fainter than $11^{m}\cdot8$ per square minute of arc are not uncommon, but exceptional nights can usually be recognized from the appearance of the sky. The western sky is noticeably brighter than the eastern, due to the lights of Cape Town, and this is confirmed by the measures. No observations were made in bright moonlight, but photoelectric measures show that the colour index of the sky is then negative.

Measurement and reduction.—All plates were measured with the modified Schilt photometer. Two analysing diaphragms were used, with projected diameters of 0·24 and 0·32 mm. respectively. (The diameter of the Fabry images was about 0·8 mm.) With the smaller diaphragm the star and calibration images were trailed, but with the larger one they were measured centrally. There is no apparent difference in the accuracy and the latter method is quicker. Before taking a reading the plate was trailed about 1 mm. away from the images and the lamp rheostat adjusted to give a galvanometer deflection of 100·0 for the plate background. The reading of the galvanometer scale then gave the percentage transmission of the images directly. A plate with 200 images can be measured in three-quarters of an hour.

A calibration curve was plotted for each plate and used to convert the readings from the star images into magnitudes. These magnitudes were then corrected for the effect of the sector (if one had been used), the differential extinction to the zenith and the light of the night sky.

The extinction correction was computed from the formula: $m=-p(\sec z-1)$. The values assumed for p were 0·50 for the photographic and 0·25 for the photovisual observations. These values are only approximate and there are considerable variations from night to night. Should the actual value differ from the assumed one there will be an apparent change in the mean zero point of the region as the altitude changes. This cannot, in general, be distinguished from a progressive change in the atmospheric transparency, and no attempt was made to separate the two effects. The differential extinction between the stars in a region was

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* A. W. J. Cousins and R. H. Stoy, *M.N.*, **106**, 287, 1946.

always small and the error introduced by using the assumed coefficients can rarely have exceeded 0·01 magnitude.

The magnitudes were then reduced to a provisional system by means of the standard stars. There was nearly always a drift of the apparent zero point during the period of observation, due to variations in the transparency of the atmosphere and possibly also to photographic effects.

At a later stage, when a number of plates had been reduced for a given region and provisional magnitudes had been obtained for most of the stars, it was possible to re-examine the drift of zero point and determine the weight to be assigned to the observations. Unit weight was given when the average difference between the observations and the provisional mean magnitudes of the stars was $0^{m}\cdot01$. When several regions occur on a plate each was considered on its own merits.

It was considered desirable that a star should be observed on at least three different nights and have a minimum weight of 3. When the individual observations of a star were not in good agreement, additional observations were made, but only obviously discordant results were rejected. The final magnitudes are the weighted means of all the usable observations, with small adjustments to the zero point of each region to conform as closely as possible with the zero point determined by Stoy from plates taken with the photometric cameras.

Several attempts were made to determine the relative zero points by means of the Fabry method, either by direct comparisons between the E regions or by comparisons with σ Octantis. These showed a considerable amount of observing would be necessary to obtain definitive results. It should be noted that a single comparison in one direction without a return to the first region is of little value because of changes in the extinction; and that each comparison involves a reversal of the telescope to the other side of the pier. The weakness of the polar comparison lies in the low altitude of the pole (34°) at the Cape. The zero points are now being checked as part of the Bright Star Programme, both by direct inter-comparisons between the standard stars and by means of stars compared independently with two E regions. Preliminary results suggest that some small changes may be necessary. Colours, now being measured photoelectrically, will assist in checking the photovisual zero points. The use of the "S" magnitudes derived by Stoy for zero point determinations is justified by the fact that the initial purpose of the present series was to fix the scale for these magnitudes, but it is possible that errors of the order $0^{m}\cdot02$ may have been introduced, due to scale and zero point errors since Stoy's zero points were determined at about $9^{m}\cdot0$.

The photographic programme.—Unbacked Ilford Zenith plates without a colour filter were used for the photographic programme. A star of magnitude 7·7 gave an image of photographic density 0·3 with an exposure of one minute. The earlier observations were made with a diaphragm 2 mm. in diameter in front of the Fabry lens, but this was later replaced by one of half that aperture to reduce stray light from the sky background. It is possible that a still smaller one could be used, but this would have no practical advantage (except in bright moonlight) to compensate for the extra care needed in setting and guiding and the risk of trouble due to the chromatic aberration of the objective. With the present diaphragm bad definition has practically no effect on the observations, provided it is not accompanied by variations in transparency, but with a further reduction in aperture the photometer would not possess this immunity. On a dark night stars observed through the 1 mm. diaphragm need only small corrections, not exceeding $0^{m}\cdot03$, for sky light. Only some of the brighter stars were observed in moonlight, the corrections then being of the same order.

The plates were calibrated in a tube sensitometer for which the adopted constants, computed from the measured diameters of the apertures and the sequence of the tubes (see Fig. 1), are as follows:—

m	No.	m	No.	m	No.
0·00	5	0·97	6	1·96	7
0·27	8	1·34	9	2·26	1
0·51	11	1·52	12	2·50	10
0·71	2	1·71	3	2·66	4

The plate was moved 3 mm. between the first and second exposures and reversed for the third and fourth. This produced twelve compact groups of four spots arranged in a circle 5 cm. in diameter. A group containing two images from tube n also contained two from tube $n+6$ and vice versa. This reduces the errors due to unevenness of the plate. The lamp is fitted with a blue filter similar to that used for the Bright Star Programme.

Twenty-five plates of uniformly good quality would have been sufficient to complete this programme. The actual number taken was 87. Of the 3900 observations, 1100 received full weight. The average weight was 0·47.

The photovisual observations.—The Ilford H.P.3 plates used for the photovisual observations were taken from three batches, but the selective colour sensitivities were not noticeably different. The first batch was backed, the others not. The last batch was appreciably faster than the others and the reciprocity failure less.

A colour filter was fitted about an inch in front of the Fabry lens. For about a year a Zeiss Ikon II filter was used. This was then replaced by an Omag 301. Approximate transmission factors for these filters were measured with a monochromator and 1P21 photomultiplier tube. The change of filter produced a change in the colour system that can be expressed in the form

$$(\text{Zeiss Pv.} - \text{Omag Pv.}) = 0{\cdot}07(\text{Pg.} - \text{Omag Pv.}).$$

The second colour system is very near that obtained by Redman with an Ilford Delta filter and aluminized mirror.

The 2 mm. diaphragm was used for all the observations in the best compromise focus of the 13-inch objective (which is photographically corrected). This is about 8 mm. beyond the usual focus. A 1 mm. diaphragm would not pass all the light to which the plate and filter combination is sensitive. This meant that sky corrections as large as $0^{m}\cdot10$ were occasionally needed for the fainter stars with a poor sky. A few observations of the brighter stars were made with the Moon present.

The plates were calibrated with the slit sensitometer used for photovisual observations in Durban*, with an Ilford Gamma filter over the light source. The apparatus was adapted for use with plates and provided with a mask having two rows of twelve holes spaced at 2·5 mm. centres ($0^{m}\cdot25$ intervals). The spots are of similar size to the star images. The plate was rotated 90° between exposures, producing eight rows of spots arranged in pairs and bordering

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* A. W. J. Cousins, *M.N.*, **103**, 154, 1943.

a hollow square. The adjacent rows of a pair are graded in opposite directions to compensate for unevenness of the plate. Normally only four rows of spots (two pairs) were measured. The star images, arranged as on a photographic plate, lie within the square.

The H.P.3 plate and filter combination is more than a magnitude slower than a Zenith plate, a photographic density of 0·3 resulting from a $6^{m}\cdot2$ star with the early plates and Zeiss filter and a $6^{m}\cdot7$ star with the recent plates and Omag filter. In order to reach a $7^{m}\cdot5$ star it was necessary to give two-minute exposures. The same standard stars were used for these but with a sector $0^{m}\cdot5$ greater. A two-minute exposure was sufficient for the sky with the new plates (and filter) but four minutes were necessary with the earlier ones.

3260 observations were made to complete this programme and 950 received full weight. The average weight was 0·51—slightly higher than for the photographic programme. This is at least partly due to the better observing conditions in 1949. 67 plates were used.

The Bright Star standards.—Ilford Special Rapid plates and a blue filter are being used for the Bright Star Programme. The first observations were made on backed plates, but practically all those used for observing the standard stars were unbacked. In other respects the equipment and observing technique were the same as those used for the photographic programme. No sky corrections were required. 580 observations were made of the Bright Star standards, apart from their routine use in the Bright Star Programme. The average weight was 0·7.

Systematic accuracy.—A magnitude system is normally defined by stating the scale, colour equation and zero point relative to some standard system. The scale should be a normal Pogson scale, but the colour system and therefore the adopted zero point will depend on the method and conditions of observation. The system should be homogeneous throughout and there should be no variation in colour equation with magnitude. The relation to another system can be found only by direct comparison between the magnitudes of individual stars.

The scales of the present magnitude systems depend primarily on the rotating sectors and to a lesser extent on the sensitometer calibrations. In both cases the constants are computed from geometrical measurements and it is believed that they are accurate to within one per cent.

The constants of the rotating sectors have also been measured photoelectrically, using a 1P21 photo-multiplier tube with the inverse-square-law apparatus previously used to make similar measures photographically.* The lamp was used (*a*) bare, as for the photographic tests, (*b*) with a coarse ground-glass window and (*c*) with a flashed opal window. The last gives the most accurate results with the greatest loss of light. Small empirical corrections (averaging $0^{m}\cdot01$ and $0^{m}\cdot003$ per magnitude for (*a*) and (*b*) respectively) were applied when the first two arrangements were used. The response of the cell-galvanometer combination is sensibly linear. The measured values are given in Table I. The agreement between these and the values computed from the geometrical measurements is satisfactory.

Tests made with Ilford Zenith, H.P.3 and Special Rapid plates have shown that when these plates are used with rotating sectors the photographic effect of the rapidly flickering light is essentially the same as that produced by a steady

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* A. W. J. Cousins and R. H. Stoy, *M.N.*, **106**, 287, 1946.

light of the same average intensity. These tests can be considered conclusive within $0^{m}\cdot 01$ or $0^{m}\cdot 02$ over a range of three or four magnitudes.

The two sensitometers have been compared with one another, using similar blue filters. No difference in scale could be detected. The Fabry images and the sensitometer spots are of nearly the same size, so no errors are expected from this cause. When the measures of the spots are compared with the calibration curve the residuals are little if any larger than would be expected from a knowledge of the errors and give no reason to suspect the accuracy of the individual constants.

TABLE I

Measurements of Sector Constants

Stepped Sector

Step	Magnitude Reduction Geometrical Measures	Photoelectric Measures	Adopted Value
1	0·497	0·498	0·50
2	0·993	0·991	0·99
3	1·489	1·486	1·49
4	1·986	1·979	1·98
5	2·483	2·480	2·48

Original Sectors

Nominal Magnitude	Geometrical Measures	Photoelectric Measures	Adopted Value
1·0	1·002	0·998	1·00
1·5	1·502	1·502	1·50
2·0	1·999	1·997	2·00
2·5	2·500	2·495	2·50
3·0	2·989	2·983	2·99
3·5	3·435	3·432	3·43
4·0	4·009	4·008	4·01
5·0	4·852:	4·846:	4·85

Occasionally a star was observed with two different sectors in succession, permitting a comparison between the sectors and sensitometer. The following results were obtained with the tube sensitometer and Zenith plates :—

Sectors used	$0^{m}\cdot 5$–$0^{m}\cdot 0$	$1^{m}\cdot 0$–$0^{m}\cdot 5$	All others
No. of comparisons	22	42	38
Average difference	$-0^{m}\cdot 001$	$+0^{m}\cdot 005$	$+0^{m}\cdot 003$
Standard error	$\pm 0^{m}\cdot 006$	$\pm 0^{m}\cdot 004$	$\pm 0^{m}\cdot 004$

The mean of 76 similar comparisons using H.P.3 plates and the slit sensitometer is $+0^{m}\cdot 011 \pm 0^{m}\cdot 002$ for a half-magnitude difference. This difference, though small, may be real and possibly due to a change in plate characteristic with wave-length. A change from the Ilford Gamma to the blue filter produced an apparent change of scale of 6 per cent with these plates. On the other hand the Zenith plates showed no difference in the calibration curve when the blue filter was omitted. If the calibration of the photovisual plates is in error by 2 per cent this may have affected individual magnitudes by $0^{m}\cdot 01$ but should not have introduced any scale error, since the scale is mainly dependent on the rotating sectors. An error of $+0^{\mathrm{m}}{\cdot}01$ is possible at and below $7^{\mathrm{m}}{\cdot}0$ due to the effect of selection. It is intended to re-observe these stars with the 18-inch visual component of the Victoria Telescope.

No direct evidence of the homogeneity of the present magnitude systems is available. Comparisons with other systems are given in a later section. A comparison between the results from a number of individual photographic plates and the mean magnitudes shows that there is little change in colour equation from night to night and that differences greater than 1 per cent are rare. Changes in the atmosphere might account for these.

Errors of observation.—The accidental errors of observation are due partly to the method and partly to the sky. They vary from night to night and even from region to region on the same plate. The best observations have a standard error of $\pm 0^{\mathrm{m}}{\cdot}01$.

The average standard error attributed to the sky for all the observations under discussion is $\pm 0^{\mathrm{m}}{\cdot}013$. On the best nights (of which there are about two per month, on the average, at the Cape) the sky error is less than $\pm 0^{\mathrm{m}}{\cdot}010$. The average value obviously depends on the observer's choice of nights. There is inevitably a compromise between the ideal of working only on the best nights and the desire to complete a programme in a reasonable time.

The errors due to the method are predominantly due to the photographic plate, its measurement and reduction. They vary according to the density of the images and somewhat from plate to plate but an estimate of their size under actual conditions can be made from the measures themselves. The errors have been analysed under a number of different heads:—

(*a*) The measuring errors.
(*b*) The intrinsic errors.
(*c*) Calibration curve errors.
(*d*) Timing errors.

The results are given in Table II.

TABLE II

Accidental Standard Errors of Method.

Ilford Plates used	Zenith	H.P.3	Special Rapid
	m	m	m
Measuring error	±0·006	±0·005	±0·004
Error due to background setting	0·006	(0·003)	0·002
Intrinsic error	0·009	0·012	0·006
Error of calibration	0·005	0·007	0·005
Error of timing exposure	0·004	0·004	0·004
Combined error for pair of images	0·011	0·012	0·008

(*a*) *The measuring errors.*—Two errors arise in measuring a plate: an error made in adjusting the reading for the plate background and an error in measuring the density of each image. These are due partly to errors in setting and reading the Schilt photometer and partly to sampling effects. It is generally accepted that the exposed portion of a plate should be measured relative to the unexposed background in preference to making absolute measurements of the transmission of the image. This procedure obviates the necessity for a separate check on the constancy of the light source, but it introduces an error due to random variations in the plate background. It would appear that either procedure could have been used with the present plates with little or no change in the accuracy.

The measuring and background errors can be obtained by re-measuring plates. Normally one background reading serves for the two adjacent images of each star. The measured percentage difference between the two nearly equal images of a pair is independent of errors in the background setting (to a first order of accuracy) while the actual (or average) percentages are not. If D_{a1} and D_{b1}, D_{a2} and D_{b2} are two sets of measures of images a and b, and ϵ_m and ϵ_b are standard errors of measurement and background setting respectively, then

$$\overline{[(D_{a1}-D_{b1})-(D_{a2}-D_{b2})]^2}=4\epsilon_m^2$$

and

$$\overline{[(D_{a1}+D_{b1})-(D_{a2}+D_{b2})]^2}=4\epsilon_m^2+8\epsilon_b^2,$$

where ϵ_m and ϵ_b are in units of 1 per cent deflection but can be converted into magnitude differences by means of the calibration curves.

The measuring errors, ϵ_m (in magnitudes) for the three brands of plates used are $\pm 0^{\mathrm{m}}{\cdot}006$ (Zenith), $\pm 0^{\mathrm{m}}{\cdot}005$ (H.P.3) and $\pm 0^{\mathrm{m}}{\cdot}004$ (Special Rapid). The corresponding values of the background errors, ϵ_b, for Zenith and Special Rapid plates are $\pm 0^{\mathrm{m}}{\cdot}006$ and $\pm 0^{\mathrm{m}}{\cdot}002$. Two independent attempts to obtain ϵ_b for H.P.3 plates by this method of differences led to values sensibly zero.

