25. COMMISSION DE PHOTOMETRIE STELLAIRE

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SOUS-COMMISSION DES SÉQUENCES DE MAGNITUDES

PRÉSIDENT: M. REDMAN.

MEMBRES: MM. Baade, Cousins, Mme Payne Gaposchkin, MM. Stoy, Vyssotsky, Wallenquist.

From the letters and memoranda sent in by members of the Commission it is clear that there is a majority of opinion to the effect that the time has come for the Commission to re-examine the fundamentals of astronomical photometry. As Stoy has said in a circular letter to members: 'Perhaps the first problem of general photometry is to consider all the multitudinous series of magnitudes that have been used, and are likely to continue to be used in practice, to see if it is possible to produce a generally acceptable definition of the magnitude of a celestial body which is such that whenever or however it is measured with reasonably suitable apparatus, the same result will be obtained within the limit of observational error. Until different observers agree on just exactly what they are trying to measure, they are unlikely to arrive at concordant results.'

The present Report is based on memoranda prepared by Stoy and other members of the Commission. It aims at recapitulating the fundamentals of photometry and at emphasizing topics of current interest. The writer, who is aware that his own ideas have been allowed to influence the presentation, hopes that the Report will serve as a basis for discussion.

I. THE DEFINITION OF MAGNITUDE

The magnitude m of a star has been defined in terms of its 'brightness' B by the equation

$$m = s \log_{10} B + k, \qquad (1)$$

where s is a constant defining the 'scale' of magnitudes and k is another constant defining their 'zero point' For a 'normal' or Pogson scale we have $s = -2{\cdot}5$. The remark has been made that it would have been better to have adopted $s = -\log_e 10 = -2{\cdot}303$ but the magnitudes which have been used in practice are based on $s = -2{\cdot}5$ and it is most unlikely that there will be any general concensus of opinion in favour of a change now. The brightness B has been described as 'the total luminous flux effective on the receiver' It can be defined formally by the equation

$$B = \int_0^\infty B(\lambda)\, \phi(\lambda)\, d\lambda, \qquad (2)$$

where $B(\lambda)\, d\lambda$ = amount of energy with wave-length between λ and $\lambda + d\lambda$ incident per unit area cross-section of beam on the outside of the Earth's atmosphere and $\phi(\lambda)$ = fraction of this energy at wave-length λ transmitted through the Earth's atmosphere and the optical system used and finally absorbed and responded to by the light receiver employed.

We thus have $$\phi(\lambda) = P . A(\lambda) . T(\lambda) . R(\lambda),$$

where P = area of telescope aperture in cm.^{2};

$A(\lambda)$ = fraction of energy transmitted at wave-length λ by the Earth's atmosphere;

$T(\lambda)$ = fraction of energy transmitted at wave-length λ by the optical train used;

$R(\lambda)$ = response at wave-length λ of the light receiver.

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As regards $R(\lambda)$, the sensitivity of the receiver, it can be regarded as a determinable function of λ alone for a physical receiver used at a definite time. But for visual photometry, when the receiver is the human eye, $R(\lambda)$ can depend on the total brightness B (Purkinje effect), and if the receiver is a photographic plate $R(\lambda)$ may be dependent to some small extent on the duration of exposure. $T(\lambda)$ may change slowly with time (e.g. owing to the tarnishing of a reflector coating). The atmospheric transmission factor $A(\lambda)$ will certainly vary with time and locality and, in addition, involves the zenith distance z of observation. For zenith distances not too near to 90° the variation of $A(\lambda)$ with z is comparatively simple and may be represented by the equation $A(\lambda)=\{A_0(\lambda)\}^{\sec z}$, where $A_0(\lambda)$ is the transmission at the zenith, but when this expression for $A_0(\lambda)$ is substituted in the integral expression for B it does not lead, except in the limiting case of monochromatic magnitudes (see below, p. 357), to a simple law of variation of magnitude with zenith distance.

From a formal point of view the definition of B, and so of m, can only be made precise if the factors $\phi(\lambda)$ are stipulated for each wave-length. In theory then a 'system' of magnitudes can be defined by specifying a definite receiver attached to a definite telescope working in a definite place with definite atmospheric transmissions, work being confined to a definite zenith distance (and, if the receiver is a photographic plate, using a definite exposure time). These stipulations are quite impracticable, and even if they could be realized, the magnitudes obtained by one observer would not be reproducible by another since the factors $\phi(\lambda)$ would never be exactly the same. Consequently, with magnitudes defined as above, each observer must necessarily work with his own system and it cannot be expected that two such systems will agree. The disagreement is an inevitable consequence of the definition of magnitude in terms of the very complex quantity which we call 'brightness'

II. Practical Approach

An obvious practical procedure is to adopt a certain system of magnitudes as standard and then to attempt to reduce all measured systems of magnitude to this system. The problem then becomes one of the practicability of such reductions. An examination of the definition of magnitude summarized above shows that there is in general no simple *rigorous* relation between different systems. The reduction of one system to another can only be performed by an approximate process and the question now at issue is the degree of approximation. It becomes important to examine the method which has usually been employed and, if possible, to estimate its accuracy, since it is this consideration which determines the main issue, i.e. the extent to which any given observer can reproduce the system of magnitudes adopted as standard.

In brief the principle of the method which has been used is that in addition to measuring the magnitude m of a star in his own system each observer also obtains a measure C of its colour. The reduction to the standard system is then effected by employing an equation of the type (for a more general reduction formula see p. 360 below)

$$m_s=\alpha m+\beta C+\gamma, \tag{3}$$

where m_s is the magnitude of the star in the standard system and α, β and γ are constants which have to be determined by comparison of the observer's measured magnitudes with the magnitudes of the standard system. The constant α would be unity if both the observers' magnitudes and the standard system were strictly on the normal Pogson scale. As regards the colour measure C, one way of obtaining it is for the observer to measure an additional system of magnitudes m' using a different set of sensitivity factors $R(\lambda)$ or transmission factors $T(\lambda)$ (e.g. in photo-electric photometry the magnitudes m and m' may be obtained by using two different colour filters). He can then take $C=m'-m$ as a measure of colour, and the above equation of reduction becomes

$$m_s=(\alpha-\beta)\,m+\beta m'+\gamma. \tag{3'}$$

Now suppose two different observers carry out this process each obtaining measures of magnitude and colour and each deducing magnitudes m_s appertaining to the standard system. The question at issue is to what extent the two sets of deduced magnitudes m_s may be expected to agree. Stoy appears to be of the opinion that, provided sufficient care is taken, magnitudes obtained by a reduction process such as the above can be reproduced, at any rate for the great majority of stars, to an accuracy of the order of $\pm 0{\cdot}01$ mag. If he is correct it means that the three magnitude systems involved are connected by a linear relation of the form (3′) to this order of accuracy. It will be worth while for the Commission to examine this claim carefully.

III. Monochromatic Magnitudes

At this point it will be useful to refer to monochromatic magnitudes since for a large number of stars, over considerable ranges of wave-length, *and provided that they refer to the continuous spectrum*, monochromatic magnitudes (reduced to outside the Earth's atmosphere) possess the property we want, viz. that three sets of monochromatic magnitudes (i.e. monochromatic magnitudes at three wave-lengths) are connected by a linear relation of the form (3′). Their importance to the general photometric problem lies in this; that if it can be shown, as has been claimed, that any system of heterochromatic magnitudes is equivalent, to the desired accuracy, to a set of monochromatic magnitudes at a determinable wave-length, then it will follow that the linear relationship between three systems will also apply to heterochromatic magnitudes, thereby justifying the reduction to a standard system as indicated above.

In monochromatic photometry the light incident on the receiver is limited to a very small spectral range (often of the order of 1 A. or less) so that $T(\lambda)$ can be regarded as being constant within the small spectral range considered and as being zero outside it. The main difficulties inherent in heterochromatic photometry disappear. The monochromatic magnitudes m_λ are relatively simple quantities, being measures of the amount of energy per angstrom received at wave-length λ, and measures made by one observer should be reproducible, apart from actual errors of measurement, by another. They also have the convenient property of being linear functions of sec z (if the zenith distance z is not too near to 90°). Incidentally it is perhaps as well to remark that monochromatic magnitudes possess the property *that they can be corrected so as to refer to light fluxes received outside the Earth's atmosphere*, whereas heterochromatic magnitudes cannot, in the nature of things, be so corrected unless the radiation is subjected to preliminary spectroscopic analysis and the flux measured within each wave-length interval λ to $\lambda + d\lambda$. It seems desirable to emphasize this point; reference should be made to a previous Report of Commission 36 (*Trans. I.A.U.* **5**, 239–40, 1936). Of course, for sufficiently small band-width an approximate correction can be made, as can be shown formally by an application of Wesselink's approximation (see Sect. IV, below). The accuracy of the approximation requires investigation in any particular case. But the evident advantages of monochromatic magnitudes are offset by the circumstance that they can only be measured for the brighter stars, and their main interest to members of Commission 25 is as was indicated in the preceding paragraph.

At this point mention must be made of a difference of opinion between astronomers as to exactly what a monochromatic magnitude is. Workers in spectrophotometry of the continuous spectrum are accustomed to define the monochromatic magnitude m_λ at wave-length λ (corrected to outside the Earth's atmosphere) *as appertaining to the continuum at that wave-length*. The formal definition of m_λ would then be

$$m_\lambda = s \log_{10} . B_c(\lambda) + k, \tag{4}$$

where $B_c(\lambda)\, d\lambda$ = amount of energy appertaining to the continuum with wave-length between λ and $\lambda + d\lambda$ incident per unit area cross-section on the outside of the Earth's atmosphere,

$s = -2{\cdot}5$ for the normal magnitude scale,

and k = a constant defining the zero point of the scale.

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With this definition it has been found by observation that for a considerable number of stars and over considerable wave-length ranges the quantity $\frac{d}{d\,(1/\lambda)}\,(m_{1_\lambda}-m_{2_\lambda})$ is, to a high approximation, independent of wave-length for a pair of stars X_1 and X_2. As a consequence of this we have a linear relation of the type (3′) between any three sets of monochromatic magnitudes at any three wave-lengths. But some astronomers seem to consider that the monochromatic magnitude m_λ should refer to some sort of smoothed spectral energy distribution in which the stellar spectral lines are incorporated. It would be desirable for the International Astronomical Union to standardize the nomenclature, but this is hardly a matter for action on a recommendation by Commission 25 alone, since Commission 36 (Spectrophotometry) should clearly be consulted. The personal view of the writer of this Report is that the term monochromatic magnitude should be restricted to apply to the continuum as far as is practicable (but for the later spectral types it becomes increasingly difficult to define the continuum) since the outstanding and convenient property of monochromatic magnitudes referred to above and expressed by equation (3′) only holds if this restriction is applied.

In this Report the term monochromatic magnitude is used as defined by equation (4), i.e. it refers to the continuum. It is well known that the constancy of the spectrophotometric gradient difference

$$\Delta G_\lambda = 0{\cdot}921\,\frac{d}{d\,(1/\lambda)}\cdot(m_{1_\lambda}-m_{2_\lambda})$$

would follow at once to a high approximation if stars were black-body radiators, which would imply that the colour temperature is independent of wave-length. For black-body radiators then the monochromatic magnitudes m_λ would possess the property (3′). But it is also now known that stars, even when the continuous spectrum alone is considered, do not radiate as black-bodies as is shown at once by the existence of discontinuities in the continuum near the Balmer and Paschen series limits. The discontinuities near the Balmer limit can be considerable and the measured values range up to a maximum value of about 1·2 mag. Further, spectrophotometric measurements at Jungfraujoch (Barbier and Chalonge, *Annales d'Astrophysique*, **4**, 30, 1941) have shown that the colour temperature of a star, and so the spectrophotometric gradient-difference between two stars, can be very different on the short- and long wave-length sides of the Balmer limit. The result of this and of the existence of the discontinuities is that an equation of the form (3′) would certainly not hold if monochromatic magnitudes on both sides of the limit were involved. But spectrophotometric work has also shown that over the visible spectral range the colour temperatures of stars of earlier types (other than stars reddened by interstellar matter) vary but little with wave-length, so that for such stars and for the visible spectral range, monochromatic magnitudes possess the property (3′) to a high approximation. For stars of later type, colour temperatures seem to vary but little with wave-length from about λ4600–λ7000, but for wave-lengths less than about λ4600 the colour temperature falls off. For such stars the property (3′) will certainly not hold to 0·01 mag. accuracy for wave-lengths less than about λ4600. The consequence of the known spectrophotometric results is thus that for stars in general monochromatic magnitudes only possess the property (3′) to a high approximation for wave-lengths greater than about λ4600. If this result can be extended to heterochromatic magnitudes the claim that these can be rendered reproducible, when reduced to a standard system by formulae of the type (3) or (3′), may be justified, but only for the longer equivalent wave-lengths. It seems necessary that this restriction should be kept in mind.

IV Equivalence of Heterochromatic and Monochromatic Magnitudes

For our purposes we require that a heterochromatic magnitude of a star should be equivalent to its monochromatic magnitude at a determinable wave-length which does not depend on the star but only on the instrumental equipment. This means that the

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equivalent wave-length should involve the function $\phi(\lambda)$ only and should not involve $B(\lambda)$. Rigorously there can be no wave-length satisfying this property and it becomes a question of approximation. Wesselink (*Trans. I.A.U* **7**, 269, 270, 1950) has pointed out that provided the second derivative $B''(\lambda)$ of $B(\lambda)$ can be ignored over the range of integration, there does exist an equivalent wave-length λ_0. Wesselink shows, that subject to the validity of the approximation whereby $B''(\lambda)$ is ignored

$$B=\int_0^\infty B(\lambda)\,\phi(\lambda)\,d\lambda=\kappa B(\lambda_0),$$

where
$$\kappa=\int_0^\infty \phi(\lambda)\,d\lambda,$$

and
$$\lambda_0=\int_0^\infty \lambda\phi(\lambda)\,d\lambda\Big/\int_0^\infty \phi(\lambda)\,d\lambda.$$

(It may be of interest to note that in the theory of stellar atmospheres use has been made of an approximation, introduced by Eddington and developed by Barbier (*Annales d'Astrophysique*, **6**, 121, 1943), which is essentially the same as Wesselink's and is formally a particular case of the latter.)