An alternative method of estimating ϵ_b is to measure the background variations. Typical plates were measured at intervals of about 2 mm., using the larger diaphragm in the photometer. The average difference between successive readings (in units of 1 per cent deflection) is a measure of the background variation and the effect of these variations on the measures of an image can be computed with the aid of the plate calibration curves. Standard errors, computed for images of 50 per cent transmission, are as follows:—

Ilford Plate	Zenith	H.P.3	Special Rapid
Plate stationary	$\pm 0^{\mathrm{m}}{\cdot}008$	$\pm 0^{\mathrm{m}}{\cdot}007$	$\pm 0^{\mathrm{m}}{\cdot}003$
Plate trailed	$0^{\mathrm{m}}{\cdot}005$	$0^{\mathrm{m}}{\cdot}003$	$0^{\mathrm{m}}{\cdot}003$

(*b*) *The intrinsic errors.*—By intrinsic error is meant the departure from equality of equally exposed images. It is purely a photographic effect and depends on the density and separation of the images and the area integrated by the photometer. When expressed as a percentage of full-scale deflection it is smallest for very dense images, but owing to the slope of the characteristic curve the minimum expressed in magnitudes occurs in the neighbourhood of 30 per cent transmission. When the images are widely separated the errors are larger than when they are close. Unevenness of the sensitivity or development of the plate gives rise to "local errors"* even when the plates are fresh.

An estimate of the intrinsic error can be obtained from the sensitometer spots since the relative intensities of the twelve spots are fixed by the constants of the sensitometer and only the zero point varies from exposure to exposure. The values given in Table II are based on images between 25 per cent and 75 per cent transmission and about 3 mm. apart when measured with the larger diaphragm in the photometer. The value of the measuring error previously determined was assumed in each case. No background error is involved, as the same setting is used for both the images. The local error may amount to $0^{\mathrm{m}}{\cdot}01$ over a distance of 5 cm. on a Zenith plate.

(*c*) *Calibration curve errors.*—Errors arise from the plotting and reading of the calibration curves. These curves are based on the measures of images that

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* G. de Vaucouleurs, *Publ. Obs. Houga*, No. 10, 1944.

are subject to appreciable local errors, only partly removed in the mean. The average error of a normal point based on the measures of four spots is $0^m \cdot 01$. Special care was taken to draw the curves as smoothly as possible, giving due weight to all the points. The errors given, which include that of reading the graph, are based on the differences between the calibration curves of plates developed together but measured and plotted independently.

(*d*) *Timing error.*—The timing error quoted, which is equivalent to an average error of 0·25 sec. per minute, is added for completeness but contributes little to the errors of observation.

It is clear that a plate can only attain unit weight (s.e. $\pm 0^m \cdot 015$) if the errors from other sources are small, and there are apparently few nights when the sky above the Cape Observatory is good enough for this. Slow and gradual changes in the transparency are not objectionable as they can be allowed for by a change in zero point, but rapid changes are generally irregular.

The finer grain and clearer background of the Special Rapid plate give it a distinct advantage over the faster plates, as shown by the larger proportion gaining unit weight (42 per cent compared with 28 per cent for Zenith and 29 per cent for H.P.3).

Results.—The detailed results are not given here. They will be published at a later date together with the magnitudes of fainter stars, but may be obtained in mimeographed form on application to the Cape Observatory. Some small adjustments in zero point from region to region may still be necessary.

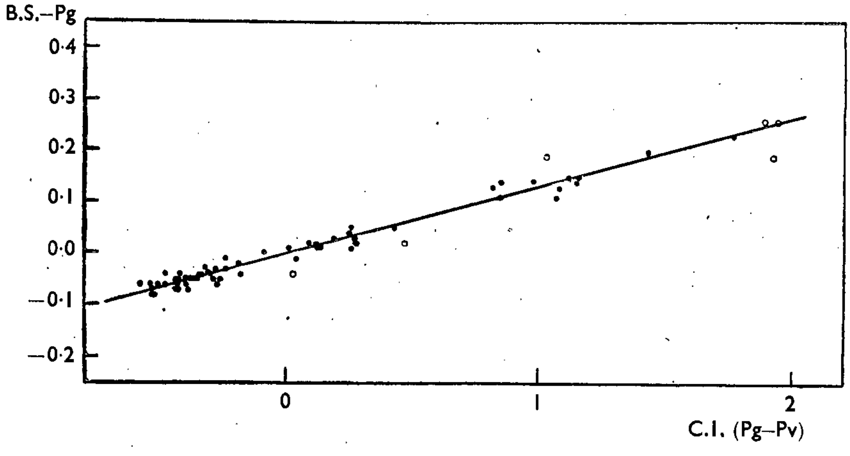

FIG. 3.—*Colour relation between photographic and bright-star magnitudes.*

The average weight per star, excluding the local standards, is 5 for both the photographic and photovisual series, corresponding to a standard error of $\pm 0^m \cdot 006$. The error deduced from the internal consistency of the observations of each star exceeds $\pm 0^m \cdot 007$ in 13 cases, but only 6 of these (4 Pg and 2 Pv exceed $\pm 0^m \cdot 008$. These latter stars, and four others for which the observations indicated an internal standard error for unit weight of $\pm 0^m \cdot 020$ or greater, include two of spectral type Mb that are probably slightly variable, 5 with Pg magnitudes fainter than 7·9, and one that was difficult because of a nearby companion. Faint stars are liable to larger accidental errors because the images are weaker than the optimum, but the possibility of slight variability cannot be overlooked. There is no obvious explanation for the remaining two stars (of spectral types A0 and F2), for which the discordance is noted in one colour only.

Table III gives a comparison between the magnitudes of Bright Stars obtained with the blue filter and equivalent magnitudes derived from the photographic and photovisual series by means of a colour coefficient.

The first column (Table III) gives the number in the *Cape Zone Catalogue* for 1900; the second the spectral type from the *Henry Draper Catalogue* and the third the revised type (when available) from the *Publications of Lick Observatory*, Vol. XVIII. The fourth, sixth and eighth columns contain the colour index (=Pg–Pv), and the photographic and Bright Star magnitudes as observed by the Fabry method. The ninth column gives the differences in the sense B.S.–Pg. These differences are plotted against C.I. in Fig. 3. They can be well represented by the straight line:—

$$\text{B.S.}-\text{Pg}=0{\cdot}132\ \text{C.I.}$$

The seventh column in the table, Pg′, gives the magnitude obtained by adding the colour correction computed with this formula to the observed photographic magnitudes in the preceding column. The tenth column gives the residuals B.S.–Pg′.

Table III

C.Z.C.	Spectral Type		C.I.		Magnitudes			B.S.–Pg	B.S.–Pg′	C.F.–C.Pe
	H.D.	Lick	Fabry	Pe	Pg	Pg′	B.S.		m.×100	m.×100
500	K0	G4	+0·85	+0·65	4·11	4·22	4·22	+0·11	0	+3
510	A3	...	−0·09		5·21	5·20	5·21	0·00	+1	
577	G0	G0	+0·43	+0·37	5·38	5·44	5·43	+0·05	−1	−2
652	K0	G8	+1·07		6·39	6·53	6·50	+0·11	−3	
680	K5	M1	+1·77		4·99	5·22	5·22	+0·23	0	
703	K0	G4	+0·98	+0·76	4·84	4·97	4·98	+0·14	+1	+1
707	A0	...	−0·19		6·07	6·04	6·05	−0·02	+1	
2092	F0	...	+0·13	+0·15	5·10	5·12	5·11	+0·01	−1	−2
2120	K0	K1	+1·15	+0·88	4·89	5·04	5·03	+0·14	−1	+2
2147	F5	...	+0·09	+0·12	4·40	4·41	4·42	+0·02	+1	−2
2168	K0	K2	+1·12	+0·85	6·33	6·48	6·48	+0·15	0	+3
3572	B9	...	−0·35	−0·25	5·51	5·46	5·47	−0·04	+1	+4
3736	B5	...	−0·48		6·49	6·43	6·43	−0·06	0	
3742	B8	...	−0·42	−0·27	2·87	2·81	2·83	−0·04	+2	−1
3770	K0	G7	+0·82	+0·66	5·67	5·78	5·80	+0·13	+2	−2
3806	B8	...	−0·44		6·31	6·25	6·24	−0·07	−1	
3933	F2	F4s	+0·26	+0·28	5·43	5·47	5·45	+0·02	−2	−2
3978	B9	...	−0·40		6·16	6·11	6·10	−0·06	−1	
4077	A0	...	−0·28	−0·15	6·03	5·99	6·00	−0·03	+1	−3
7024	K5	cK4	+1·94	+1·31	3·90	4·16	4·16	+0·26	0*	
7091	B5	B3	+0·03	+0·01	5·01	5·01	4·97	−0·04	−4*	
7103	B3	(B3s)	−0·53	−0·38	5·35	5·28	5·27	−0·08	−1	+3
7119	B8	(B8nn)	−0·39	−0·30	5·25	5·20	5·18	−0·07	−2	+6
7132	B9	...	−0·31	−0·20	5·69	5·65	5·65	−0·04	0	+1
7142	B5	...	−0·43	−0·28	5·51	5·45	5·46	−0·05	+1	0

TABLE III (*contd.*)

C.Z.C.	Spectral Type		C.I.		Magnitudes			B.S.−Pg	B.S.−Pg′	C.F.−C.Pe
	H.D.	Lick	Fabry	Pe	Pg	Pg′	B.S.		m.×100	m.×100
7145	B3	(B5n)	−0·43	−0·32	4·89	4·83	4·83	−0·06	0	+5
7171	A0	...	−0·36	−0·22	5·98	5·93	5·93	−0·05	0	−1
7327	B5	...	−0·48	−0·25	5·89	5·83	5·85	−0·04	+2	−9
7333	B9	...	−0·40	−0·24	5·90	5·85	5·85	−0·05	0	−3
9812	B8	...	−0·43	−0·28	4·95	4·89	4·90	−0·05	+1	0
9884	K0	K4	+1·43	+1·10	5·72	5·91	5·92	+0·20	+1	0
10051	F0	F5	+0·26	+0·23	5·41	5·44	5·42	+0·01	−2	0
10111	A0	...	−0·26	−0·16	5·17	5·14	5·12	−0·05	−2	+1
10121	A2	...	+0·04	+0·06	5·85	5·86	5·84	−0·01	−2	+1
12297	B3	B3	−0·51	−0·32	4·16	4·09	4·10	−0·06	+1	−3
12300	F8	F1	+0·27	+0·22	4·62	4·66	4·65	+0·03	−1	+2
12309	A3	...	+0·12	+0·15	5·98	6·00	6·00	+0·02	0	−3
12353	B9	...	−0·36	−0·23	5·24	5·19	5·19	−0·05	0	0
12445	B3p A2p	B3ne	−0·52	−0·34	1·94	1·87	1·86	−0·08	−1	−1
12549	B2	B2s	−0·53	−0·35	1·89	1·82	1·82	−0·07	0	−1
12618	A0	...	−0·18	−0·10	5·66	5·64	5·62	−0·04	−2	0
12713	B5	B6	−0·43	−0·33	4·00	3·94	3·93	−0·07	−1	+6
12780	B9	(B9)	−0·32	−0·20	5·42	5·38	5·39	−0·03	+1	0
12813	B2p	B3n	−0·58	−0·35	2·23	2·15	2·17	−0·06	+2	−6
12828	B3	B2s	−0·54	−0·36	2·71	2·64	2·65	−0·06	+1	−1
12915	B5	B5n	−0·43	−0·31	3·57	3·51	3·50	−0·07	−1	+4
15844	G5	G2	+0·85	−0·70	5·85	5·96	5·99	+0·14	+3	−4
15868	F2	A7n	+0·25	+0·23	3·61	3·64	3·65	+0·04	+1	−1
15997	B9	...	−0·29	−0·18	5·58	5·54	5·53	−0·05	−1	0
16087	B3p	B3nne	−0·38	−0·26	4·92	4·87	4·87	−0·05	0	+2
16121	B8	...	−0·34	−0·21	4·89	4·85	4·85	−0·04	0	−1
16195	B9	(B9)	−0·31	−0·20	5·07	5·03	5·03	−0·04	0	+1
16407	A0	...	−0·27	−0·17	4·42	4·38	4·36	−0·06	−2	+1
16458	F0	cF1	+0·26	+0·22	2·16	2·19	2·21	+0·05	+2	+1
16476	B9	...	−0·31	−0·20	5·89	5·85	5·85	−0·04	0	+1
16540	A0	...	−0·24	−0·13	5·64	5·61	5·61	−0·03	0	−2
18469	K0	...	+1·16	+0·88	5·14	5·29	5·29	+0·15	0	+3
18533	A5	...	+0·13	+0·13	5·93	5·95	5·94	+0·01	−1	+1
18762	A0	...	−0·24	−0·11	5·40	5·37	5·39	−0·01	+2	−4
18771	A3	...	+0·01	+0·05	5·68	5·68	5·69	+0·01	+1	−1
19883	F0	...	+0·19	+0·21	5·83	5·86	5·86	+0·03	0	−4
19939	G5	G2	+1·03	+0·81	4·91	5·05	5·10	+0·19	+5*	
19946	Mb	M4	+1·92		5·80	6·05	5·99	+0·19	−6*	
20067	G0	...	+0·47	+0·40	6·43	6·49	6·45	+0·02	−4*	
20068	Mb	M6	+1·89		3·73	3·98	3·99	+0·26	+1*	
20077	K0	G5	+1·08	+0·79	5·82	5·96	5·95	+0·13	−1	+7

* These stars appear to be slightly variable on the evidence of the Bright Star Programme. The observed range is $0^{\mathrm{m}}{\cdot}10$ for C.Z.C. 19946 and 20067; somewhat more for C.Z.C. 20068 and less for the other stars. The variation of C.Z.C. 20068 was noted in the photographic observations, but none of the other stars attracted attention in either the photovisual or the photographic series.

CAPE MIMEOGRAM

No. 2.

A FINDING LIST FOR THE STANDARD STARS IN THE E REGIONS

Royal Observatory
Cape of Good Hope

June 1953

A Finding List for the Standard Stars in the E Regions

The general scheme of the Harvard Standard Regions is described in H.A. 14, 477, 1885 and H.A. 71, 27, 233, 1917. The identification and coordinates of the lettered sequence stars in the E regions will be found in H.A. 71, pages 293 - 302. The pages that follow give the identification of the Cape "Q" numbers which were first assigned in 1944. Approximately the first forty stars in each region were chosen for use as standards in the reduction of the photographic observations of the magnitudes of stars in the southern A.G. zones. Others were added later; these include some of the remaining Harvard sequence stars, most of the bright stars in the region and a number of stars whose parallaxes have been determined at the Cape.

The positions given in the main tables are for 1950.0. The third column gives the number in the Henry Draper Catalogue and the fourth the number in the Cape Astrographic Zone Catalogues, an f in front denoting that the number is from the second or faint star catalogue.