So the heterochromatic brightness B differs only by a constant factor κ from $B(\lambda_0)$, the monochromatic brightness at wave-length λ_0 outside the Earth's atmosphere. (We are ignoring the existence of spectral lines for the moment, and so we are identifying $B_c(\lambda)$ with $B(\lambda)$.) Accordingly, apart from a possible difference of zero-point, the heterochromatic magnitude is identical with the monochromatic magnitude at wave-length λ_0. As regards the validity of the approximation whereby $B''(\lambda)$ is ignored, the principal neglected term in the expression for B is $\frac{1}{2}B''(\lambda_0)\int_0^\infty (\lambda-\lambda_0)^2\,\phi(\lambda)\,d\lambda$. It thus appears that *provided the existence of spectral lines can be neglected* ($B''(\lambda)$ and the higher derivatives can be large within the profile of a line) the approximation will be a good one if the effective range of integration is sufficiently small, as would be realized in practice, for example, for photo-electric magnitudes using filters of reasonably small band-width. For photometry involving large band-widths the approximation cannot be so good, and in particular it is presumably rather poor for photographic photometry in which a large spectral range is involved.

Statements are sometimes made which seem to imply that a heterochromatic magnitude is equivalent to the monochromatic magnitude at *the effective wave-length*. The effective wave-length λ_{eff} is defined as being the weighted mean of λ with weight $B(\lambda)\,\phi(\lambda)$ so that

$$\lambda_{eff}=\int_0^\infty \lambda B(\lambda)\,\phi(\lambda)\,d\lambda\Big/\int_0^\infty B(\lambda)\,\phi(\lambda)\,d\lambda,$$

and λ_{eff} varies from star to star, the variation involving the *first* derivative $B'(\lambda)$, as Wesselink has pointed out. The statement that the heterochromatic magnitude is equivalent to the monochromatic magnitude at λ_{eff} is clearly not rigorously true, and it could only be regarded as an approximation for a star which approximated to a monochromatic source, which actual stars do not. Consequently, the effective wave-length is of no interest in stellar photometry apart from its possible use as a measure of colour, a fact which does not seem always to have been clearly realized.

It now appears that, provided Wesselink's approximation can be accepted, heterochromatic magnitudes are equivalent to monochromatic magnitudes (outside the Earth's atmosphere) at the equivalent wave-length λ_0, and so they may be expected to have the very convenient property that monochromatic magnitudes of the continuous spectrum possess, viz. that in a large number of cases three separate systems are connected by a linear relation. Of course, as has been pointed out above, this statement cannot always be true, since it is not always true for monochromatic magnitudes, and the photometric worker who wishes to reduce his magnitudes to a standard system must be on his guard against cases in which the reduction is not applicable to the high degree of approximation he expects. But in addition to this there is the question of whether Wesselink's approximation is justified. It depends on ignoring the second and higher derivatives of $B(\lambda)$, and the approximation will not be so good for magnitudes involving large spectral ranges. There is also the matter of the effect of spectral lines which must now be considered.

V THE EFFECT OF SPECTRAL LINES

We can retain Wesselink's approximation by restricting its application to the continuum. For a given set of heterochromatic magnitudes denote the contribution of spectral lines to the magnitude m of a star by δm. Thus if the spectral lines were absent the magnitude would be $m-\delta m$. We can apply Wesselink's approximation to this magnitude $m-\delta m$ and so the monochromatic magnitude (appertaining to the continuum) at the equivalent wave-length λ_0 is $m-\delta m$. Consequently, for three systems the quantities $m-\delta m$ will be connected by a linear relation in those cases when the same is true for the monochromatic magnitudes. But the method of reduction which has been advocated for the reduction of magnitudes to a standard system requires that the magnitudes m in the three systems should be connected by a linear relation. This can only be true if the line contributions δm in the three systems are connected by a linear relation.

It should be stated at this point that the line contributions δm cannot always be ignored in themselves. As an example of the kind of contribution that sometimes exists, reference may be made to the spectrophotometric work of E. G. Williams who has investigated (*Ap. J* **79**, 280, 1934) the value of δm for photo-electric magnitudes obtained by Elvey with a violet filter, and by Stebbins and Huffer with a blue filter. The values of δm for these two systems range up to 0·44 mag. and 0·23 mag. respectively Clearly if our standard of accuracy is of the order of $\pm$0·01 mag. we cannot ignore the line contributions without further consideration, and the question now is whether for three systems we may expect to find that the values of δm are linearly connected to this standard of accuracy. It is unlikely that this should be so, and accordingly it is unlikely that for heterochromatic magnitudes in general reduction to a standard system can be effected, to $\pm$0·01 mag. accuracy, by formulae of the type (3) or (3′). It would only be safe to employ such a reduction when the spectral ranges used are such that the line contributions δm are relatively small (and even then we should have to be sure that the reduction is valid for monochromatic magnitudes at the equivalent wave-lengths).

This, however, is not to say that an observer who measures magnitudes in two systems cannot refer them to a standard. He could certainly do this if the equivalent monochromatic systems $m-\delta m$ are connected by formulae of the type (3) or (3′) and if, in addition, *the quantities δm all depend only on the colour of the star as expressed by its spectrophotometric gradient*. The reduction equation (3) would then have to be replaced by the more general equation

$$m_s=\alpha m+f(C)+\gamma, \tag{5}$$

where $f(C)$ is a function of C to be determined numerically by a comparison between the observer's measured magnitudes and the standard system. Further, the conditions just stated are too rigorous; equation (5) is of more general validity since it does not really depend on the assumption that the equivalent monochromatic systems $m-\delta m$ are connected by formulae of the type (3) or (3′), an assumption which would limit its use to systems such that the equivalent wave-lengths lie in a spectral range (such as λ4600–λ7000 for the later type stars) for which the colour temperature is approximately constant so that a uniform spectrophotometric gradient exists. The reduction equation (5) will remain valid if (i) the spectral energy distribution function $B_c(\lambda)$ of the continuum depends, apart from a scale factor, only on one parameter G such that there is a definite value of G attached to each individual star; (ii) if the band-width used is small enough for Wesselink's approximation of the equivalent wave-length to be valid; and (iii) if the line intensity contributions δm also depend only on the same parameter G. G may be taken as the spectrophotometric gradient over the range (λ4600–λ7000) for which the gradient is (approximately) uniform. Condition (i) will then be satisfied if the departures (measured in magnitudes) at each wave-length from the black-body curve represented by the gradient G are themselves functions of G alone. This is a matter for observational investigation.

As regards the line intensity contributions it is doubtless roughly true on the whole that δm is a function of colour (i.e. of the parameter G) for any specified magnitude system. Line strengths depend roughly on spectral type and so (excluding stars reddened by interstellar matter) roughly on spectrophotometric gradient. But this can only be a rough approximation since for stars of the same colour line strengths (at any rate for some lines) are known to involve absolute magnitude effects. For this reason it appears unlikely to the writer of this Report that heterochromatic magnitudes in general can be reduced to a standard system with an accuracy of the order of $\pm 0{\cdot}01$ mag. if each observer only measures two magnitude systems.

VI. Three Colour Photometry

On the other hand the increasing accuracy, *within each system* of photometric measurements (this applies particularly to photo-electric systems) has brought us to a point at which the internal accuracy of a magnitude system is of order $\pm 0{\cdot}01$ mag. Consequently it becomes desirable to be able to reduce measured systems to a standard system with a comparable accuracy. It is at once suggested that this may be possible if the single parameter C representing colour were replaced by two parameters (which may be thought of roughly as representing colour and line strength), this would mean that each observer would have to measure three systems. The possible need for three colour photometry was mentioned briefly in a previous report submitted to the Commission (Report of the Sub-Commission on Standards of Stellar Magnitude, *Trans. I.A.U* **7**, 268, 1950). It has now been advocated to the Commission in a much more definite and detailed form in a memorandum by W Becker. The following passages are extracted from this memorandum (see also *Mitteilungen der Göttinger Sternwarte*, No. 79, 1946):

The fact that the spectral ranges (*pg*, *pv*, red) used in astronomy have been chosen without full regard to present astronomical requirements (the first two were selected at a time when astronomers knew next to nothing about stellar radiation) opens the question whether we are entitled to consider the position and the limits of these ranges as fulfilling their purpose.

To answer this question requires that we make perfectly clear what we are to consider as 'fulfilling the purpose' The first point of view is that we must reach the faintest possible celestial objects by photographic methods with the shortest possible exposures. The second point of view lies in the fact that it is desirable to learn as much as possible of the intensity distribution in the spectra of celestial bodies by using integral-photometric methods as far as possible, since spectral photometry, as far as we can see, will remain restricted to very few of the brighter objects.

In the class of problems which are related to the first point of view, a magnitude means nothing but a quantity which is fundamentally undefined. Together with right ascension and declination this figure is, so to speak, a label attached to an object in order that we may recognize it and subject it to statistical analysis.

In the class of problems of the second point of view the magnitude is a physical quantity, which, according to the position and limits of the spectral range, informs us of the peculiarities of the intensity distribution (e.g. Balmer-limit, depression of the intensity curve in the ultraviolet in later spectral types). From this information we should be able to draw conclusions as to those fundamental characteristics of these objects which are more difficult or impossible to obtain in other ways (e.g. colour temperature, radiation temperature, deviations from black-body radiation, spectral type, luminosity).

There are of course problems where both points of view are of importance, but in general only one or the other is prominent.

Returning to our question as to the fitness of the spectral ranges in use at present, we must undoubtedly consider the international photographic spectral range (m_{pg}) as appropriate within the framework of the *first* range of problems, since this range is the most suitable one if we wish to reach the faintest possible stars with the shortest possible exposures. Its weakness, however, lies in the fact that it achieved this importance not for astronomical reasons, but only for reasons of observational technique. It may lose its importance if the technique succeeds in producing more efficient plates sensitive for other spectral ranges.

The *second* range of problems involves physical demands on the magnitude scale. It is clear first of all that one cannot understand the intensity distributions and spectra of celestial bodies by using magnitudes in two spectral ranges only. In my experience there is, however, no necessity to use, for example, six spectral ranges as Stebbins and Whitford did for their special purposes, but three ranges are sufficient; these can be defined and limited by the proper choice of plate and filter in such a way that the particularly important peculiarities of the intensity distribution can be grasped quantitatively. Since astronomical integral-photometry is normally carried out in the wave-length range of the panchromatic plate (about 700–330 mμ), we must select our three spectral regions as appropriately as possible, e.g. with regard to our experience of spectral photometry in the continuous spectrum. This experience indicates that the intensity distribution between 700 mμ and about 460 mμ can be represented for stars of all spectral classes (apart from stars showing band spectra) by *one* gradient, which is particularly suitable for the determination of colour temperature because there are so few absorption lines. A comparison of the radiation with that of a black-body shows deviations from black-body radiation in the spectral range <460 mμ, which appear in the form of the Balmer absorptions in hydrogen stars, and as a depression of the intensity curve which increases with decreasing wave-length in later spectral types. Next to the colour temperature it is most important to obtain the Balmer absorption and the short-wave depression of the intensity curve by integral-photometry, because they are the essential applications of photometry in the second range of our problems (dependence of the Balmer absorption and the depression on spectral type and luminosity). We should therefore call the following three spectral ranges appropriate: about 640, 470 and 370 mμ.

The last mentioned should actually be still further in the ultra-violet if this would not affect its sensitivity too much. All three ranges can easily be realized by the right choice of plate and filter. Their width can then easily be narrowed down (to about 50 mμ) beyond that on which the m_{pg} is based. I have already used these spectral ranges for more than ten years. To distinguish them from the international ranges, I have called them standard ranges, to emphasize the fact that they are not defined by irrelevant coincidences, but with regard to the requirements of stellar radiation. It may be that this choice of name is not a happy one, since it has already given rise to misunderstandings. The above consideration thus leads to the conclusion that neither the international *pg* nor the *pv* range is appropriate to the class of problems where the magnitude is considered as a physical quantity. The *pv* range lies at an 'uninteresting' place in the spectrum and the *pg* range has an effective wave-length which is too short or too long, and its width is much too great, as it includes the whole 370 mμ and 470 mμ ranges. I believe that the division of the problems of integral-photometry into two groups, with all its consequences for the selection of spectral ranges, should generally receive much more emphasis, and that Commission 25 of the I.A.U. should take care of this by undertaking the establishment of scales not only in the usual international spectral ranges, but also in other ranges. In this connection I should also consider it the task of the I.A.U. to contact an efficient optical firm in order that all observatories may always have filters of exactly the same composition at their disposal.

It seems to the writer of this Report that Becker has made out a very strong case and that members of the Commission should consider it with great care. Some remarks may be added concerning the existing system of International Photographic Magnitudes. The large spectral range involved makes Wesselink's approximation of the equivalent wave-length a rather poor one and this circumstance makes it doubtful whether the International Photographic System is reproducible when we aim at high accuracy.

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In fact Becker considers that it is appropriate only to the first group of problems in which 'a magnitude means nothing but a quantity which is fundamentally undefined' But it is perhaps necessary to remark that in our desire to give magnitudes precise meaning we must not forget the existence of problems appertaining to Becker's first group! We do desire to obtain what photometric information we can about the faintest celestial objects, and most astronomers will probably agree that we shall have to employ photographic magnitudes for some time to come. It may well be, however, that we must recognize that we cannot give them precise meaning, and that in reducing them to the International Standard we must be satisfied with a tolerance, as judged by Stoy's criterion that different observers should be able to reproduce each other's results, which is substantially greater than 0·01 mag.

The attention of the Commission is directed to Becker's concrete proposal that the International Astronomical Union should undertake the task of making standard filters generally available.

VII. Photo-electric Magnitudes

The development of physical receivers has emphasized the importance of the fundamental problems which, in response to what appear to be the wishes of the majority of members of the Commission, form the main theme of this Report. The internal accuracy of any given system of carefully measured photo-electric magnitudes is so high that it may well be doubted whether one system can be compared with another, or reduced to another, with comparable accuracy. Nevertheless, some astronomers feel that an attempt should be made to lay down a standard system to which photo-electric magnitudes can be reduced. Weaver has forwarded a memorandum in which he advocates that a new sub-commission should be created which will have as its task:

(1) The establishment of criteria of an 'ideal' photo-electric colour and magnitude system.