E	R.A. (1900.0)		S. Dec.		pα	pδ	R.A. (1950.0)		S. Dec.		λ	β
	h	m	°	'	s	"	h	m	°	'	°	°
1	1	20	45	00	+2.62	+18.84	1	22	44	44	248	-71
2	4	00	45	00	+1.91	+10.02	4	02	44	52	158	-35
3	6	40	45	00	+1.76	- 3.48	6	01	45	03	221	-19
4	9	20	45	00	+2.21	-15.36	9	22	45	13	237	+ 4
5	12	00	45	00	+3.07	-20.04	12	03	45	17	263	+16
6	14	40	45	00	+3.93	-15.36	14	43	45	13	291	+12
7	17	20	45	00	+4.40	- 3.48	17	24	45	03	312	- 7
8	20	00	45	00	+4.23	+10.02	20	04	44	52	322	-33
9	22	40	45	00	+3.51	+18.84	22	43	44	44	316	-61

Cape Numbers corresponding to Harvard Letters

H.L.	E 1	2	3	4	5	6	7	8	9
A	43	44	15	44	41	41	48	8	46
B	46	5		51	39		46	2	42
C	41	2	3	3	27	42	50	26	29
D	21	27	4	28	1	51	2	11	17
E	4	28	1	29	2	44	3	28	5
F	6	4	2	13	20	52	1	9	1
G	10	14	6	14	16	2	4	15	8
H	32	30	16	16	6	6	16	6	11
I	12	16	19	18	13	20	5	3	19
K	7	1	38	7	10	22	32	16	6
L	33	15	30	8	12	25	6	33	4
M	3	17	39	17	34	8	11	34	9
N	24	18	26	38	44	9	33	35	3
O	16	19	25	33	8	15	12	40	37
P	19	36	28	9	32	16	13	18	33
Q	20	34	54	52	45	26	14	19	26
R	35	22	55	26	49	17	17	37	27
S	44	20	34	37	46	1	7	39	38
T	45	25	33	48	47	11	31	23	23
U	48	35	56	49	48	19	15	46	47
V	49	37	57	50	56	32	27	47	28
W	50	54	58	53	57	49	8	48	36
X	51	46	59	54	58	48	52	49	52
Y		47	60	55	59	34	53	50	53
Z		49	61	56	60	50	42	51	54
a		50	62	57		54	54		
b			63	58		55	55		
c			64	59		56	56		
d				60		57	57		
e							58		
f							59		
g							60		

E 1

Q	H	HD	CZC	α	δ		Q	H	HD	CZC	α	δ
				1^h	-						1^h	-
1		8977	677	25^m27^s	$46^\circ24'$		51	X			21^m19^s	$44^\circ29'$
2		8382	637	20 01	46 29		52		8024	605	16 40	46 25
3	M	8147	618	17 50	45 43		53		8050	609	16 58	46 53
4	E	8305	632	19 20	45 24		54		8488	641	21 02	43 24
5		7040	528	07 50	44 46		55					
6	F	9404	705	29 21	44 54		56		7498	568	12 11	42 09
7	K	7972	602	16 10	44 27		57			f380	19 10	41 54
8		7533	573	12 28	45 32		58		10513	793	39 27	45 39
9		9403	706	29 23	44 06		59			f331	09 08	43 42
10	G	7581	578	12 57	44 53		60			f464	37 37	46 45
11			f450	35 51	43 46		61		6595	500	03 51	46 59
12	I	10190	773	36 35	44 51		62		9053	680	26 11	43 34
13		10069	759	35 19	45 56		63		9362	703	29 09	49 20
14		9361	701	29 02	46 38		64		10553	795	39 42	50 18
15		7261	549	09 55	44 46							
16	O	8340	634	19 42	44 55							
17		8962	675	25 21	44 11							
18		9029	679	25 57	45 20							
19	P	8843	f400	24 07	44 57							
20	Q	8501	643	21 06	44 56							
21	D	9733	738	32 13	45 57							
22		7886	594	15 33	46 26							
23		8049	610	17 02	43 53							
24	N	8023	606	16 43	45 12							
25			572	12 20	44 44							
26		9619	726	31 17	44 09							
27		9183	690	27 25	45 04							
28		9694	733	31 52	44 40							
29		9662	730	31 44	44 37							
30		7706	582	13 58	42 16							
31		10121	764	35 58	46 21							
32	H	8963	676	25 20	46 06							
33	L	8663	651	22 24	45 59							
34		8001	604	16 31	43 36							
35	R	8362		19 51	44 41							
36		7570	577	12 53	45 48							
37		6767	510	05 31	41 45							
38		8651	652	22 28	41 45							
39		9184	691	27 23	47 00							
40		9414	707	29 32	45 49							
41	C	8681	655	22 31	44 47							
42		10167	768	36 23	43 11							
43	A	8391	638	20 12	43 52							
44	S			22 02	44 42							
45	T			22 44	45 12							
46	B	7795	589	14 47	42 48							
47		6869	515	06 20	46 56							
48	U			22 22	44 31							
49	V			22 47	44 54							
50	W			20 45	44 26							

E 2

Q	H	HD	CZC	α	δ
				h 3/4	-
1	K	25714	2013	01^{m}11^s	44°26'
2	C	25843	2023	02 09	44 52
3		26273	2059	05 47	44 08
4	F	25653	2007	00 39	44 48
5	B	26074	2040	04 00	45 48
6		26352	2061	06 33	42 59
7		26375	2068	06 38	45 21
8		24406	1902	49 25	44 31
9		26854	2107	11 08	44 48
10		25169	1968	56 18	46 31
11		24200	1881	47 41	44 56
12		26731	2094	10 03	44 45
13		27054	2131	12 55	44 56
14	G	24976	1948	54 39	43 45
15	L	25503	1994	59 30	44 36
16	I	25740	2014	01 22	44 32
17	M	26244	2054	05 30	45 05
18	N	25842	2022	02 09	44 37
19	O	25421	1988	58 51	44 38
20	S	25842	2021	02 08	44 36
21		26744	f1225	10 10	44 56
22	R	25253	1974	57 06	44 26
23		25138	1967	56 05	44 52
24		24392	1901	49 21	44 46
25	T	25513	1996	59 35	45 00
26		24291	1896	48 26	45 32
27	D	25301	1977	57 42	44 03
28	E	25537	1997	59 44	46 17
29		26820	2104	10 56	44 29
30	H	24967	1947	54 36	43 15
31		24576	1917	51 03	45 06
32		24696	1929	52 07	43 18
33		25795	2018	01 52	44 17
34	Q	25762	2016	01 28	44 44
35	U		f1149	57 15	44 38
36	P	25966	f1191	03 11	44 48
37	V		f1181	01 28	44 20
38			1956	55 08	44 45
39		24500	1912	50 09	47 28
40		24706	1928	51 59	47 02
41		24805	1935	53 03	46 34
42		25860	2026	02 10	48 00
43		26413	2074	07 00	46 00
44	A	27019	2125	12 36	46 15
45		27588	2168	17 41	44 23
46	X			02 16	44 48
47	Y			02 44	44 20
48		26262	2058	05 46	43 03
49	Z			58 29	44 29
50	a			01 08	44 24
51	b			02^{m}07^s	44°55'
52		24249	1890	48 07	42 53
53		27471	2157	16 28	45 47
54	W			58 27	44 37
55			f1145	56 33	44 08
56			f1136	55 12	45 39
57			1953	54 46	45 39
58			f1125	53 24	45 29
59		24331	1898	48 51	42 44
60			f1099	47 54	46 20
61					
62			f1140	55 48	46 29
63			f1213	08 05	43 30
64		26612	2092	09 09	42 07
65		26967	2120	12 19	42 24
66		27209	2141	14 11	46 05
67			f1264	15 52	46 03
68			f1265	15 59	43 31
69		27290	2147	14 42	51 37

E 3

Q	H	HD	CZC	α	δ
				6^h	-
1	E	47645	3738	35^m58^s	$44^\circ 56'$
2	F	47657	3740	36 04	45 33
3	C	47923	3763	37 17	43 47
4	D	47671	3746	36 14	44 27
5		46817	3676	31 46	45 20
6	G	47872	3758	37 03	45 20
7		47925	3768	37 16	46 08
8		47444	3726	34 58	44 29
9		47445	3727	35 00	44 36
10		48906	3841	41 56	46 54
11		47188	3703	33 43	44 14
12		49754	3893	46 15	43 50
13		48905	3840	42 03	44 00
14		46835	3678	31 49	46 07
15	A	49850	3904	46 47	43 44
16	H	48429	3809	39 47	45 04
17		47426	3725	34 50	45 45
18		47119	3697	33 16	46 28
19	I	48464	3811	39 51	45 14
20		47806	3755	36 48	45 14
21			3859	43 45	44 24
22		47720	3750	36 28	44 15
23		48384	3804	39 28	45 42
24		50786	3971	50 58	45 00
25	O	47582	f2337	35 42	45 32
26	N	48730	3824	41 04	45 18
27		50787	3972	50 57	46 00
28	P		3771	37 28	45 01
29		48342	3802	39 21	44 22
30	L	49355	3871	44 22	45 56
31		50883	3980	51 15	46 45
32		49074	3851	42 50	47 01
33	T			40 57	45 06
34	S			38 43	45 04
35		46415	3644	29 34	43 41
36		50196	3931	48 30	45 23
37		46652	3660	30 53	45 16
38	K	49559	3880	45 18	44 55
39	M	48151	3788	38 15	45 31
40		47267	3711	34 07	45 01
41		46859	3680	32 00	45 01
42			3739	36 03	44 19
43			f2332	35 31	44 55
44		49799	f2465	46 28	45 10
45		45572	3572	24 25	48 09
46		49942	3912	47 12	43 44
47		50223	3933	48 29	46 33
48		50785	3973	51 06	42 27
49		50860	3978	51 16	43 55
50		48402	3806	39 26	47 35

Q	H	HD	CZC	α	δ
				6^h	-
51		52196	4067	56^m35^s	$46^\circ 02'$
52		52362	4077	57 15	45 42
53		50126	3926	48 04	45 31
54	Q		f2386	40 27	44 50
55	R	48855	f2401	41 47	45 11
56	U			40 36	45 09
57	V			39 56	45 10
58	W			39 55	45 18
59	X			41 52	45 10
60	Y			39 38	45 07
61	Z			39 42	45 01
62	a			41 12	45 12
63	b			41 45	45 07
64	c			41 19	45 03
65		48486	f2378	39 57	45 30
66				39 24	45 25
67				41 52	45 34
68				41 03	44 39
69				42 09	45 28
70				39 55	44 56
71			f20557	56 26	44 13
72			f2249	27 32	45 20
73			f2256	28 02	44 12
74			f2283	30 23	43 30
75			f2340	35 56	43 38
76			f2384	40 06	48 11
77		48969	3849	42 29	42 40
78			f2487	48 36	44 27
79			f2513	50 08	44 15
80		50568	3959	50 10	44 15
81			f2578	54 39	47 00
82			f2382	40 06	43 44
83			f2317	33 43	44 55
84				40 09	45 44
85		47601	3736	35 48	43 24
86		47670	3742	36 14	43 09
87		47973	3770	37 18	48 10
88		48150	3783	38 15	43 21
89		49260	3862	43 48	47 10

66 = C.P.D. -45° 990
67 -45° 1015
68 -44° 1047
69 -45° 1017
70 -44° 1040
84 -45° 998

Q	H	HD	CZC	α	δ		Q	H	HD	CZC	α	δ
				9^h	–						9^h	–
1		79811	7159	12^m51^s	45°22'		51	B	81825	7385	24^m46^s	44°02'
2		80692	f5919	17 49	45 28		52	Q		f6084	23 55	45 15
3	C	81276	7315	21 20	44 45		53	W			22 33	45 20
4		81135	7302	20 35	43 53		54	X			21 06	45 20
5		81401	7336	22 02	46 51		55	Y			21 52	45 13
6		80484	7232	16 45	44 25		56	Z			21 24	45 07
7	K	81414	7337	22 12	45 16		57	a			22 02	45 09
8	L	81680	7369	23 50	45 23		58	b			22 34	45 06
9	P	80976	f5960	19 38	45 16		59	c			21 56	45 09
10		81035	7292	19 54	47 07		60	d			21 37	45 11
11		80922	7280	19 13	44 50		61		80515	7235	17 01	43 50
12		80817	7269	18 42	44 05		62		81333	7326	21 40	46 03
13	F	81802	7380	24 35	45 55		63		81971	7406	25 50	43 26
14	G	82551	7474	29 26	45 23		64		82416	7458	28 36	44 39
15		81289	7318	21 32	43 23		65			f6003	21 15	44 43
16	H	81844	7389	24 50	45 55		66				23 44	45 26
17	M	81076	7298	20 14	45 26		67				23 56	45 27
18	I	81665	7368	23 49	45 37		68		80923		19 15	45 21
19		80345	7215	15 59	45 17		69				18 42	42 25
20		82552	7471	29 22	45 47		70				18 41	45 24
21		82080	7416	26 32	45 33		71		81076		20 08	45 24
22		80433	7224	16 25	44 48		72				23 13	45 21
23		82152	7422	26 55	43 35		73				22 06	44 46
24		79736	7144	12 24	44 51		74				20 31	44 55
25		82386	7453	28 26	44 38		75		78429	7000	04 48	43 18
26	R		f6014	21 41	45 20		76		76847	7024	06 09	43 14
27		81077	7300	20 12	46 33		77		79601	7131	11 53	42 06
28	D	82436	7462	28 41	45 21		78		79694	7142	12 18	43 56
29	E	80777	7265	18 25	44 58		79		79735	7145	12 33	43 02
30		80527	7236	17 01	44 48		80		80572	7246	17 16	47 46
31		82183	7431	27 14	44 35		81			7019	05 54	44 26
32		82515	7469	29 12	45 14		82		82516	7468	29 06	47 09
33	O	81610	f6069	23 22	45 16		83		83386	7591	34 45	47 48
34		82184	f6164	27 13	45 14		84		82455	7465	28 46	47 23
35			f5883	16 44	45 20		85		83385	7593	34 47	46 07
36			f6144	26 18	44 22		86		81575	7350	23 15	43 46
37	S		f6005	21 18	45 28		87			f5653	08 50	44 53
38	N	81576	7349	23 10	45 10		88			f5662	09 03	45 06
39		79403	7115	10 27	45 38		89			f5663	09 04	45 06
40		79416	7119	10 39	43 24		90			f5688	09 58	42 05
41		79900	7171	13 25	45 20		91		79039	7070	08 08	47 16
42		80108	7191	14 32	44 03		92		79186	7091	09 15	44 40
43		80761	7262	18 14	46 45		93		79275	7103	09 47	46 22
44	A	81136	7303	20 35	45 50		94		79621	7132	11 50	47 07
45		82224	7434	27 27	42 58		95		80057	7184	14 13	44 41
46		82578	7475	29 31	47 44		96		80205	7203	15 08	44 48
47		83548	7609	36 04	42 57		97		81347	7327	21 39	48 04
48	T			23 13	45 04		98		81369	7333	21 51	46 42
49	U			22 16	45 36		99		82109	7418	26 32 ~~09 26~~	45 17
50	V			19 53	45 08		100		82121	7421	26 48	45 17
101		82207	7435	27 26	44 19		102		82241	7439	27 36	44 19

66 = C.P.D. -45° 3738
67 = -45° 3742

69 = C.P.D. -45° 3665
70 -45° 3664

72 = C.P.D. -45° 3733
73 -44° 3743
74 -44° 3724

E 5

Q	H	HD	CZC	α	δ
				$11/12^{h}$	-
1	D	106902	10248	$15^{m}08^{s}$	$45^{\circ}07'$
2	E	105498	10118	06 07	44 39
3		103910	9978	55 17	43 27
4		105993	10166	09 14	44 51
5		103619	9954	53 14	44 14
6	H	105116	10087	03 30	45 37
7		103911	9977	55 15	46 31
8	O		f9636	03 57	45 11
9		105714	10145	07 35	46 43
10	K	103899	9976	55 14	45 04
11		105606	10130	06 57	44 37
12	L	103745	9966	54 11	45 26
13	I	103396	9931	51 42	45 33
14			f9539	57 40	45 18
15			f9709	08 18	45 17
16	G	104226	10013	57 36	44 35
17		105688	10140	07 28	43 17
18		104598	f9573	00 11	46 08
19		104211	f9537	57 31	45 46
20	F	105837	10153	08 21	46 03
21		104663	10047	00 32	46 15
22			f9667	06 03	44 36
23		104212	10010	57 31	46 30
24		106233	10186	10 46	45 21
25		105364	f9659	05 21	45 39
26			f9538	57 34	45 16
27	C	105852	10156	08 27	45 09
28		106456	10207	12 15	43 50
29		105784	10150	08 04	46 15
30		105671	10138	07 22	45 56
31		105363	10105	05 23	45 07
32	P	104720		00 55	45 53
33		105381	10106	05 25	44 33
34	M	103729	9965	54 06	45 16
35		104806	f9595	01 31	45 40
36		102703	9850	46 58	45 48
37		103746	9968	54 13	46 48
38		103975	9980	55 44	47 42
39	B	104138	10001	57 01	46 22
40		104731	10051	01 02	42 09
41	A	105313	10100	04 57	45 18
42		105509	10121	06 18	44 03
43		107422	10284	18 28	42 17
44	N	105415	f9664	05 38	45 49
45	Q			01 21	45 29
46	S			01 55	45 12
47	T			03 40	45 16
48	U			01 19	45 13
49	R			04 06	45 17
50		105919	10160	08 51	44 01

Q	H	HD	CZC	α	δ
				$11/12^{h}$	-
51		102232	9812	$43^{m}15^{s}$	$45^{\circ}25'$
52		102865	9872	47 55	46 12
53		103281	9922	51 03	46 28
54		105283	10097	04 47	42 58
55		106321	10197	11 25	45 27
56	V			03 07	45 39
57	W			03 11	45 29
58	X			03 25	45 28
59	Y			02 50	45 15
60	Z			03 17	45 30
61				07 30	46 00
62				07 11	45 38
63				07 33	45 40
64				07 28	45 41
65				01 33	45 00
66				05 54	45 37
67				04 51	45 49
68		105873	10158	08 35	46 07
69		106107	10175	10 02	45 15
70		104080	9994	56 38	45 33
71		104664	10046	00 32	47 55
72		106589	10217	13 01	48 09
73			f9501	55 44	42 43
74		104532	10034	59 40	48 27
75		105905	f9720	08 44	44 35
76		102964	9884	48 39	44 54
77		102981	9887	48 42	43 39
78		105416	10111	05 38	48 25
79		107392	10282	18 14	47 11

61 = C.P.D. -45° 5809
62 -45° 5803
63 -45° 5810
64 -45° 5808
65 -44° 5803
66 -45° 5794
67 -45° 5783

E 6

Q	H	HD	CZC	α	δ
				14^h	−
1	S		f12411	$43^m 36^s$	$45^\circ 02'$
2	G	130119	12633	44 35	45 57
3		130546	12676	46 57	46 04
4		128726	12516	36 44	45 32
5		130998	12733	49 21	46 49
6	H	131243	12752	50 38	44 44
7		128211	12468	33 50	46 48
8	M	129688	12606	42 09	45 28
9	N	130365	12657	45 54	45 40
10		128948	f12333	37 58	45 30
11	T	130201	12645	45 01	45 28
12		131627	12776	52 55	43 53
13		131503	12768	52 07	44 08
14		131099	12740	49 48	43 31
15	O	130862	12716	48 43	45 16
16	P	129660	12603	41 57	45 13
17	R	130792	12711	48 22	45 16
18		130035	12626	44 05	44 15
19	U		f12406	43 20	44 55
20	I	129221	12564	39 31	45 23
21		127294	12386	28 30	42 52
22	K	128760	12521	36 56	45 20
23		130931	12727	49 02	46 26
24		127694	12423	30 51	45 18
25	L	129747	12610	42 28	45 40
26	Q	130364	f12460	45 56	45 36
27		131464	12766	51 56	46 25
28		129623	12599	41 42	44 27
29		131078	12737	49 43	46 25
30		127216	12378	28 13	45 29
31			f12312	36 54	45 25
32	V			45 27	45 25
33		128413	12492	34 56	45 39
34	Y		f12408	43 26	45 11
35		129964	f12414	43 40	44 33
36		130997	12734	49 22	45 24
37		132203	12827	55 58	45 15
38		130932	12728	49 02	46 34
39		126981	12353	26 54	45 06
40		128068	12460	33 02	46 02
41	A	128582	12505	35 54	46 22
42	C	129791	12613	42 40	44 40
43		129858	12618	43 08	47 14
44	E	130073	12628	44 16	43 21
45		131637	12783	53 05	44 30
46		132202	12831	56 01	43 16
47		132301	12838	56 28	43 36
48	X	129857		43 06	45 34
49	W			44 24	45 04
50	Z			42 34	45 03
				14^h	−
51	D	129070	12553	$38^m 44^s$	$46^\circ 05'$
52	F	130904	12725	48 56	44 44
53		131678	12784	53 10	46 45
54	a			44 26	45 08
55	b			43 13	45 23
56	c			43 08	45 09
57	d			44 03	45 08
58			f12377	41 22	45 15
59				41 33	45 16
60				42 11	45 37
61				43 19	45 00
62				42 11	44 56
63		131226	12749	50 32	45 07
64		131609	f12585	52 52	44 56
65		126803	12336	25 49	46 31
66		130761	12710	48 08	46 53
67		129735	12609	42 25	46 36
68		130416	12665	46 18	44 20
69		129792	f12394	42 42	46 35
70		126999	f12148	27 03	46 43
71			f12132	26 03	46 14
72		130435	f12472	46 24	44 40
73			f12626	56 14	43 53
74			f12679	59 42	46 06
75			f12683	59 53	42 25
76		126903	12343	26 19	43 32
77			f12547	50 18	45 00
78		126341	12297	22 55	45 00
79		126354	12300	22 57	45 09
80		126504	12309	23 58	45 55
81		126759	12331	25 33	47 47
82		127864	12436	31 53	46 14
83		127972/3	12445	32 19	41 56
84		127976	12451	32 31	46 36
85		128266	12471	34 02	45 55
86		128267	12472	34 03	45 55
87		128344	12485	34 34	47 48
88		128775	12525	37 01	45 35
89		129056	12549	38 35	47 11
90		130697	12699	47 43	42 37
91		130807	12713	48 21	43 23
92		131657	12780	53 06	47 40
93		132058	12813	55 14	42 56
94		132200	12828	55 53	41 54
95		132242	12833	56 09	42 58
96		133242/3	12915	01 41	46 52

59 = C.P.D. -44° 6935
60 -45° 7001
61 -44° 6949
62 -44° 6942

E 7

Q	H	HD	CZC	α	δ
				17^h	$-$
1	F	158864	16364	$30^m 15^s$	45° 35'
2	D	157624	16185	22 53	44 35
3	E	159402	16433	33 01	44 32
4	G	158746	16348	29 28	44 28
5	I	157063	16091	19 34	44 45
6	L	157573	16173	22 33	44 31
7	S	157697	16197	23 15	44 40
8	W		f16585	22 36	45 08
9		159474	16452	33 30	45 52
10		159037	16383	30 54	43 07
11	M		16217	24 20	44 41
12	O		16226	24 53	45 17
13	P		16258	26 11	44 56
14	Q	158058	16239	25 34	44 46
15	U	157506	16159	22 09	44 49
16	H	157477	16157	22 02	45 13
17	R	158006	16231	25 17	45 12
18		158456	16302	28 00	45 31
19		157131	16107	20 01	45 07
20			16454	33 44	45 47
21			f16582	22 34	44 50
22		157795	16211	23 56	43 30
23		156236	15986	14 58	46 45
24		158159	16254	26 09	46 58
25		160150	16525	36 50	43 50
26		158585	16325	28 40	46 36
27	V		f16531	21 38	44 49
28		157798	16210	24 02	46 55
29		157931	16221	24 47	46 50
30		159039	16385	31 00	45 06
31	T	157815	16212	24 01	44 46
32	K	157487	16158	22 02	44 44
33	N	157062	16092	19 34	44 40
34		158667	16342	29 07	46 14
35		159057	16389	31 06	45 05
36		160283	f17112	37 31	43 36
37			f16593	22 55	45 01
38		157520	f16566	22 20	46 03
39		159384	16435	33 02	44 51
40		159749	16479	34 51	44 51
41		160028	f17062	36 17	45 07
42	Z			24 27	45 05
43		154948	15844	07 04	44 30
44		156274	15993	15 11	46 36
45		156398	16008	15 47	44 10
46	B	156623	16035	17 10	45 22
47		157243	16121	20 35	44 07
48	A	157316	16133	21 03	44 58
49		160263	16540	37 32	46 54
50	C	158175	16260	26 13	44 43

Q	H	HD	CZC	α	δ
				17^h	$-$
51		156044	15961	$13^m 52^s$	44° 44'
52	X			23 47	44 53
53	Y			24 06	45 04
54	a			23 12	45 00
55	b			23 45	45 03
56	c			23 27	45 06
57	d			23 24	44 58
58	e			24 14	45 02
59	f			23 56	45 01
60	g			23 47	45 01
61		155203	15868	08 34	43 10
62				22 51	44 42
63				23 03	44 37
64			f16662	24 49	46 50
65		159656	16473	34 17	42 32
66		159868	16493	35 26	43 07
67			f17096	37 08	44 56
68		160207	16534	37 09	44 56
69		155185	f16119	08 40	46 29
70			f16161	09 52	42 40
71			f16337	15 51	44 02
72			f16429	18 53	43 06
73			f16680	25 18	44 34
74			f20560	33 31	44 16
75					
76		160097	16521	36 31	43 42
77		160171	16530	36 57	43 38
78					
79		157931	16221	24 46	46 50
80		156293	15997	15 11	44 05
81		155896	15938	12 43	42 18
82		155985	15949	13 26	44 44
83		157042	16087	19 31	47 25
84		157661	16195	23 10	45 48
85		157832	16213	24 10	46 59
			16236)	25 23)	43 56)
86		158042	16237)	25 23)	43 57)
87		159217	16407	31 56	46 28
88		159532	16458	33 43	42 58
89		159707	16476	34 33	42 51
90		160715	16605	39 54	45 57

62 = C.P.D. -44° 8491
63 -44° 8497

E 8

Q	H	HD	CZC	α	δ
				h 19/20	–
1		191796	18679	10^m05^s	$45^\circ44'$
2	B	189502	18555	58 39	44 37
3	I	189226	18534	57 20	45 50
4		189834	18572	00 23	43 59
5		192092	18691	11 32	43 50
6	H	189767	18567	59 59	44 44
7		187442	18438	48 21	44 30
8	A	191273	18654	07 22	43 45
9	F	189951	18582	00 58	45 06
10		192758	18719	14 50	43 01
11	D	191305	18656	07 37	43 37
12		189719	18565	59 49	43 04
13		189247	18536	57 21	44 07
14		193213	18747	17 24	45 42
15	G	190269	18592	02 32	45 08
16	K	190709	18619	04 32	44 21
17		189121	18527	56 49	44 49
18	P	189933	18580	00 53	45 11
19	Q	190897	18633	05 32	45 01
20		188815	18508	55 23	46 13
21		188392	18490	53 24	45 57
22		188116	18470	52 01	45 42
23	T		f18984	01 08	44 54
24			f18939	55 57	46 20
25		192826	18724	15 15	42 47
26	C	191349	18657	07 49	43 48
27				51 47	44 19
28	E	189563	18557	59 04	45 20
29		191117	18643	06 38	44 03
30		190057	18588	01 34	46 15
31		192844	18726	15 28	44 41
32		193132	18743	16 58	43 04
33	L	190309	18594	02 42	44 29
34	M	191007	18637	05 58	44 04
35	N	189855	18575	00 28	44 47
36		192633	18709	14 11	45 23
37	R	190827	18630	05 13	45 35
38		191464	18661	08 25	45 31
39	S	190777		05 01	44 49
40	O	190480	18605	03 25	44 27
41		191556	18669	08 49	45 00
42		189198	18533	57 16	45 15
43		189307	18541	57 49	47 32
44		192886	18728	15 42	47 44
45		193571	18762	19 04	42 13
46	U	190878		05 22	44 34
47	V			01 49	44 53
48	W			00 51	45 07
49	X			03 09	44 48
50	Y			03 25	44 57
				h 19/20	–
51	Z			04^m12^s	$44^\circ46'$
52		189667	f18971	59 28	45 00
53		189404	f18959	58 12	44 37
54		189057	f18942	56 32	44 31
55				59 00	44 19
56		189585	18558	59 04	44 22
57				03 22	44 22
58				02 42	44 25
59				03 02	45 14
60				04 15	45 31
61		191849	18682	10 16	45 19
62		193133		16 57	44 37
63		192961	18733	16 09	46 35
64		188031	f18902	51 31	42 47
65		189856	f18978	00 31	45 56
66		189856	f18979	00 31	45 56
67		190333	18597	02 50	43 22
68				03 35	45 42
69		188114	18469	51 49	42 00
70		188246	18476	52 34	44 08
71		193807	18771	20 29	42 35
72		194188	18789	22 33	46 49

27 = C.P.D. −44° 9672
57 −44° 9724
58 −44° 9723
59 −45° 9867
60 −45° 9874
68 −45° 9871

E 9

Q	H	HD	CZC	α	δ
				22^h	−
1	F	216009	20142	46^m57^s	44°41'
2		216090	f20098	47 42	44 18
3	N	215559	20112	43 49	44 33
4	L	214509	20039	36 27	45 00
5	E	216989	20202	55 05	45 26
6	K		20054	37 56	44 46
7		216679	20186	52 37	46 36
8	G	215571	20114	43 56	45 19
9	M	215156	20080	41 03	44 22
10		215468	20098	43 08	46 06
11	H	214729	20053	37 55	45 27
12		215788	20125	45 27	45 31
13		214791	20059	38 23	44 06
14		214730	20056	38 00	45 29
15		216098	20149	47 48	43 52
16			f20094	47 14	45 23
17	D	215657	20119	44 32	45 14
18		216531	20175	51 22	46 09
19	I	215877	20134	46 04	44 52
20		216155	20151	48 15	45 00
21		215628	20118	44 19	43 52
22			f20048	40 42	45 40
23	T		f20072	44 17	45 17
24		213457	19976	29 14	43 32
25		215818	20129	45 37	43 42
26	Q	215544	20104	43 42	44 09
27	R	215105	20076	40 37	44 49
28	V			41 41	44 52
29	C	213658	19984	30 57	44 57
30		216406	20167	50 22	45 25
31		216291	20160	49 33	46 15
32		214174	20021	34 22	44 55
33	P	215800	20127	45 27	44 46
34		214943	20064	39 31	44 21
35			20081	41 14	45 28
36	W			42 05	45 08
37	O	215629	20116	44 14	44 09
38	S	215756	f20079	45 12	44 31
39		216213	20155	48 46	45 16
40		213220	19956	27 14	44 21
41		213363	19970	28 47	46 51
42	B	214094	20015	33 44	43 44
43		214987	20070	39 47	44 30
44		215405	20092	42 45	46 48
45		216743	20191	53 05	42 49
46	A	217172	20214	56 23	45 27
47	U		f20057	42 11	44 54
48		213155	19953	27 18	42 33
49		215627	20117	44 17	41 57
50		216667	20185	52 34	43 09
				22^h	−
51				47^m42^s	44°22'
52	X			42 22	45 06
53	Y			41 37	44 32
54	Z			42 57	44 47
55				43 43	45 22
56		216223	20157	48 55	45 03
57		214216	20023	34 35	44 49
58		214388	20033	35 32	44 51
59		214706	f20023	37 51	45 49
60		214017	20010	33 14	43 50
61		214033	20011	33 21	43 55
62					
63		214953	20067	39 39	47 27
64		213657	19983	30 51	42 18
65			f20007	35 41	47 00
66			f20044	40 18	47 04
67		215467	20099	43 06	42 41
68		215801	20128	45 34	46 19
69		216054	20148	47 22	41 45
70		209952	19748	05 05	47 12
71		211053	19814	12 32	44 42
72		212132	19883	20 04	46 11
73		212180	19888	20 22	46 55
74		213009	19939	26 18	43 45
75		213080	19946	26 47	44 00
76		213785	19992	31 48	46 03
77		214308	20028	35 04	46 58
78		214952	20068	39 42	47 08
79		215104	20077	40 36	41 40
80		215545	20106	43 47	47 12

51 = C.P.D. −44° 10273
55 −45° 10333

CAPE MIMEOGRAM

No. 3.

STANDARD MAGNITUDES IN THE E REGIONS

(The 1953 S System)

Royal Observatory
Cape of Good Hope

June 1953

Standard Magnitudes in the E Regions
(The 1953 S System)

The Southern or "S" system of magnitudes, as incorporated in a mimeogram circulated in 1948, referred mainly to stars between magnitudes 7 and 11 and was intended to provide standards suitable for the reduction of the extensive Cape photographic programme which aims at providing magnitudes for 70,000 stars in the A.G. zones south of -30°.

The 1948 system was based on three series of in-focus plates supplemented by a number of Fabry observations. During the compilation of the data, a photographic effect analogous to the Purkinje effect in visual photometry was noted for the in-focus series of magnitudes. An attempt was made to eliminate this effect with the help of what Fabry results were available, but these were not sufficiently numerous for the purpose and traces of the effect remained, especially in the photographic magnitudes.

The 1953 system is completely independent of in-focus photometry and should be entirely free of any type of Purkinje effect. In other respects the new standards reproduce as far as possible the 1948 S system but with a change of $0\overset{m}{.}07$ in the zero point of the photographic magnitudes. The change in zero point was suggested by a comparison made in 1950 between the S and International systems, using the best data then available. Magnitudes are available for over 700 stars between magnitudes 2 and 16, though the system can, as yet, be considered as reasonably well defined only to magnitude 11.

The series of observations from which the 1953 S system has been built up are summarised in Table I and are given in detail in Cape Mimeogram No. 4. The standard internal errors of all the major Cape series are under $\pm\,0\overset{m}{.}01$. The agreement between the various series is very satisfactory. As can be seen from the quantities given in the last two columns of Table I, the mutual external errors do not greatly exceed the internal errors.