(2) The recommendation to photo-electric observers of ways and means of attaining this ideal system, and of achieving a standardization of their results that will permit those results to attain their greatest possible usefulness.

Weaver's proposal is endorsed by Shapley who has suggested (in opposition to the majority who desire a general discussion on fundamental photometric problems) that questions of photo-electric standards should be made the subject of the proposed symposium to be held on the occasion of the General Assembly. Weaver recognizes that there is present 'the possible danger that, to the accuracy obtainable in photo-electric systems, a simple linear transformation between systems is inadequate' But he points out that 'the diversity of colour systems and zero points of magnitude scales now found in the literature of photo-electric photometry is a source of great inconvenience to any investigator interested in comparing and making use of the results of several observers' Clearly it would be desirable to reduce all photo-electric magnitudes to a standard system, but it appears that some inquiry is needed as to the feasibility of this. Weaver considers that 'because of the large number of observational results that have been obtained in the past (mostly by photography) on the International System, it would seem, from general considerations, that any photo-electric system (unless it is for a special purpose) should not depart greatly from the International System' This opinion seems to be directly opposed to the principles advocated by Becker (see above, Sect. VI) who regards the existing International Photographic System as being only applicable to problems appertaining to his first group. Becker would doubtless argue that if photo-electric standard systems are to be developed now they should conform to the equivalent wave-lengths he advocates as being appropriate to problems of the second group.

It does seem that it would be appropriate to set up a sub-commission charged with the task of reporting on the feasibility and desirability of setting up internationally recognized photo-electric standards. But it would probably be unwise at the present juncture if the terms of reference of such a sub-commission were restricted by any attempt to stipulate what the standards should be. It is important to ensure that the sub-commission should be thoroughly representative of all shades of opinion. It may well include in its task the question of the provision of standardized filters which has been raised by Becker.

Some remarks may be added here about the band-widths of filters. It is clearly desirable that Wesselink's approximation for the equivalent wave-length should be a good one, and this means that the band-width should not be too large. Becker contemplates band-widths of the order of 500 A. but it would seem that some numerical investigation should be made of the upper limit to a filter band-width which would ensure that the approximation of the equivalent wave-length is good to, say, 0·01 mag. Hogg and Beryl Hall (*Monthly Notices, R.A.S.*, **111**, 325, 1951) have measured the magnitudes of bright southern stars using the band 4500–4600 A., a band-width of only 100 A. Incidentally in this work the starlight was dispersed by a prism and only the light over the range 4500–4600 A. was allowed to enter the receiver (a 931 A. electron multiplier), this being effected by a slit of the necessary width inserted in the focal plane. The arrangement gives, in effect, a filter of 'square' form, the use of which is advocated by Woolley. It has the effect of reducing the range of integration required for a given sensitivity and so improves the Wesselink approximation of the equivalent wave-length. For a band-width as small as 100 A. the approximation should be a very good one. There remains the contribution of spectral lines to the integrated magnitude, and if internationally recommended filters are to be adopted it would be helpful if these contributions could be measured spectrophotometrically for the brighter stars of all types.

VIII. Conclusion

It is probably inadvisable for Commission 25 to make any formal recommendations unless it can be ascertained that such recommendations will have practically the unanimous support of all photometric workers. It is somewhat doubtful whether such unanimous support will be forthcoming for many recommendations at the present time. It may prove possible (although even this is doubtful) that we may all agree on a definition of the term monochromatic magnitude (the main point is whether it should refer to the continuum or not). But this is a minor matter. What is important is that there has been a renewed interest in photometric problems, and I think that in this connection members of the Commission will wish me to pay especial tribute to the work of Stoy who has stimulated this interest, particularly an interest in the fundamentals of photometry. At present photometry has entered on a phase in which individual initiative is playing a large part and this is all to the good. The results now being obtained by many of our members, often by the use of new technique, should in themselves throw light on the fundamental problems sketched in this Report. In the meanwhile discussion can do nothing but good, and it seems to the writer very desirable that most of the time available to the Commission at the General Assembly should be devoted to some kind of symposium dealing with the matters raised and not to formal business such as the drafting of resolutions, which may easily prove to be premature.

Some reports which have been received on actual work done are given in the Appendix to this Report.

W. M. H. Greaves
President of the Commission

APPENDIX

Reports and Comments on Photometric Work

Cambridge (England) Observatories. Report by Redman:

Pg and *Pv* magnitudes of 1265 stars in a range approximately $7{\cdot}5 - 10Pv$ have been measured in the twenty-four Selected Areas at $+15°$, by direct comparison with the Pole, using eighty-two pairs of plates. In nine of these Areas the results have been checked

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by photo-electric observations of 442 stars, involving 715 direct comparisons with the Pole. The results of both programmes are now being worked up in preparation for publication. The chief errors in the photographic work appear to be zero errors, mostly due to sky irregularity, but on the whole the photographic results, including the zeros, are very satisfactorily confirmed by the photo-electric observations, systematic differences being of the order of one or two hundredths of a magnitude.

In the course of this work about 100 stars of the *Seares Ross Joyner Catalogue* have been compared photo-electrically with the N.P.S. Brighter than 10^m there is very close adherence to the existing N.P.S. *Pg* and *Pv* scales. At the same time convincing evidence of the N.P.S. scale errors for brighter stars, near 6^m, has been obtained and a revision of N.P.S. values has been attempted, as described in the Report of the Sub-Commission on Sequences of Magnitudes.

The photo-electric work at Cambridge has been carried out using a 931 A. photomultiplier with a pulse-counting arrangement to measure its output. In the existing set-up, with a 15-inch telescope and the photomultiplier not refrigerated, the magnitude limit is about $11^m{\cdot}5$. This is determined principally by the brightness of the sky and could be improved only by using a smaller diaphragm in the focal plane. The precision of the measures seems to be almost wholly controlled by the sky.

Cape Observatory (*Royal Observatory, Cape of Good Hope*). Report by Stoy and Cousins:

The following is a brief report of the work being carried out at the Cape Observatory which falls within the scope of Commission 25.

Standard Magnitudes. A preliminary system of standard magnitudes (the Southern or '*S*' system) was set up in 1948 and the magnitudes for 467 stars between $6^m{\cdot}5$ and $10^m{\cdot}0$ in the nine *E* regions at $-45°$ were circulated in mimeogram form. Since then work by Prof. Redman at Cambridge has provided the material for a much stronger link with the International System. He suggests a change of $0^m{\cdot}07$ in the zero point of *SPg*. Further information that has recently become available indicates that the *S* system so corrected coincides with the International System within the limits of ambiguity with which that system is at present defined. Thus we have

$$IPg = SPg - 0{\cdot}07,$$
$$IPv = SPv.$$

Since 1948 '*S*' magnitudes have been derived for all stars brighter than the 10th magnitude in an area of $5° \times 5°$ round each *E* region and considerable progress has been made with extending the system both to brighter and to fainter stars. For the brighter stars the observations have been made with Fabry photometers, and magnitudes with internal standard errors of less than $0^m{\cdot}01$ have been obtained for all stars brighter than 7·0 *Pg* and for many stars between 7·0 and 10·5. For the fainter stars, work for the present being concentrated on the range of magnitude from 10 to 15. A *Durchmusterung* is being prepared of all stars within the central $1° \times 1°$ area of each region and the corresponding photometric measurements are being made as completely as possible for stars within the central $45' \times 45'$ and brighter than 14·0 *Pg*. The observational material on which this survey is based was obtained partly at the Cape and partly at Pretoria.

The Bright Stars. A programme to determine the photographic magnitudes of stars south of 6° N. with *HR* magnitudes 5·0 and brighter was started in 1945. When this programme was started the inherent accuracy of the Fabry photometer with which the observations are being made was not fully realized and it was only hoped to attain a standard error of $\pm 0^m{\cdot}03$. The present aim is an internal standard error of $\pm 0^m{\cdot}01$, and as the stars are scattered all over the sky this calls for special precautions in maintaining a constant zero point. The programme is nearly completed. Many of the 850 stars have been observed over ten times and several variables of small range detected. A programme to determine the colours of these stars with comparable accuracy was begun in 1948 and the observations are now nearly complete. A photo-electric photometer is being used and each star is being observed at least five times.

The Zone Stars. Steady progress is being made with the programme which aims at providing photographic and photovisual magnitudes for the 75,000 stars south of −30° of which the positions and proper motions are being determined in the photographic revision of the AG zones. Nearly 50,000 such stars have now been measured and publication of these magnitudes on the adopted standard system ($SPg - 0{\cdot}07$, SPv) has been started. The magnitudes for the 12,000 stars in the −35° to −40° zone are included, together with spectral types and proper motions in the positional catalogue which has been sent to the printers in a form suitable for direct photographic reproduction. The final copy of the catalogue for −30° to −35° which includes nearly 13,000 stars is now being typed. Of the 23,500 stars in the zones between −52° and −64°, the magnitudes are measured and reduced to the *S* system as far as 21 hours of R.A. and it is hoped that these zones will be completed early in 1951. The magnitudes for the stars in the −35° to −40° and the −52° to −64° zones are based on plates taken at Pretoria by Dr Redman.

Parallax Stars. A programme begun by Dr Jackson in 1948 aimed at providing photographic and photovisual magnitudes for all the stars whose parallaxes had been determined at the Cape. Though this programme was not complete at the time of his retirement, considerable progress with it had been made and preliminary results incorporated in *Cape Annals*, Vol. **16**, which gives details of the Cape parallax determinations up to star 1600. It is hoped to complete Dr Jackson's original programme and to extend it to include all stars in the Southern Hemisphere for which a parallax has been determined.

Commonwealth Observatory. Report by Woolley:

(1) Monochromatic magnitude differences between the Sun and Sirius were measured by photographic spectrophotometry in four wave-lengths at the focus of the Mount Stromlo solar tower. (Woolley and Gascoigne, *M.N.* **108**, 491, 1948.)

(2) Very low dispersion spectra, obtained with a coarse grating in front of a 30-inch reflector were used to determine magnitudes at 5980 and 4480 A. Thirty-four were observed with standard errors of about ±0·05 in magnitude and ±0·08 in gradient. (Woolley and Gotlieb, *M.N.* **110**, 206, 1950.) The method has been extended to stars of the 9th magnitude.

(3) Relative spectrophotometric gradients were measured for 166 southern stars by photographic spectrophotometry. The results, which were obtained by a slitless spectrograph on a 30-inch reflector, were reduced to a scale uniform with Greenwich. (Gascoigne, *M.N* **110**, 15, 1950.)

(4) Magnitudes of sixty-three bright southern stars using the band 4500–4600 A. have been determined by photo-electric photometry. Dispersion was effected by means of an objective prism. (Hogg and Mrs Hall, *M.N* **111**, 325, 1951.) The standard deviation for a primary star was $\pm 0^{m}{\cdot}002$.

With regard to (4) Woolley comments as follows:

Systems of stellar magnitude based on narrow band photometry present several advantages, viz.:

(*a*) If the band is of 'square' form and does not exceed a few hundred angstroms in width then the effective wave-length of the system is quite independent of the colour of the source.

(*b*) Accordingly there follow advantages that corrections for atmospheric extinction can be more satisfactorily determined and applied and that the transfer of results from one system to another can be effected more precisely than is the case with wider band systems.

(*c*) Slight variations of band width in such a system are unlikely to affect results seriously because of an averaging effect between any absorption lines at the longer and shorter wave-lengths of the band.

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Edinburgh Observatory (*Royal Observatory, Edinburgh*). Report by Greaves:

Preliminary work has been carried out by Ellison, using a 10-inch triplet lens and Kipp Actinometer.

Harvard Observatory:

Shapley reports that a special effort is being made at Harvard to improve the basic photometry in the Magellanic Clouds, chiefly because of its great importance in the study of the super-giant stars and in the establishing of the period-luminosity relation. Mr Ivan King has used a photo-electric photometer with the 60-inch reflector at the South African station of the Observatory to study some of the major sequences in the two Clouds. He has also measured sequences in some of the large globular clusters. These steps, and similar steps made by other photo-electric photometrists in the Southern Hemisphere, are a necessary preliminary to accurate photometry in the southern sky where so much work has heretofore of necessity been based on inadequate magnitude standards.

Shapley adds the following comments:

A number of American astronomers believe that in the near future (perhaps not yet this year) we must accurately define the *photo-electric* standards of magnitude, which are now being obtained in six or more colours. With the accuracy now attainable with photo-electric photometers, we need a more securely defined set of magnitude standards than are provided by the currently accepted North Polar Photographic (*Pg*) sequence. It is quite possible that within a few years all new magnitude work will be based on photo-electrically adjusted standards. But a photo-electric magnitude system depends on the type of telescope, whether silvered or aluminized (when a mirror), the age (or stage of decay) of the silver or aluminium coating, the precise nature of the filters used, and, of course, upon the characteristics of the photo-electric equipment. Hence the need of agreements.

For the time being it may be best to determine the deviation of each photo-electric system from the North Polar Sequences (blue, yellow, red) or from sequences derived from the North Pole, and to postpone the setting up of International Photo-electric Standards until further experience has accumulated.

Kapteyn Astronomical Laboratory, Groningen:

Van Rhijn reports that photographic magnitudes of the stars brighter than magnitude 13 in Kapteyn's northern Selected Areas are being determined at present at the Kapteyn Laboratory. The field is $3^\circ\!\cdot 5 \times 3^\circ\!\cdot 5$. The spectral classes of the same stars have been determined at the Hamburg Observatory. The magnitudes and spectral classes are being published in the *Bergedorfer Spektral Durchmusterung*. Vols. **1–3** containing the areas at declination $+30^\circ$ to $+90^\circ$ have been published, Vol. **4** containing the areas at declination $+15^\circ$ is being printed at present and the zone 0° will be completed in 1951.

Van Rhijn adds the comment that the problem of establishing sequences of standard magnitudes all over the sky needs discussion.