The zero points depend on a special series of photoelectric observations made with the Cape Astrographic Refractor in 1952. It is beleived that these observations established the relative zero points of the various E regions with a standard error of only $\pm\,0\overset{m}{.}003$ and transferred the zero point of the E regions as a whole to sequences of stars in the Pleiades, Hyades and Preasepe with a standard error of $\pm\,0\overset{m}{.}005$. The magnitudes for the cluster stars as observed in this programme are given in Table II.

The relationship of the 1953 S system to other standard systems is still being investigated. The best <u>linear</u> relationship with the International system available at present is

$$\begin{aligned} IPg &= SPg + 0.01\ SCI + 0.05 \\ IPv &= SPv + 0.08\ SCI - 0.06 \\ ICI &= 0.93\ SCI + 0.11 \end{aligned}$$

The various comparisons on which these relations are based are given in Table III. It will be noted that the application of the 1950 zero point correction of $-0\overset{m}{.}07$ to the 1948 SPg was unfortunate. It has been retained in the 1953 system because over 45,000 zone magnitudes have already been reduced with this correction applied.

With the Johnson B,V system, the best linear relations are

$$B = SPg - 0.07\,SCI + 0.20$$
$$V = SPv + 0.08\,SCI - 0.06$$
$$B-V = 0.85\,SCI + 0.26$$

These linear relations must be used with a certain amount of reserve. As Johnson has shown (Ap. J. 116, 272, 1952), the International system is not adequately defined by the magnitudes of stars in the North Polar Sequence, because of the differing amounts of light to the violet of 3800A that have been included in the various interpretations of the IPg magnitudes. SPg was originally built up from observations with refractors and very little light to the violet of 3800A contributes to it. In the case of very blue stars, however, the contribution of such light cannot be ignored. Observations with a photometer belonging to the Washburn Observatory attached to the Cape Victoria Telescope show that a change from the usual Cape **blue filter** to a combination removing all the ultra-violet light has no effect on the colour equation for stars between A0 V and K0. For stars earlier than A0 there is a small difference which is shown in the following table:-

Sp. T.	B0.5	B2	B3	B5	B8	B9
$B_W - B_C$	$+0^m.045$	$+0^m.035$	$+0^m.03$	$+0^m.025$	$+0^m.02$	$+0^m.005$
No. of Stars	3	6	5	7	3	9

A similar difference is apparent when the BPg magnitudes of Mimeogram No. 1 are compared with Johnson's blue magnitudes, so that the linear relations given above probably need small corrections for the very blue stars.

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Explanation of the Table

Column 1 identifies the star by its Q number given in Cape Mimeogram No. 2.

Column 2 gives the HD spectral type except for a few of the fainter stars for which the type given is that determined by Becker at Potsdam.

Columns 3, 4 and 5 give SPg, SPv and the deduced colour index, SCI. Those enclosed in parentheses must be regarded as not sufficiently well determined to be used as standards; in most cases they have been supplied from the earlier in-focus work.

Column 6 gives the weights to be assigned to the individual magnitudes. Unit weight was assigned to a series of observations when the mean residual was ± $0^m.008$ or less. Less reliable series were assigned proportionally lower weight. The number of series contributing to any given magnitude is therefore never less than its weight as given in Column 6. When the various determinations of a magnitude are discordant, the magnitude in question is followed by a colon and further details are usually given in the Notes. The numbers given there refer to the individual series of observations as shown in Table I while "In" refers to the earlier in-focus results.

Column 7 refers to the Notes at the end of the main table. A "D" indicates that the various series of magnitude determinations for that particular star were discordant, while an "R" usually refers to some other property of the star such as duplicity, composite spectrum, etc., that may affect the use of the star as a standard.

Table I

The Observational Basis of the 1953 S System

	Date	Inst.	Obs.	Col.	Mag. Range	Regions	No. of Stars	Col. Cor. x SCI		Mean Res. unit $0^{m}.01$	
								Pg.	Pv.	Pg.	Pv.
	Fabry										
1	1945-46	P.12	Redman	Pv	5 -10½	1,5-9	241		+0.12		2.0
2	1947-48	C.13	Cousins	Pg	2 - 8½	1-9	258	-0.03		0.6	
3	1947-49	C.13	Cousins	Pv	2 - 7½	1-9	209		+0.08		0.6
4	1947-49	C.13	Cousins	BPg	2 - 6	1-9	66	-0.18		0.6	
5	1949-50	C.24	Stoy	Pg	7 -10	1-9	244	0.00		0.7	
6	1949	C.24	Cousins	Pg	9 -11	5	26			0.7	
7	1950	C.18	Stoy	Pv	6½- 9½	3,4	69		+0.03		0.9
	Photoelectric										
8	1949-50	B.60	King	B,Y	6 -13½	4-9	170	(-0.05)	-0.20	0.7	0.6
9	1950	P.74	Irwin	B,Y	6 -16	1,4,7,9	126	+0.08	-0.15	1.3	1.2
10	1951	C.24		B,Y	5½-12½	1-5	206	+0.04	-0.15	0.7	0.5
11	1951	P.74		B,Y	10 -15	1,6,8	37	+0.03	-0.17		
12	1952	C.13		B,Y	2 - 9	1-9	280	-0.02	-0.17	0.4	0.5
13	1952	P.74	Cousins	B,Y	9½-13	1,5-9	111	(0.00)	-0.32	0.8	0.6
14	1952	C.24	Cousins	B,Y	7 -11	1,2,7,8,9	112	-0.01	-0.07	0.7	0.6
15	1953	C.13		B,Y	2 - 7	2-5	60	-0.03	-0.08	0.5	0.5
16	1953	C.24	Cousins	B,Y	5 -10	4,5	59	(-0.06)	-0.12		0.7

Notes to Table I

Instruments

P.74	The Radcliffe 74-inch reflector at Pretoria
P.12	A 12-inch mirror used on the mount of the 74-inch
B.60	The Harvard Rockefeller 60-inch Reflector at Bloemfontein
C.24, C.18	The 24-inch photographic and the 18-inch visual components of the Victoria Telescope at the Cape.
C.13	The 13-inch photographically corrected Astrographic Refractor at the Cape.

The various observed series of magnitudes were reduced to the S system by the application of simple colour and zero point corrections only. The colour correction was usually of the form c x CI, where CI refers to the colour as observed in that particular series. For the sake of easy comparison the factor given in columns 9 and 10 has been made to refer to SCI. In the case of the B magnitudes of Series (8) and (13) non linear colour corrections were used. These two sets of measures include considerably more light to the violet of 3800 A than do the others.

The last two columns give, in units of $0^{m}.01$, the arithmetical mean of the residuals from the adopted magnitudes for those stars for which at least two other series of observations have been available for deriving the adopted magnitude. An estimate of the external standard error can be obtained by multiplying this quantity by 1.5.

Series (1) was made under very trying conditions. The aim was to observe as many stars as possible in order to check the systematic accuracy of Pv magnitudes measured on in-focus plates.

Series (2), (3) and (4) have been described by Mr Cousins in M.N., <u>110</u>, 531, 1950.

Series (5) was intended to provide material by which a suspected Purkinje effect in in-focus magnitudes could be detected and removed.

Series (6) was a short experimental programme to investigate the capabilities of the Fabry photometer for observing fainter stars.

Series (7) was observed simultaneously with Series (5). The observations are not as extensive as in (5) because the 18-inch lens was in England for the greater part of 1949 being repolished.

Series (8) has been described by Dr. King in his PhD thesis.

Series (9) was observed as an incidental programme by Irwin and Cox during their South African visit. The accuracy of the observations varies considerably from region to region according to the conditions under which they were made. The external mean error given is an average for all the regions observed.

Series (11) was observed by Evans and Churms using a photometer belonging to the Leiden Observatory. The photometer was only available for two nights.

Series (13) was observed with the Cassegrain Photoelectric Photometer of the Radcliffe Observatory, which was built at Leiden.

Series (14) and (15) were observed with the Cape Photoelectric Photometer Mark II.

Series (16) was observed with a photoelectric photometer belonging to the Washburn Observatory. The blue magnitudes were not included in the means.

Table II

Magnitudes of stars in the Pleiades, Preasepe and the Hyades

The Pleiades

E	H	SPg	SPv	SCI
10	117	5.19	5.57	-0.38
16	150	5.38	5.76	-0.38
22	216	7.14	7.30	-0.16
27	255	5.52	5.87	-0.35
28	265	6.20	6.53	-0.33
40	436	6.62•	6.92	-0.29•
43	510	6.81•	7.08	-0.26•
45	520	7.06	7.27	-0.21
47	540	6.68	6.92	-0.24
54	722	5.16	5.55	-0.39
56	742	6.88•	7.05	-0.16•
67	977	5.90•	6.27	-0.36•

The Hyades

	10	7.33	7.01	+0.32
	15	5.73	5.70	+0.03
	36	8.00	7.63	+0.37
	38	7.20	7.00•	+0.19•
	66	6.73	6.49	+0.24
	72	7.67	7.59	+0.08
	82	7.85	7.53	+0.32
	90	4.54	4.56•	-0.02•
	112	8.20	6.81	+1.39
	144	7.74	7.45•	+0.28•
	177	6.01	5.95	+0.06
	193	8.07	8.04	+0.03
	199	6.90	6.61•	+0.28•
	236	5.68	5.63	+0.05
	244	4.75	4.86	-0.11
	252	5.52	5.54	-0.02
	261	6.72	6.55•	+0.16•
	274	7.89	6.27	+1.62
	280	8.08	7.93	+0.15
	296	6.12	6.07	+0.05
	353	4.69	4.71•	-0.02•

Praesepe

KW	R	SPg	SPv	SCI
	57	7.08	6.61	+0.47
	73	7.43	7.56•	-0.13•
	100	7.40	7.56	-0.16
40	193	7.75	7.83•	-0.08•
50	206	6.72	6.80••	-0.08•
94	257	8.11	7.88	+0.23
114	279	8.17	8.23	-0.06
143	314	8.35	8.37•	-0.02•
150	322	7.50•	7.50•	-0.00•
203	379	7.77	7.81	-0.04
204	381	6.71	6.73	-0.02
207	387	7.66	7.73	-0.07
212	390	7.39	6.57•	+0.81•
224	402	7.31	7.38	-0.07
229	405	7.58	7.57	+0.01
253	427	7.21	6.37	+0.84
265	438	6.40	6.68•	-0.28•
276	448	7.48	7.59	-0.11
279	452	7.66	7.73	-0.07
284	454	6.83	6.83•	-0.00•
283	456	7.26	6.38	+0.88
286	457	8.00	8.08•	-0.08•
292	462	8.28	8.27	+0.01
300	469	6.26	6.37	-0.11
323	491	7.82	7.87•	-0.05•
328	496	6.84	6.91	-0.07
348	514	6.74	6.85	-0.11
377	540	6.64	6.81	-0.17
385	544	7.97	7.99•	-0.02•
428	587	7.73	6.91	+0.82
445	609	7.97	8.04	-0.07
	823	8.07	8.08	-0.01
	825	7.88	7.63	+0.25
	844	7.82	7.61	+0.21

In the case of the Pleiades, the stars are identified by their number in Eggen's list (Ap.J 111, 81, 1950) and by their Hertzsprung number (Mem. Danish Acad. No. 4, 1923); for the Hyades and Preasepe, the R number given is from Ramberg's catalogues (Stok. Obs. An., 13, No. 9, 1941). The KW number for Preasepe is from Klein-Wassink's list (Groningen Pub., No. 41, 1927).

The magnitudes given for E 45 in the Pleiades are significantly different from Johnson's and were not used in finding the zero correction.

Table III

Comparison of the International and the 1953 S systems

IPg	=	SPg	+ 0.00	SCI	+ 0.03	Redman, 5 KSAs at +15°	(1)
			+ 0.005		+ 0.097	Cox, 4 C regions at +15°	(2)
			+ 0.025		+ 0.074	Johnson, Bright Stars	(3)
			+ 0.030		+ 0.050	Johnson, Preasepe	(4)
					+ 0.022	Johnson, Pleiades	(5)
IPv	=	SPv	+ 0.09	SCI	- 0.07	Redman, 5 KSAs at +15°	
			+ 0.090		- 0.047	Cox, 4 C regions at +15°	
			+ 0.068		- 0.049	Johnson, Bright Stars	
			+ 0.093		- 0.057	Johnson, Preasepe	
					- 0.098	Johnson, Pleiades	
ICI	=		0.91	SCI	+ 0.10	Redman, 5 KSAs at +15°	
			0.915		+ 0.144	Cox, 4 C regions at +15°	
			0.957		+ 0.123	Johnson, Bright Stars	
			0.937		+ 0.107	Johnson, Preasepe	
					+ 0.120	Johnson, Pleiades	
			0.929		+ 0.089	Colours of HD types	(6)
			0.928		+ 0.114	Colours of MKK types	(7)

Remarks

(1) Comparison of two series of magnitudes for stars in KSA. 78, 81, 84, 86 and 89. The first series were determined by direct comparison with the E regions on plates taken at Pretoria in 1947. The second series were determined by direct comparison with the north polar area on plates taken at Cambridge. This is only an interim result as all 24 KSAs at +15° were observed at Cambridge and are now being observed at the Cape.

(2) An independent comparison based on data given by Cox in Ap.J. 117, 83, 1953.

(3) See Cape Mimeogram No. 1.

(4) Ap. J. 116, 640, 1952

(5) Ap. J. 114, 526, 1951

(6) Comparison for over 800 bright stars of $\bar{C}_{pe}$, the mean photoelectric colour as observed at the Cape with Seares's C_s, the International colour index corresponding to a given H.D. spectral type. (Ap. J., 98, 261, 1943)

(7) Comparison for a number of bright stars of $\bar{C}_{pe}$, the mean photoelectric colour corresponding to an MKK type as observed at the Cape with $\overline{B-V}$, the mean photoelectric colour for the same MKK type as observed by Johnson for a number of northern stars.

E 1

Q	SpT	SPg	SPv	SCI	w	
1	A0	7.56	7.76	-0.20	5 ,3	
2	A2	8.42	8.50	-0.08	1 ,1	
3	A2	9.52:	9.69	-0.17:	2½,1½	D
4	F0	7.58	7.49	+0.09	5 ,4	
5	F0	9.59	(9.49)	(+0.10)	1	
6	F2	8.02	7.91	+0.11	5 ,3	
7	F2	8.82	8.64	+0.18	2½,2	
8	F2	9.11	(8.94)	(+0.17)	1	
9	F5	8.47	8.20	+0.27	2 ,1	
10	F5	8.63	8.39	+0.24	3 ,2	
11	F5					
12	F8	8.37	8.15	+0.22	3½,2	
13	F8	9.56	(9.30)	(+0.26)	1	
14	F8	9.71	(9.45)	(+0.26)	1	
15	G0	9.82	(9.52)	(+0.30)	1	
16	G0	10.14	9.76	+0.38	3½,2½	
17	G0	10.21	9.87	+0.34	1½,1½	
18	G5	10.00	9.46	+0.54	1½,1½	
19	G5	10.26	9.62	+0.64	3½,2½	
20	G5	10.39	9.83	+0.56	2½,2½	
21	G5	7.61	6.90	+0.71	3 ,2	
22	G5	8.86	(8.00)	(+0.86)	1	D
23	G5	9.38	(8.63)	(+0.75)	1	
24	G5	9.83	8.88	+0.95	2 ,1	
25	G5					
26	K0	8.46	(7.82)	(+0.64)	1	
27	K0	(10.08)	(9.31)	(+0.77)		
28	K0	9.46	(8.52)	(+0.94)	1	
29	K0	9.58	(8.59)	(+0.99)	1	
30	K0	7.62	6.52	+1.10	3½,2½	
31	K0	7.97	6.92	+1.05	3½,2½	
32	K0	8.31	6.87	+1.44	2 ,2	
33	K0	9.10	7.68	+1.42	1 ,2	D
34	K2	8.12	6.67	+1.45	3 ,2½	D
35	K2	10.75:	9.40	+1.35:	2½,2½	D
36	G0	5.30	4.98	+0.32	3 ,2	
37	A3	5.14	5.28	-0.14	3 ,2	
38	K0	6.27:	5.39	+0.88:	3 ,2	D
39	Mb	7.8	6.0	+1.8		R
40	A0	6.00	6.24	-0.24	3 ,2	
41	K0	7.23	6.22	+1.01	2½,2	
42	F0	6.77	6.71	+0.06	3 ,3	
43	F0	7.11	7.06	+0.05	3½,3	
44		11.32	10.90	+0.42	1½,2	
45						
46	B9	7.51	7.93	-0.42	5½,3	
47	A5	6.94	6.93	+0.01	3 ,3	
48						
49		(11.98)	(11.63)	(+0.35)		
50						