Leiden Observatory. Report by Oosterhoff:

(1) *Photographic Magnitudes in the Southern Selected Areas*. This programme consists of two parts:

(*a*) Determination of photographic magnitudes of stars in areas of about $4^\circ \times 4^\circ$ with a limiting magnitude of about 10·5. The plates were taken by Dr Wesselink with the Rockefeller astrograph of the Leiden station at Johannesburg. All plates were taken with an objective grating for the determination of scale. In order to obtain a common zero point the areas have been interconnected zonal-wise, whereas the different zones have been connected with the zone of declination -45° by means of the areas 164, 170, 176 and 182, which have been used as standard fields. All exposures have been made with both components of the telescope used simultaneously.

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The plates are measured in a Schilt microphotometer which has been specially adapted for this programme. Before the next I.A.U. meeting all 159 plates taken with one of the objectives will probably have been measured by Mr Kooreman. Only the first steps in the reduction have been made so far.

(*b*) The extension of these magnitudes to a fainter limit of about 14·5. The plates for this programme have been taken. The measurement, however, will not be started until part (*a*) of the programme has been completed.

(2) *Work on Colours of B- and A-type Stars in Kapteyn's Selected Areas.* Dr Walraven has measured photo-electric colours (at four wave-lengths) of B- and A-type stars in a number of Selected Areas with the 120 cm. reflector of Saint Michel Observatory. The stars range from about 9 to 13 magnitude. A dozen stars on the average were measured in each of fifty-four Selected Areas, mostly below 30° galactic latitude and down to −15° declination. The measures have been reduced completely and will be discussed and prepared for publication in the near future.

(3) *Work on Colours of B-type Stars in the Southern Sky.* Oosterhoff has observed photo-electric colours (at three wave-lengths) of O, BO, B1 and B2 type stars for the determination of colour excess with the Rockefeller telescope of the Leiden station at Johannesburg. All known stars of these types south of −40° declination have been observed together with about fifty stars north of −40° which had been observed by Stebbins. In addition, colours of forty members of the Scorpio-Centaurus cluster have been measured. In all about 400 stars were observed. The results have been published in *B.A.N* No. 425, 1951.

With the exception of the last the above investigations have not yet been published. Since the Zürich Meeting an investigation by Dr De Kort on photographic magnitudes of stars brighter than 7·75 between +75° and +80° declination has been published in *B.A.N.* No. 407.

Oosterhoff remarks that the Commission should discuss the problem of Standard Magnitudes in the Southern Hemisphere. He comments that the valuable initiative by Stoy should provide a very good basis for such a discussion.

Lick Observatory. Report by Kron:

A programme has recently been completed at this Observatory for photo-electrically determining standard magnitudes in the red and infra-red spectral regions for a number of stars. The wave-lengths, isolated by glass absorption filters, are 6800 and 8250 A. Stars were measured in ten areas, N.P.S., C4, C6, C12, 51, 57, 61, 64, 68, and 71. A total of 125 stars were measured, not less than five in one area. The zero point was fixed by reference to the N.P.S. stars. The limiting magnitude of all sequences except 57 and 61 is from 8 to 12 magnitude, but areas 57 and 61 were carried to 16 magnitude with the 100-inch reflector. The results of this programme have been published in *Ap. J* **113**, 324, 1951.

A parallel programme has been carried on for determining the red and infra-red magnitudes for fifty dwarf stars of known parallax. Most of the stars are red dwarfs, of spectral type later than early K. This programme is nearly finished, but publication of the results may be delayed pending possible extension of the work to stars of the Southern Hemisphere.

Eggen has been determining photo-electric magnitudes of C-region stars in wave-lengths nearly the same as International. These magnitudes were originally intended for his own use, but he has been requested by many workers in the field to prepare them for general use as magnitude standards. He is therefore expanding the work, and he is determining transfer equations for converting magnitudes and colours to the International System.

A matter for discussion has arisen from the red magnitude work. The photo-electric magnitude contributions of Nikonov and Eggen have shown that photo-electric precision in the photographic special region is limited strictly by the precision with which corrections for atmospheric extinction can be made. In particular, the precision of transfer

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of zero point is affected, especially for long transfers under conditions where atmospheric extinction may not be uniform over the sky.

The red magnitudes are relatively free from difficulties resulting from extinction corrections. The red mean zenith extinction at Mount Hamilton is only $0^m{\cdot}11$, and it changes only slowly with wave-length. The photographic mean zenith extinction, on the other hand, is $0^m{\cdot}35$ at Mount Hamilton, and it changes rapidly with wave-length.

It is clear that red magnitudes may be more suitable for highly precise standards than blue magnitudes, owing to the relative ease with which they may be determined and used according to specified standards of precision.

Though the present system of photographic standards is so highly developed that a complete change will be impractical, I think it advisable to bring this matter of red standards before the Commission for its information.

Mount Wilson and Palomar Observatories and Washburn Observatory:

Stebbins reports the publication of a paper by Stebbins, Whitford and Johnson on 'Photo-electric Magnitudes and Colours of Stars in Selected Areas 57, 61 and 68 (*Ap. J* **112**, 469). The range covered extends from photographic magnitude 9·0 to 19·3. Comparison with the North Polar Sequence gave data for reducing all magnitudes and colours to the International System. In all three Selected Areas the difference between the photo-electrically determined magnitudes so reduced and the *Mount Wilson Catalogue* values is nearly zero at the bright end but shows progressively larger positive values (in the sense photo-electric *minus* photographic) as the faint limit is reached. The difference ranges up to +0·6 magnitude. Various tests confirm the linear response of the photo-electric apparatus and point towards an error in the photographic scale. If the trend found in the Selected Areas should prove applicable to the nebular counts, the calculated nebular density would be lowered in the outer parts of the explored region.

Stebbins also reports that 'our group of photo-electric workers have settled on observations in at least two colours, with magnitudes and colour indices always reduced to outside atmosphere. This procedure is natural, when the extinction is determined every night or part of night'

Rutherfurd Observatory. Report by Schilt.

We have completed the photographic magnitudes for the zone stars between +10° and +20° and between +30° and +50° The zones between +20° and +30° and between +50° and +60° were published several years ago. All that remains to be done is to make a final set of punched cards from which the catalogues can be printed and to obtain the funds for publication. This will conclude our programme of photographic magnitudes for zone stars which we do not contemplate extending beyond the present limits.

We are working on the red and blue photographic magnitudes (plates taken with the 26-inch refractor) for ω Centauri, NGC 6397, and especially for the central region of the Minor Cloud. The region under investigation takes in the densest part of the Cloud, $24' \times 24'$, to magnitudes about 16·5 in both the red and the blue. Dr Epstein is working on this programme using the new photometer of the Rutherfurd Observatory described in *Astronomical Journal*, **53**, No. 2, 1947.

Schilt comments that 'several workers have expressed the view that the North Polar Sequence is unsatisfactory as the primary key region and it should perhaps gradually be replaced by a field in a region that is away from the Pole and, moreover, observable in both hemispheres. The ideal declination would be somewhat north of the equator because the average latitude of observatories in the Northern Hemisphere is greater than the average southern latitude of the observatories in the Southern Hemisphere. The choice of one of the Selected Areas in declination +15° is therefore an obvious one. The most work has probably been done on Selected Area 68 and it has been remarked that this Area does not contain a sufficient number of B stars. Selected Area 85 or 89 might therefore be more suitable if any particular area should be chosen as a sort of absolute standard to replace the North Polar Sequence.'