Q	SpT	SPg	SPv	SCI	w	
52	F8	9.31	(9.15)	(+0.16)	1	
53	F8	8.97	8.80	+0.17	1 ,1	
54	F5	9.33	9.10	+0.23	1 ,1	
58	G0	9.79			1	
61	K0	4.01	3.30:	+0.71:	3 ,2	R
62	K5	4.86	3.36	+1.50	2½,1½	R
63	K0	4.74	3.93	+0.81	3 ,2	
64	A2	6.54	6.71	-0.17	2 ,2	
Y		(12.70)	(12.41)	(+0.29)		
Z		(12.88)	(12.43)	(+0.45)		
a		(13.06)	(12.68)	(+0.38)		
b		(13.46)	(13.17)	(+0.29)		
d		(13.99)	(13.34)	(+0.65)		
h		(14.37)	(13.84)	(+0.53)		
l		(14.54)	(13.74)	(+0.80)		

E 2

Q	SpT	SPg	SPv	SCI	w	
1	B9	8.69	8.88	-0.19	1 ,1	
2	A0	7.59	7.71	-0.12	4 ,3	
3	A0	9.68	9.72	-0.04	1½,1	
4	A2	8.09	8.27	-0.18	5 ,3	
5	A5	7.58	7.62	-0.04	4 ,3	
6	A5	8.39	8.35	+0.04	4 ,3	
7	A5	9.05	8.99	+0.06	1 ,1	
8	F0	8.16	8.04	+0.12	4½,2½	
9	F0	8.65	8.64	+0.01	1 ,1	
10	F5	8.25	8.04	+0.21	4 ,1½	
11	F5	(9.56)	(9.34)	(+0.22)		
12	F5	9.63	9.40	+0.23	1½,1	
13	F5	9.14	9.03	+0.11	1 ,1	
14	F8	8.42	8.18	+0.24	3 ,2	
15	F8	8.73	8.50	+0.23	2 ,2	
16	G0	8.57	8.15	+0.42	1 ,1	
17	G0	8.71	8.39	+0.32	1½,1½	
18	G0	9.00	8.49	+0.51	1½,1	
19	G0	9.28	9.08	+0.20	1 ,1	
20	G0	9.87	9.53	+0.34	2 ,1½	
21	G	10.03	9.70	+0.33	2 ,1	
22	G0	9.74	9.02	+0.72	2 ,1	
23	G5	(9.32)	(8.74)	(+0.58)		
24	G5	9.92	(9.13)	(+0.79)	1	
25	G5	9.96	9.22	+0.74	2 ,1	
26	G5	7.69	6.92	+0.77	3 ,3	
27	G5	7.76	6.81	+0.95	3½,3	
28	G5	8.07	7.22	+0.85	3 ,3	
29	K0	8.05	6.63:	+1.42:	4 ,3	D
30	K0	8.62:	7.49:	+1.13:	3 ,4	R
31	K0	8.78	7.54	+1.24	1 ,1	D
32	K0	(8.81)	(7.87)	(+0.94)		
33	K0	9.26	7.98	+1.28	1 ,1	
34	K0	9.58	8.74	+0.84	1½,1	
35	K0	10.27	9.39	+0.88	1½,1	
36	K2	9.45	7.97	+1.48	1½,1	
37	K2	10.63	9.94	+0.69	1½,1½	
38	M0	10.96	9.62	+1.34	1 ,1	
39	A3	6.76	6.76	0.00	4 ,4	
40	K0	7.01	5.89	+1.12	4 ,4	
41	A0	6.84	6.97	-0.13	4 ,4	
42	A5	6.60	6.69	-0.09	4 ,4	
43	F0	6.73	6.63	+0.10	4 ,4	
44	G0	7.13	6.80	+0.33	3 ,3	
45	K0	6.24	5.31	+0.93	5 ,4	
46		10.99:	10.44:	+0.55:	1½,1½	D
47		11.14:	10.97:	+0.17:	1½,1½	D
48	G5	7.33	6.58	+0.75	4 ,4	
49		11.48	11.09	+0.39	1 ,1	
50		11.60	10.93	+0.67	1 ,1	
51		11.90	11.61	+0.29	1 ,1	
52	A2	7.30	7.42	-0.12	3 ,3	
53	G0	7.96	7.55	+0.41	4 ,3	
54		10.94	10.65	+0.29	1½,2	
55	F5	10.56	10.33	+0.23	1 ,1	
56	K0	10.66	9.89	+0.77	1 ,1	
57	G0	10.38	10.08	+0.30	1 ,1	
58	K0	10.36	9.56	+0.80	1 ,1	
59	K0	(9.37)	(8.60)	(+0.77)		
63	K2	10.81	10.12	+0.69	1 ,1	
64	F0	5.02	4.97	+0.05	5 ,4	
65	K0	4.78	3.82	+0.96	4 ,3	
66	G5	9.48	8.92	+0.56	1½,1	
67		11.64	10.82	+0.82	1 ,1	
68		11.80	11.49	+0.31	1 ,1	
69	F5	4.3	4.3	+0.01:	4 ,3	R

SpT	SPg	SPv	SCI	w	
B9	7.72	8.13	-0.41	4 ,2½	
B9	7.95	8.34	-0.39	3½,3	
A0	7.28	7.64	-0.36	4 ,4	
A0	7.44	7.77	-0.33	3½,3	
A0	7.94	8.11	-0.17	4 ,2½	
A0	8.13	8.23	-0.10	3 ,2	
A0	8.16	8.45	-0.29	4 ,2	
A0	(8.35)	(8.50)	(-0.15)		
A0	8.62	8.98	-0.36	1 ,1	
A0	9.20	(9.32)	(-0.12)	1	
A0	9.53	9.66	-0.13	2 ,1	
A2	9.58	9.72	-0.14	2 ,1	
A2	8.21	8.33	-0.12	4 ,2	
A2	9.44	(9.58)	(-0.14)	1	
A3	7.34	7.46	-0.12	3½,3	
A3	8.70	8.71	-0.01	2 ,1	
A3	9.48	9.55	-0.07	2 ,1	
F0	8.63	(8.60)	(+0.03)	1	
F0	9.01	9.03	-0.02	2 ,2	
F2	8.47	8.31	+0.16	2 ,1½	
F2	9.96	9.77	+0.19	2 ,1	
F5	8.71	(8.48)	(+0.23)	1	
F5	9.90	(9.72)	(+0.18)	1	
F8	9.19	(8.87)	(+0.32)	1	
F8	9.90	9.55	+0.35	2 ,1	
F8	9.77	9.56	+0.21	2 ,1½	
G0	8.77	(8.36)	(+0.41)	1	
G0	9.91	9.45	+0.46	1 ,1	R
G5	(9.08)	8.69	(+0.39)	1	
G5	9.35	9.02	+0.33	2 ,1½	
G5	8.81	8.02	+0.79	2 ,2	
G5	8.94	8.14	+0.80	2 ,1½	
G8	11.04	10.02	+1.02	1 ,1	
K0	10.47	9.70	+0.77	1 ,1	
K0	7.50	6.66	+0.84	5 ,5	
K0	7.92	6.46:	+1.46:	3 ,3	D
K0	8.07	7.13	+0.94	4 ,3½	
K5	9.33	7.90:	+1.43:	3 ,3	D
K2	9.40	8.55	+0.85	2 ,2	
K2	9.44	(8.40)	(+1.04)	1	
K2	9.64	(8.63)	(+1.01)	1	
K2	9.99	9.00	+0.99	2 ,2	
K2	(10.14)	(9.33:)	(+0.81)		
K2	10.74	9.31	+1.43	1½,1	
B9	5.45	5.83	-0.38	5 ,4	R
B8	6.97	7.42	-0.45	4½,5	
F2	5.35	5.17	+0.18	5 ,4	
F2	6.70	6.55	+0.15	5 ,5	
B9	6.11	6.54	-0.43	5 ,4	
B8	6.25	6.73	-0.48	5 ,4	

Q	SpT	SPg	SPv	SCI	w	
51	A0	6.52	6.90	-0.38	5 ,5	
52	A0	5.98	6.28	-0.30	5 ,4	
53	B8	6.85	7.18	-0.33	3½,4	
54	A0	10.03	10.20	-0.17	2 ,1	
55	A0	10.46	10.73	-0.27	1 ,1	
56		11.09	10.43	+0.66	1 ,1	
57		11.15	10.92	+0.23	1 ,1	
58		11.46	11.65	-0.19	1 ,1	
59		11.53	11.38	+0.15	1 ,1	
60		12.14	11.94	+0.20	1 ,1	
61		12.12	11.18	+0.94	1 ,1	
62		12.53	12.24	+0.29	1 ,1	
63		12.29	11.55	+0.74	1 ,1	
65	K0	10.59	9.58	+1.01	1 ,1	
66		10.72	10.61	+0.11	1 ,1	
67		10.99	10.68	+0.31	1 ,1	
68		11.28	11.01	+0.27	1 ,1	
69		11.37	11.03	+0.34	1 ,1	
70		11.52	11.37	+0.15	1 ,1	
71		12.28	10.78	+1.50	1 ,1	
72		11.94	10.76	+1.18	1 ,1	
73		10.42	10.24	+0.18	1 ,1	
75	K0	10.52	9.93	+0.59	1 ,1	
76	F8	10.72	10.58	+0.14	1 ,1	
77	G5	9.02	8.54	+0.48	2 ,1½	
78	K2	10.48	9.77	+0.71	1 ,1	
82	A2	10.20	10.23	-0.03	1 ,1	
83	A3	10.07	10.04	+0.03	2 ,1	
84		10.77	10.94	-0.17	1 ,1	
85	B5	6.45	6.95	-0.50	5 ,4	
86	B8	2.82	3.25	-0.43	3 ,2	
87	K0	5.59	4.91	+0.68	4 ,3	R
88	B8	7.00	7.49:	-0.49:	4 ,4	D
89	B3	6.79	7.29	-0.50	4 ,4	

E 4

Q	SpT	SPg	SPv	SCI	w		Q	SpT	SPg	SPv	SCI	w	
1	B8	(9.31)	(9.41)	(-0.10)		R	56		(12.27)	(11.49)	(+0.78)		
2	B9	9.56	(9.65)	(-0.09)	1 ,		57		(12.47)	(11.34)	(+1.13)		
3	A0	7.75	8.01	-0.26	5 ,3		58		(12.51)	(12.27)	(+0.24)		
4	A0	7.91	8.22	-0.31	2 ,1½		59		(12.95)	(11.69)	(+1.26)		
5	A0	7.96	8.27	-0.31	3½,2½		60		(13.06)	(12.59)	(+0.47)		
6	A0	8.21	8.42	-0.21	4 ,2½		61	A3	8.85	(8.91)	(-0.06)	1	
7	A0	9.23	9.48	-0.25	1 ,1		62	A2	9.09	(9.19)	(-0.10)	1	
8	A0	9.43	9.78	-0.35	3 ,1		63	A3	8.86	8.92	-0.06	2 ,1½	
9	A0	9.72	(9.91)	(-0.19)	2	R	64	F2	8.66	8.54	+0.12	1½,1½	
10	A2	7.36	7.53	-0.17	4 ,4		67		10.92	9.82	+1.10	1 ,1	
11	A2	7.49	7.70	-0.21	5 ,3		68	A	10.26	10.29	-0.03	1 ,1	
12	A2	7.88	8.09	-0.21	2½,2		71	A2	11.24	11.05	+0.19	1 ,1	
13	A2	7.94	8.05	-0.11	4½,3		73		11.29	11.21	+0.08	1 ,1	
14	A2	7.99	8.22	-0.23	5 ,2½		74		11.53	11.51	+0.02	1 ,1	
15	A2	8.18	8.50	-0.32	4 ,2		75	G0	7.75	7.33	+0.42	1 ,1	
16	A2	8.49	8.65	-0.16	2½,1		76	K5	3.79	2.14	+1.65	3 ,2	R
17	A2	9.55	(9.65)	(-0.10)	2		77	G0	8.37	(8.05)	(+0.32)	1	
18	A3	9.19	9.26	-0.07	2½,1½		78	B5	5.46	5.93	-0.47	4 ,3½	
19	A5	(9.38)	(9.29)	(+0.09)			79	B3	4.83	5.32	-0.49	4 ,3½	
20	F0	8.04	8.03	+0.01	3½,2½	R	80	G5	7.85	7.00	+0.85	1 ,1	
21	F0	9.62	9.59	+0.03	2 ,1		81	B5	6.49	6.86:	-0.37:	3 ,3½	D
22	F2	9.48	(9.43)	(+0.05)	1		82	K0	9.22	(8.49)	(+0.73)	1	
23	F8	8.39	8.15	+0.24	1 ,1		84	G5	9.07	(8.66)	(+0.41)	1	
24	F8	8.76	(8.53)	(+0.23)	1		85	G0	8.76	(8.42)	(+0.34)	1	D
25	G0	7.83	7.61	+0.22	4 ,4		86	Mb	7.86	(6.36)	(+1.50)	1	
26	G0	10.31	10.02	+0.29	2 ,1		88 89	K0	(9.7)	(9.1)	(+0.6)		R
27	G5	8.48	7.66	+0.82	2 ,2								
28	K0	7.65	6.59	+1.06	5 ,4		90		11.39	10.45	+0.94	1 ,1	
29	K0	7.77	6.66	+1.11	4 ,4		91	B8	6.46	6.93	-0.47	3 ,3½	
30	K0	8.12	7.17	+0.95	2½,4		92	B5	4.93	5.04:	-0.11:	4 ,3½	D
31	K0	9.48	8.48	+1.00	2 ,1½		93		5.30	5.88	-0.58	4 ,3½	
32	K0	9.50	8.78	+0.72	2 ,1½		94	B9	5.63	5.99	-0.36	4 ,3½	
33	K0	9.63	8.82	+0.81	3 ,2		95	B5	6.08	6.09	-0.01	3 ,3½	
34	K0	9.80	9.07	+0.73	2 ,1½		96	A0	6.50	6.81	-0.31	3 ,3½	
35	K0	(10.09)	(9.21)	(+0.88)		R	97	B5	5.86	6.36	-0.50	4 ,3½	
36	K0	10.37	9.43	+0.94	1 ,1		98	B9	5.86	6.30	-0.44	4 ,3½	
37	K5	10.61	9.44	+1.17	1 ,1		99	B5	6.76	7.23	-0.47	3 ,3	
38	Mb	9.5	7.8	+1.7	2	R	100	B8	7.23	7.72	-0.49	2 ,1½	
39	F5	6.86	6.70	+0.16	3½,4		101	F5	7.32	7.04	+0.28	2 ,2½	
40	B8	5.18	5.64	-0.46	4 ,3½	R	102	F5	7.26	7.02	+0.24	2 ,2½	
41	A0	5.93	6.33	-0.40	4 ,3½	R	e		(13.71)	(13.21)	(+0.50)		
42	K5	6.7	5.0	+1.7	3½	D	f		(13.75:)	(13.28:)	(+0.47:)		
43	B8	6.90	7.35	-0.45	4 ,4		g		(13.89)	(13.53)	(+0.36)		
44	G5	6.46	5.72	+0.74	5 ,5		h		(14.09)	(13.74)	(+0.35)		
45	F5	6.85	6.63	+0.22	3 ,3½		i		(14.37)	(13.67)	(+0.70)		
46	F0	6.56	6.58	-0.02	3½,3		k		(14.84)	(14.15)	(+0.69)		
47	K0	6.32	5.46	+0.86	3 ,2½	D	l		(15.17:)	(13.90:)	(+1.27:)		
48		10.55	10.65	-0.10	2 ,1		m		(15.18:)	(14.78:)	(+0.40:)		
49		10.92	10.79	+0.13	2 ,1		n		(15.59:)	(14.96:)	(+0.63:)		
50		11.02	10.77	+0.25	2 ,1		o		(16.42)	(14.92)	(+1.50)		
[illegible]	A0	7.27	7.56	-0.29	4 ,3½	R							
[illegible]		11.55	(11.48)	(+0.07)	1								
[illegible]		11.66	(11.46)	(+0.20)	1								
[illegible]		11.76	(11.49)	(+0.27)	1								

Q	SpT	SPg	SPv	SCI	w	
1	B9	7.60	8.04	-0.44	5 ,3	
2	A0	7.78	8.13	-0.35	4 ,3	
3	A0	7.98	8.05	-0.07	3 ,1	R
4	A0	8.50	(8.65)	(-0.15)	1	D
5	A0	8.78	(8.73)	(+0.05)	1	
6	A2	8.48	8.60	-0.12	3 ,2	
7	A2	8.79	8.90	-0.11	1 ,1	
8	A2	10.12	10.05:	+0.07	5 ,3	D
9	A3	8.49	(8.50)	(-0.01)	1	D
10	A3	8.91	8.90	+0.01	2½,2	
11	A5	(9.40)	(9.34)	(+0.06)		R
12	A	9.38	9.32	+0.06	3½,2	
13	F0	8.79	8.70	+0.09	3 ,3	
14	F2	10.04	9.82	+0.22	3 ,2	
15	F2	(10.45)	(10.26)	(+0.19)		
16	F8	8.17	7.88	+0.29	5 ,3	
17	F8	(9.08)	(8.80)	(+0.28)		R
18	F5	9.95	9.79	+0.16	3½,3	
19	F5	10.06	9.87	+0.19	2½,2	
20	G0	7.85	7.55	+0.30	5 ,4	
21	G0	9.23	8.91	+0.32	2 ,2	
22	G0	(10.25)	(10.13)	(+0.12)		
23	G5	8.82	8.39	+0.43	2½,2	
24	G5	9.32	(8.89)	(+0.43)	1	D
25	G5	9.97	9.37	+0.60	2½,2	
26	G5	10.33	9.97	+0.36	2 ,2	
27	K0	7.51	6.59	+0.92	5 ,4	
28	K0	8.48	7.52	+0.96	3 ,3	
29	K0	(9.21)	(8.35)	(+0.86)		
30	K2	9.44	(8.38)	(+1.06)	1	
31	K2	9.94	9.06	+0.88	2½,2	
32	K2	10.62	9.19	+1.43	3 ,2	
33	K5	9.66	(7.96)	(+1.70)	1	
34	K5	9.93	8.47	+1.46	3 ,2	
35	K5	9.94	(8.54)	(+1.40)	1	
36	A3	7.23	7.23	0.00	3 ,3	
37	F2	6.44	6.30	+0.14	3½,3½	
38	F5	7.06	6.78	+0.28	3½,2½	
39	F8	6.99	6.68	+0.31	5 ,5	
40	F0	5.32	5.18	+0.14	4½,3½	
41	A0	7.09	7.38	-0.29	4 ,4	
42	A2	5.77	5.81	-0.04	4 ,2½	
43	A0	6.64	6.90:	-0.26:	3 ,3	D
44	A0	9.91	10.08	-0.17	3½,2	
45		10.53:	10.65:	-0.12:	3 ,2	D
46		10.97:	10.63	+0.34:	2 ,2	D
47		11.27:	10.85	+0.42:	2 ,2	D
48		11.65	10.46	+1.19	1 ,1½	
49		10.89:	9.25	+1.64:	3 ,3	D
50	F5	6.81	6.62	+0.19	3 ,3	

Q	SpT	SPg	SPv	SCI	w	
51	B8	4.90	5.37:	-0.47:	4½,3½	D
52	F2	7.82	7.70	+0.12	4 ,2	
53	G5	8.07	7.20	+0.87	4 ,3	
54	F2	7.39	7.25	+0.14	3 ,3	
55	K0	6.59	5.23	+1.36	3 ,3	R
56		11.71	10.85	+0.86	1 ,1	
57		12.25	12.10	+0.15	1 ,1	
58		12.58	12.02	+0.56	1 ,1	
59		12.71	12.95	-0.24	1 ,1	
60		12.97	12.32	+0.65	1 ,1	
61		10.67	9.39	+1.28	1½,2	
68	A3	9.50	9.54	-0.04	1½,1	
69	K0	9.62	8.90	+0.72	2½,2	
70	A0	6.03	6.42	-0.39	3 ,3	
71	A2	6.63	6.67	-0.04	3 ,3	
72	G0	9.41	8.96	+0.45	2½,2	
74	G5	9.72	9.25	+0.47	2½,2	
75	K2	10.02	9.36	+0.66	1½,1	
76	K0	5.61	4.40	+1.21	4 ,3	
77	A0	6.35	6.67	-0.32	3 ,3	
78	A0	5.09	5.41	-0.32	4 ,3	
79	A3	7.14	7.17	-0.03	2 ,2	

Q	SpT	SPg	SPv	SCI	w	
1	B5	9.90	10.25	-0.35	3 ,2	
2	B9	7.81	8.16	-0.35	4 ,2	
3	B9	(9.37)	(9.75)	(-0.38)		
4	A0	7.84	(8.14)	(-0.30)	1½	
5	A0	8.02	(8.27)	(-0.25)	2½	
6	A0	8.31	8.57	-0.26	1 ,1	R
7	A0	8.65	(8.83)	(-0.18)	1	
8	A0	9.04	9.29	-0.25	1 ,1	
9	A0	9.03	9.16	-0.13	1 ,1	
10	A0	9.89	10.06	-0.17	2 ,1	
11	A0	9.94	10.17	-0.23	2 ,1½	
12	A2	7.82	7.94	-0.12	3 ,1	
13	A2	8.01	8.05	-0.04	3 ,1	
14	A2	8.17:	8.20	-0.03:	2 ,1	D
15	A2	9.40	9.46	-0.06	2 ,1	
16	A2	9.41	9.43	-0.02	2 ,1	
17	A2	9.83	9.79	+0.04	2 ,1	
18	F0	9.49	(9.37)	(+0.12)	1	
19	F2	10.17	10.01	+0.16	3 ,2	
20	F5	8.39	8.16	+0.23	3 ,2	
21	F8	8.12	7.89	+0.23	3 ,1	
22	F8	8.46	8.15	+0.31	3 ,2	
23	F8	9.31	(9.00)	(+0.31)	1	
24	F8	9.64	(9.42)	(+0.22)	1	
25	G0	(8.93)	(8.47)	(+0.46)		
26	G	9.58	9.33	+0.25	2 ,1	
27	G5	8.10	7.28	+0.82	2½,1½	
28	G5	8.28	7.51	+0.77	2½,2	
29	G5	8.65	8.17	+0.48	1½,1	
30	G5	9.90	(9.02)	(+0.88)	1	
31	G5	10.23	(9.98)	(+0.25)	1	
32	G7	10.49	9.59	+0.90	1 ,1½	
33	K0	7.84	6.78	+1.06	2½,1½	
34	K0	10.76	10.15	+0.61	1½,2	
35	K2	10.12	(9.01)	(+1.11)	1	
36	K5	10.07	(9.09)	(+0.98)	1	
37	K5	(10.30)	(8.74)	(+1.56)		
38	Ma	8.37	6.76:	+1.61:	1½,2	D
39	B9.	5.17	5.57	-0.40	3 ,2	
40	K2	6.88	5.46:	+1.42:	2 ,2	D
41	F8	6.34	6.10	+0.24	3 ,3	
42	B9	6.73	6.99	-0.26	3 ,3	
43	A0	5.58	5.82	-0.24	3 ,2	
44	G5	7.19	6.26	+0.93	2½,2½	
45	A0	6.58	6.84:	-0.26:	3 ,2	D
46	F0	7.17	7.09	+0.08	2 ,2	
47	F5	6.82	6.61	+0.21	2 ,2	
48		10.54	9.57	+0.97	2 ,2	
49		10.56	10.59	-0.03	2½,1½	
50		10.83	10.77	+0.06	1 ,1	
51	A0	7.10	7.44	-0.34	2 ,3	D
52	G0	7.50	7.22	+0.28	4 ,3	
53	A2	7.45	7.12:	+0.33:	2½,2	D
54		11.24	11.02	+0.22	2 ,1	

Q	SpT	SPg	SPv	SCI	w	
55		11.61	10.71	+0.90	2 ,1½	
56		12.07	10.63	+1.44	2 ,1½	
57		12.06	(11.80)	(+0.26)	1	
58	A2	10.51	10.48	+0.03	1 ,1	
59		10.93	10.20	+0.73	1 ,1	
60		10.59	10.44	+0.15	1 ,1	
63	A5	(9.17)	(9.09)	(+0.08)		
64	G0	(9.68)	(9.31)	(+0.37)		
65	G0	9.41			1	
66	F2,	8.22	(8.05)	(+0.17)	2	
67	F2	8.89	(8.65)	(+0.24)	1	
68	F0	9.60	(9.48)	(+0.12)	1	
69	F5	9.80	(9.56)	(+0.24)	1	
72	F5	10.23			1	
77	F5	10.28			1	
78	B3	4.1	4.6	-0.54	3 ,2	R
79	F8	4.53	4.38	+0.15	3 ,2	R
80	A3	5.90	5.87	+0.03	3 ,2	
81	B9	6.03	6.47	-0.44	2 ,1½	
82	B9	6.62	6.96	-0.34	2 ,2	
83		1.9	2.4	-0.56	2 ,1	R
84	K0	7.55	6.76	+0.79	2 ,2	
85	K0	6.18	5.35	+0.83	2 ,2	R
86	A					
87	B9	6.37	6.72	-0.35	2 ,2	
88	A0p	6.25	6.70	-0.45	2 ,2	
89	B2	1.82	2.39	-0.57	2 ,1	
90	A2	6.75	6.92	-0.17	1½,1½	
91	B5	3.93	4.40	-0.47	2 ,1	D
92	B9	5.35	5.71	-0.36	3 ,2	R
93	B2p	2.17	2.77	-0.60	2½,1½	
94	B3	2.65	3.22	-0.57	2 ,1½	
95	F8	6.48	6.12	+0.36	2 ,2	
96	B5	3.49	3.97	-0.48	2 ,1½	R
B	B8	6.62	7.08	-0.46	1 ,1	R
e		(12.31)	(12.05)	(+0.26)		
f		(12.51)	(11.61)	(+0.90)		
g		(12.52)	(12.24)	(+0.28)		
h		(12.72)	(11.75)	(+0.97)		
i		(13.02)	(12.01)	(+1.01)		
k		(13.03)	(11.73)	(+1.30)		
l		(13.43:)				
m		(13.53)	(12.32)	(+1.21)		
n		(13.46)	(12.69)	(+0.77)		
o		(13.97)	(12.76)	(+1.21)		
r		(15.07)	(14.20)	(+0.87)		
s		(15.23)	(14.61)	(+0.62)		

E 7

Q	SpT	SPg	SPv	SCI	w	
1	B0	7.9	8.3	-0.4	4 ,1½	R
2	B8	7.57	7.96	-0.39	3 ,1½	R
3	B8	7.84	8.18	-0.34	4 ,2½	
4	B8	8.00	8.30	-0.30	3 ,2½	
5	B8	8.34	8.56	-0.22	2 ,1½	
6	B8	8.83	9.18	-0.35	1 ,1½	
7	B8	9.81	10.08	-0.27	3 ,2½	
8	B8	10.50	10.61	-0.11	2 ,2½	
9	A0	(8.51)	(8.65)	(-0.14)		
10	A0	8.58	(8.90)	(-0.32)	1	
11	A0	8.74	8.69	+0.05	2 ,1½	
12	A0	9.14	9.26	-0.12	1 ,2	
13	A0	9.20	9.45	-0.25	1 ,2	
14	A0	9.25	9.28	-0.03	1 ,2	
15	A0	9.95	10.05	-0.10	2 ,2½	
16	A3	8.11	8.14	-0.03	4 ,2½	
17	A5	9.35	(9.20)	(+0.15)	1	
18	F0	8.62	(8.54)	(+0.08)	1	
19	F0	(9.31)	(9.12)	(+0.19)		
20	F0	9.33	(9.43)	(-0.10)	1	
21	F0	(10.31)	10.16	(+0.15)	1	
22	F2	7.46	7.29	+0.17	3 ,2	
23	F2	7.61	7.24	+0.37	3 ,2	
24	F2	8.60	(8.40)	(+0.20)	1	
25	F2					
26	G0	(9.02)	(8.61)	(+0.41)		
27	G0	10.28:	9.98:	+0.30:	1½,1	R
28	G5	8.65	(8.13)	(+0.52)	1½	
29	G5	(9.17)	(8.52)	(+0.65)		R
30	G5	9.53	(8.72)	(+0.81)	1	
31	G5	9.85	9.04	+0.81	2 ,2	
32	K0	8.72	7.58	+1.14	3 ,3½	
33	K0	8.92	7.82	+1.10	2 ,3	
34	K0	9.10	(8.09)	(+1.01)	1	
35	K0	9.77	(8.71)	(+1.06)	1	
36	K0					
37	K0	10.76	9.74	+1.02	1 ,1	
38	K0	10.75	(9.62)	(+1.13)	1	
39	K2	8.65	7.31	+1.34	2 ,2	
40	K2	9.31	(7.84)	(+1.47)	1	
41	K2	10.00	(8.61)	(+1.39)	1	
42		10.91	10.20	+0.71	1 ,2½	
43	G5	5.74	5.06	+0.68	3 ,2	
44	K0	6.07	5.47	+0.60	2 ,2	R
45	A0	6.61	6.71	-0.10	2 ,2	R
46	A0	7.12	7.32	-0.20	3 ,3½	
47	B8	4.80	5.20	-0.40	3 ,2	
48	F0	6.81	6.70	+0.11	3 ,3½	
49	A0	5.55	5.87	-0.32	3 ,2	
50	B8	7.24	7.61	-0.37	3 ,3½	
51	A2	8.26	(8.42)	(-0.16)	1	
52		10.55	10.84	-0.29	1 ,2½	
53		10.72	10.88	-0.16	1 ,2	
54		11.22	10.97	+0.25	2 ,2½	
55		11.43	10.98	+0.45	2 ,2½	
56		11.37	10.37	+1.00	2 ,2½	
57		11.44	11.17	+0.27	2 ,2½	
58		11.85	12.02	-0.17	1 ,2	
61	F2	3.51	3.39	+0.12	3 ,2	
62		10.97	10.98	-0.01	1 ,1	
63		11.50	11.29	+0.21	1 ,1	
65	G5	7.58			1	
66	G5	7.75	7.24	+0.51	2 ,1	
69	G5	9.86			1	
72	G0	10.86:	10.46:	+0.40 :	1 ,1	D
76	B9	9.22			1	
77	K0	9.60			1	
80	B9	5.48	5.84	-0.36	3 ,2	
81	B5	6.67	6.88:	-0.21:	2 ,2	D
82	B2	6.44	6.54	-0.10	2 ,2	
83	B3p	4.83	5.29	-0.46	3 ,2	
84	B9	4.97	5.35	-0.38	3 ,2	R
85	B2p	6.39	6.71 :	-0.32:	2 ,2	D
86	B9	5.92	6.26	-0.34	2 ,2	R
87	A0	4.31	4.67	-0.36	3 ,2	
88	F0	2.05:	1.92:	+0.13:	3 ,2	D
89	B9	5.79	6.17	-0.38	3 ,2	
90	B9	6.66	7.02	-0.36	2 ,2	
h		12.51	11.85:	+0.66:	1 ,2	D
i		12.80	12.49	+0.31	1 ,1	
k		13.05:	12.92	+0.13 :	1 ,1	D
l		(13.54)	(12.41)	(+1.13)		
m		13.67	(12.39)	(+1.28)	1	
n		(14.01)	(12.92)	(+1.09)		
o		(14.23)	(12.72)	(+1.51)		
p		(14.14:)	(13.13:)	(+1.01:)		
q		(14.60)	(12.96)	(+1.64)		
r		(14.83:)	(13.28)	(+1.55:)		
s		(14.73:)	(14.28)	(+0.45:)		
u		(15.41)	(15.07)	(+0.34)		
v		(15.68)	(13.93)	(+1.75)		
w		(15.81)	(15.26:)	(+0.55:)		

Q	SpT	SPg	SPv	SCI	w	
1	A0	7.54	7.86	-0.32	3½,1	
2	A0	7.64	7.98	-0.34	3½,2	
3	A0	8.57	8.81	-0.24	1 ,1	
4	A0	9.09	9.32	-0.23	1 ,1	
5	A2	8.15	8.22	-0.07	2 ,1	
6	A2	8.28	8.40	-0.12	1 ,1	
7	A2	9.78	9.97	-0.19	2 ,1	
8	A3	7.85	7.88	-0.03	4 ,2	
9	A5'	7.89	7.88	+0.01	4 ,2	
10	F0	7.10	7.08	+0.02	2 ,2	
11	F0	7.70	7.75	-0.05	4 ,2	
12	F2	7.71	7.62:	+0.09:	3 ,2	D
13	F2	7.87	7.69	+0.18	2 ,1	
14	F5	7.61	7.36:	+0.25:	2 ,2	D
15	F5	8.31	8.11	+0.20	3½,3	
16	F5	8.70:	8.53	+0.17:	2 ,1	D
17	F5	9.37	9.18	+0.19	2 ,1	
18	F5	9.53	9.36	+0.17	3 ,2	
19	F5	9.79	9.51	+0.28	3 ,2	
20	F8	7.73	7.52	+0.21	3 ,2	
21	F8	9.18	8.85	+0.33	2 ,1	
22	F8	(10.2)	(10.1)	(+0.1)		R
23	F8	10.54	10.22	+0.32	4 ,3½	R
24	F8	(10.45)	(10.36)	(+0.09)		
25	G0	7.83	7.48	+0.35	3 ,2	
26	G5	7.24	6.54	+0.70	3 ,3	
27	G8					
28	K0	7.63	6.52	+1.11	4 ,3	
29	K0	7.77	6.92	+0.85	2 ,2	
30	K0	8.32	6.87	+1.45	2 ,2	
31	K0	8.30	7.52	+0.78	2 ,1	
32	K0	8.61:	7.75	+0.86:	2 ,1	D
33	K0	8.80	7.83:	+0.97:	2 ,2	D
34	K0	8.87	7.80	+1.07	2 ,2	
35	K0	9.27	8.31	+0.96	2 ,2	
36	K0	9.51	8.54	+0.97	2 ,1	
37	K0	9.90	9.03	+0.87	3½,2½	
38	K0	10.02	8.86	+1.16	2½,1½	
39	K0	10.50	9.50	+1.00	4 ,3½	
40	K2	9.39	8.06	+1.33	3 ,2	
41	K2	10.59	9.50	+1.09	1½,1.	
42	A5	5.85	5.85	0.00	3 ,2	
43	F0	7.08	7.01:	+0.07:	2 ,2	D
44	F5	6.36	6.16	+0.20	2 ,2	
45	A0	5.34	5.66	-0.32	3 ,2	
46		10.70	9.99	+0.71	3 ,3	
47		10.94	10.66	+0.28	2½,2	
48		11.47	10.71	+0.76	2 ,2	
49		11.56	11.34	+0.22	3 ,2½	
50		11.73:	11.52	+0.21:	2 ,2	D

Q	SpT	SPg	SPv	SCI	w	
51		12.22	11.86:	+0.36:	1½,2	D
52	K0	(10.29)	(9.39)	(+0.90)		
53	G5	10.12	(9.39)	(+0.73)	1	
55		10.71	10.56:	+0.15:	1 ,2	D
56	G5	9.69	8.90	+0.79	2 ,1	
57		11.27	9.71:	+1.56:	1½,2	D
58		11.60	10.51	+1.09	1 ,1	
59		11.49	10.55	+0.94	1 ,1	
60		11.02	10.09:	+0.93:	1 ,2	D
61	K5	(9.25)	(7.89)	(+1.36)		
63	K2	9.75			1	
67	G5	9.70	(9.21)	(+0.49)	1	
68		10.96	10.50	+0.46	1 ,1	
69	K0	5.02	4.09	+0.93	3 ,2	
70	A0	6.85	7.26	-0.41	2 ,2	
71	A3	5.61	5.71	-0.10	3 ,2	R
72	A5	6.78	6.79	-0.01	2 ,2	
a		12.51	12.13	+0.38	3 ,2½	
b		12.44	12.00	+0.44	2½,2	
c		12.67	12.25	+0.42	2½,2	
d		12.81	12.81	0.00	2½,2	
e		12.88	12.64	+0.24	1½,1½	
f		13.01	12.88	+0.13	1½,1	
h		13.71	(13.35)	(+0.36)	1	
i		14.10	(13.56)	(+0.54)	1	
k		14.10	(13.75)	(+0.35)	1	
l		14.48	(13.98)	(+0.50)	1	
n		14.85	(14.51)	(+0.34)	1	

Q	SpT	SPg	SPv	SCI	w	
1	A0	7.88	8.12	-0.24	5 ,3½	
2	A0	10.58	(10.93)	-0.35	1	
3	A2	9.37	9.39	-0.02	4 ,2½	
4	A5	9.02	8.97	+0.05	3½,2½	
5	F0	7.85	7.76	+0.09	6 ,3½	
6	F0	8.96	8.94	+0.02	3 ,2½	
7	F2	7.68	7.56	+0.12	3 ,3	
8	F2	8.37	8.28	+0.09	3 ,2½	
9	F2	9.39	9.26	+0.13	4 ,2½	
10	F5	8.17	8.07	+0.10	3 ,2	
11	F5	8.37	8.16	+0.21	3 ,2½	
12	F5	8.89	8.73	+0.16	1 ,1	
13	F5	Var.	Var.			R
14	F5	9.73	9.44	+0.29	2 ,1	
15	F8	9.92	(9.58)	(+0.34)	1	
16	F8	10.66	10.43	+0.23	1½,2	
17	G0	7.60	7.23	+0.37	5 ,3½	
18	G0	8.69	(8.32)	(+0.37)	1	
19	G0	8.94	8.52	+0.42	2 ,1½	
20	G0	(9.17)	(8.42)	(+0.75)		
21	G0	(9.17)	(8.82)	(+0.35)		
22	G0	10.65	10.39:	+0.26:	2 ,2	D
23	G0	10.68	10.40	+0.28	3 ,3	
24	G5	7.71	6.88	+0.83	2 ,2	
25	G5	7.87	7.04	+0.83	3 ,2	
26	G5	10.07	9.19	+0.88	4½,3	
27	G5	10.57	9.44	+1.13	4 ,3½	
28	G5	11.27	10.34	+0.93	4 ,3½	
29	K0	7.56	6.77	+0.79	4 ,3½	
30	K0	7.80	6.80	+1.00	2 ,2	
31	K0	8.58:	7.16:	+1.42:	2 ,2	D
32	K0	9.03	7.88	+1.15	1½,1½	
33	K0	9.81	8.82	+0.99	3½,2½	
34	K0	10.29	9.32	+0.97	3 ,2	
35	K0	11.07	10.47	+0.60	2 ,2	
36	K0	11.3	9.7	+1.6	3½,3½	R
37	K2	9.55	8.67	+0.88	3½,2	
38	K2	10.78	9.45	+1.33	4 ,3½	
39	K5	10.18	(8.61)	(+1.57)	1	
40	A0	6.79	6.99	-0.20	2 ,2	
41	F8	7.46	7.27	+0.19	3 ,2	
42	F8	7.05	6.78	+0.27	3 ,3½	
43	K0	6.87	6.05:	+0.82:	2 ,2	D
44	K0	6.68	5.45	+1.23	2 ,2	
45	A2	7.19	7.32	-0.13	2½,2½	
46	A0	7.21	7.35	-0.14	3½,4	
47	G5	11.08	10.70	+0.38	4 ,3½	
48	A0	6.64	6.99	-0.35	2 ,2	
49	K0	7.97	6.78	+1.19	3 ,2	
50	F8	8.75	8.48	+0.27	1½,1	
52		11.79	11.07	+0.72	2½,2	
53		11.98	11.58	+0.40	2 ,1½	
54		12.01	11.71	+0.30	2 ,1½	
55			11.21		1	
56	G5	9.26	8.31	+0.95	1 ,1	
57	G0	9.89	(9.53)	(+0.36)	1	
58	F5	10.06			1	
59	K2	10.57	9.33	+1.24	1 ,1	
60	F8	10.26	(10.01:)	(+0.25)	1½	
61	F5	9.79	9.65	+0.14	2 ,1	
63	G0	6.33:	6.00	+0.33:	2½,2	D
64	F5	9.85:	(9.68)	(+0.17)	1½	D
69	G5	8.31	7.77	+0.54	2½,2	
70	B5	1.33	1.81:	-0.48:	1 ,2	D
71	K0	6.92	6.06	+0.86	2 ,2	
72	F0	5.75	5.65	+0.10	3 ,2	
73	A2	6.76	6.98	-0.22	2 ,2	
74	G5	4.82:	3.92:	+0.90:	3 ,2	D
75	Mb	5.6	4.0	+1.6	3 ,2	R
76	F0	7.91	7.83	+0.08	2 ,1	
77	F5	7.89	7.73	+0.16	2 ,1	
78	Mb	3.6	2.0	+1.6	2 ,1	R
79	K0	5.70	4.81	+0.89	3 ,2	
80	A5	6.64	6.61	+0.03	2 ,2	R
a		12.08	11.41	+0.67	2 ,1½	
b		12.26	11.73	+0.53	2 ,1½	
c		12.58:	12.26:	+0.32:	2 ,1½	D
d		12.80	12.41:	+0.39:	1½,1	D
e		12.85	12.43:	+0.42:	1½,1	D
f		13.24	12.82	+0.42	1 ,1	
g		(13.41)	(12.59)	(+0.82)		
h		(13.55)	(12.98)	(+0.57)		
i		(13.92)	(13.43)	(+0.49)		
k		(14.26)	(13.92)	(+0.34)		
l		(14.57)	(13.86)	(+0.71)		
m		(14.77)	(14.13)	(+0.64)		
n		(15.02)	(14.66)	(+0.36)		
o		(15.12)	(14.41)	(+0.71)		
p		(15.55:)	(14.76:)	(+0.79:)		
q		(15.59)	(15.14)	(+0.45)		
r		(15.89)	(15.25)	(+0.64)		
s		(15.80)	(15.51)	(+0.29)		

N O T E S

E 1

3 Pg 5 9.50; 13 9.54; 14 9.50: .
22 Pg 5 8.86; In 8.79 .
33 Pg 10 9.10; 14 9.16 .
34 Pg 2 8.12; 5 8.12; 12 (8.10); 14 8.12: Obs for 12 intern disc
35 Pg 10 10.76; 13 10.71; 14 10.80: .
38 Pg 2 6.29; 4 6.25; 12 6.28 .
39 Var.
61 Bi 4.1:4.1, 1"7; Pv 3 3.32; 12 3.29.
62 Sp Bi 193.8 d .

E 2

29 Pv 3 6.61; 10 6.65; 12 6.64 .
30 Var ? Pg 10 8.61; 12 (8.59); 14 8.64 .
31 Pg 14 8.78; In 8.71 .
46 Pg 10 11.01; 14 10.96: ; Pv 10 10.46; 14 10.41: .
47 Pg 10 11.13; 14 11.16: ; Pv 10 10.96; 14 10.99: .
69 Var.

E 3

28 Bi 9.3:11.1, 7" .
36 Bi 6.4:11.0, 7" ; Pv 3 6.42; 12 6.49; 15 6.46 .
38 Pv 7 7.88; 10 7.92; 12 7.91 .
45 Bi 6.0:8.5, 1" .
87 Bi 5.0:7.3, 13" .
88 Pv 3 7.46; 10 7.51; 12 7.49; 15 7.49.

E 4

1 Bi 9.0:9.6, 40".
9 Bi 10.0:12.3, 11" .
20 Bi 8.0:12, 30" .
35 Bi 9.4:10.1, 35" .
38 Probably var.
40 Bi 6.1:6.9, 3" .
41 Bi 6.6:7.7, 1" .
42 Pg 2 6.68; 12 6.68; 15 6.62; Pv 3 5.01; 12 5.04; 15 4.99;
16 4.99 .
47 Pg 2 6.34; 12 6.31; 15 6.31; Pv 3 5.54; 12 5.46; 15 5.46;
16 5.47 .
51 Bi 7.7:11.5, 20" .
76 Var ? SBS 3634 See Cape Mimeogram No. 1.
81 Bi 7.6:8.0, 0"4. Pv 3 6.83; 12 6.87; 15 6.86; 16 6.90 .
85 Pg 5 8.76; In 8.82.
88,9 Bi 10.3:11.2, 10" .
92 Pg 2 4.95; 4 4.90; 12 4.95; 15 4.93 .
Pv 3 5.01; 12 5.07; 15 5.04; 16 5.05 .

E 5

3 Bi 7.5:12.2, 23" .
4 Pg 5 8.50; In 8.44 .
8 Pv 1 10.04; 8 10.02; 10 10.05; 13 10.02; 16 10.07 .
9 Pg 5 8.49; In 8.44 .
11 Bi 9.0:10.3, 25".
17 Bi 8.8:9.5, 27".
24 Pg 5 9.32; In 9.39 .
43 Pv 3 6.92; 12 6.90; 15 6.88 .
45 Pg 6 10.54; 8 10.56; 10 10.49; Pv 8 10.66, 10 10.63.
46 Pg 8 10.99; 10 10.96 .
47 Pg 8 11.28; 10 11.25 .
49 Pg 8 10.90; 10 10.86 .
51 Pg 2 4.88; 4 4.90; 10 4.92: ; 12 4.89; 15 4.90
Pv 3 5.36; 10 5.40; 12 5.34; 15 5.38 .
55 Bi 5.5:7.1, 3" .

E 6

6 Bi 8.4:10.2, 33" .
14 Pg 2 8.19; 12 8.15; Obs for 2 intern disc .
38 Pv 1 6.77; 3 6.73; 12 6.78 .
40 Pv 3 5.43; 12 5.49 .
45 Pv 3 6.86; 12 6.82 . 51 Pg 2 7.10; 8 7.16; 12 7.10 .
53 Pg 2 7.43; 5 7.45:; 12 7.46. Pv 3 7.10; 12 7.14 .
78 Var. SBS 5395 See Cape Mimeogram No. 1.
79 Bi 5.2:5.3, 0".3 .
83 Var. B3p + A2p . SBS 5440 See Cape Mimeogram No. 1.
85,6 Bi 5.4:7.8, 20"
91 Bi 0".12 ; Pg 2 3.93; 4 3.92. Obs for 2 intern disc .
92 Bi 5.8:7.3, B9 .
96 Bi 4.7:4.8, 2" .
B Bi 7.4:9.6, 17".

E 7

1 Var.
2 Bi 7.9:9.2, 30" .
27 Bi 10" .
29 Bi 8.6:9.6, 36" .
44 Bi 5.7:8.3, 4" .
45 Bi 7.6:7.7, 0".5 .
72 Var ? . Obs for 13 intern disc .
81 Pv 3 6.86; 12 6.90 .
84 Bi 6.0:6.8, 3" .
85 Pv 3 6.69; 12 6.73 .
86 Bi 6.7:8.5, 13".
88 Pg 2 2.05; 4 2.07; 12 2.03; Pv 3 1.93; 12 1.90 .
h Pv 8 11.82; 9 11.87; 13 11.92:: .
k Pg 8 13.07; 9 12.99; 13 13.07:: .

E 8

12 Pv 1 7.63; 3 7.60; 12 7.64 .
14 Pv 1 7.38; 3 7.34; 12 7.37 .
16 Pg 5 8.71; 8 8.68 .
22 Var.
23 Bi 30" .
32 Pg 5 8.63; 12 8.60 .
33 Pv 1 7.87; 8 7.81; 12 7.84 .
43 Pv 1 6.99; 3 7.03; 12 7.00 .
50 Pg 8 11.72; 13 11.75 .
51 Pv 8 11.85; 13 11.88 .
55 Pv 13 10.58; 14 10.55 .
57 Pv 13 9.74; 14 9.69 .
60 Pv 13 10.07; 14 10.11 .
71 Bi 5.9:7.5, 1" .

E 9

13 Var. W Gruis .
22 Pv 1 10.35; 13 10.37; 14 10.40 .
31 Pg 5 8.60; 12 8.56; Pv 1 7.20; 3 7.13; 12 7.19 .
36 Var.
43 Pv 1 6.03; 3 6.04; 12 6.07 .
63 Pg 2 6.34; 4 6.29; 12 6.33 .
64 Pg 5 9.86; 14 9.82: .
70 Var ? SBS 8425. Pv 3 1.83; 12 1.79 .
74 Pg 2 4.80; 4 4.85; 12 4.81 . Pv 3 3.95; 12 3.90 .
75 Var.
78 Var. SBS 8636 See Cape Mimeogram No. 1.
80 Bi 6.8:9.9, 10" .
c Pg 9 12.56; 13 12.60 . Pv 9 12.23; 13 12.27 .
d Pv 9 12.39; 13 12.44: .
e Pv 9 12.40; 13 12.45: .