Schilt also comments that 'something might also be done in relation to the bright stars. For the Southern Hemisphere, Stoy and his co-workers have this topic well in hand, but for the Northern as far as I know not sufficient attention has been given to the bright stars. The work should perhaps be co-ordinated with a view to obtaining a set of magnitudes and colours all reduced to one scale including all stars (9100) to magnitude 6·5. These observations would doubtless have to be done photo-electrically, and magnitude 6·5 seems to be a reasonable limit for a complete programme. I suggest this limit because it is the limit of the *Bright Star Catalogue* and it would be desirable to look at this body of stars as one for which all observables should eventually be observed with the highest degree of accuracy obtainable.'

Stockholm Observatory. Öhman reports as follows:

Among stellar photometric investigations carried out at the Stockholm Observatory a catalogue by J. Ramberg of 4000 stars down to photographic magnitude 13·5 in selected regions in Lacerta is almost ready for publication. Photographic, photovisual and monochromatic magnitudes (λ4215 or λ4360) have been determined.

A catalogue by T. Elvius of 2550 stars in twelve of the Kapteyn Selected Areas has been published. In this work photographic, photovisual and monochromatic magnitudes have also been determined. (*Stockholm Observatoriums Annaler*, **16**, Nos. 4 and 5.)

G. Larsson-Leander has completed an investigation on the region of the open cluster NGC 1664. A catalogue will appear soon of 700 stars down to photographic magnitude 17·0. Photovisual and photo-red magnitudes have also been determined.

All these three investigations include classifications of stellar spectra as well.

In the field of photo-electric work my paper, 'Photo-electric work on the Flicker Principle' (*Stockholm Observatoriums Annaler*, **15**, No. 8, 1949), may be mentioned. On p. 41 a photo-electric photometer with comparison lamp is described, which might find several useful applications.

Strasbourg Observatory:

Muller reports the continuation of his work on the measurement of magnitude differences between the components of double stars (0".5 to 12" separation).

Uccle Observatory (Observatoire Royal de Belgique):

Velghe reports the publication of the following two communications by himself which have appeared as *Communications de l'Observatoire Royal de Belgique*, Nos. 3 and 9, 1948 and 1949.

1. Sur la Détermination Théorique d'un Equivalent de Couleur.

This is an investigation concerning the accuracy of theoretical determinations of effective wave-lengths.

2. Sur la Diversité des Tables d'Extinction en Photométrie Stellaire.

This is an investigation concerning the possible errors introduced into extinction tables and the importance of the different factors in the theoretical extinction formulae.

Velghe comments that it would be of interest for the Commission to discuss the question of standard relations between spectral types and normal colour-indices of dwarfs and giants (for *different* effective wave-lengths). He remarks that these relations are very important when studying the selective absorption in obscured regions.

Uppsala Observatory. Report by Malmquist and Wallenquist:

Publications include the following:

E. Bodén: Colours and magnitudes in the galactic cluster NGC 457, *Uppsala Annals*, **2**, No. 1, 1946.

Å. Wallenquist: Determinations of magnitude differences in double stars, *Uppsala Annals*, **2**, No. 2, 1947.

Å. Wallenquist: Determinations of magnitude differences in southern double stars, *Uppsala Annals*, **2**, No. 3, 1948.

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C. Schalén: Spectra, magnitudes and colours of stars of different galactic latitude. I + 20° galactic latitude and II + 40° galactic latitude, *Uppsala Annals*, **2**, No. 4, 1948, and **3**, No. 3, 1949.

C. Schalén: The colour distribution in the nebula surrounding the star Merope in the Pleiades, *Uppsala Annals*, **2**, No. 5, 1948.

Å. Wallenquist: Photo-electric photometry at the Uppsala Observatory, *Uppsala Annals*, **3**, No. 2, 1949.

E. Bodén: Colours and magnitudes in the galactic cluster NGC 436, *Nova Acta Reg. Soc. Sci. Upsaliensis*, **14**, No. 10, 1950.

E. Bodén: Red magnitudes in the galactic cluster NGC 457, *Nova Acta Reg. Soc. Sci. Upsaliensis*, **14**, No. 11, 1950.

C. Schalén: A red nebula, *Ark. Mat. Fys.* **35**A, No. 34, 1948.

N. Tamm: On the variability of the star BD + 31° 3932, *Ark. Mat. Astr. Fys.* **36**A, No. 7, 1948.

Å. Wallenquist: On the photometry of double stars, *Pop. Astr.* **57**, 9–14, 1949.

Å. Wallenquist: A photo-electric study of the eclipsing variable BD + 31° 3932, *Ark. Astr.* **1**, No. 6, 1949.

O. Eklöf: Blue and red magnitudes in the Auriga region. I. Preliminary note, *Ark. Astr.* **1**, No. 8, 1949.

B. Westerlund: A method for the determination of stellar magnitudes and colours, *Ark. Astr.* **1**, No. 9, 1949.

Å. Wallenquist: Photo-electric colours of stars in the galactic cluster Praesepe, *Ark. Astr.* **1**, No. 10, 1949.

T. Adolfsson: On the possible existence of some nonhomogeneities in the international photographic magnitude scale for brighter stars, *Ark. Astr.* **1**, No. 15, 1950.

Å. Wallenquist: Some preliminary results of photo-electric determinations of colours and magnitude differences in double stars, *Ark. Astr.* **1**, No. 17, 1950.

The last nine papers in the above list have been issued as *Uppsala Meddelande* Nos. 90, 91, 92, 96, 98, 99, 100, 102 and 103.

U.S.S.R. Observatories. Report by Nikonov:

P. P. Parenago (Sternberg State Astronomical Institute) has completed a catalogue of photographic magnitudes of 2982 stars in the region of the Orion Nebula. This catalogue is complete to 15^m and includes many stars to $16^m.5$. Photovisual magnitudes are determined to 11^m. The stars of the catalogue cover an area of 9 square degrees.

V. B. Nikonov at the Abastumani Astrophysical Observatory and the Crimean Astrophysical Observatory of the Academy of Sciences of the U.S.S.R. has developed a new method of reduction for atmospheric extinction in the compilation of fundamental catalogues of stellar magnitudes and colours of stars (*C.R. Acad. Sci. U.R.S.S.* **45**, 151, 1944). This method was used when deriving the photo-electric colours of 1000 stars, preferentially of spectral subtypes B8–B9 (*Abastumani Bull.* 1951, in the Press). The mean error of a catalogue value reduced to the scale of international colour indices is $\pm 0^m.007$. This method has also been used by E. K. Nikonova (Crimean Astrophysical Observatory) when determining the photo-electric magnitudes of the reference stars used for deriving the stellar magnitudes of the Sun and the Moon. In this case the mean error of a stellar magnitude reduced for atmospheric extinction was $\pm 0^m.02$ (*Crimean Obs. Publ.* **4**, 1950). This shows that the method under consideration should be used when compiling fundamental catalogues of stellar magnitudes and colours (comparison stars for variables, stars in selected areas, bright star catalogues, etc.).

Warsaw University Observatory. Zonn sends in the following remark:

According to Fesenkov's suggestions in his book *Meteoric Dust in Interplanetary Space* (in Russian) the density of the dust surrounding the Sun is proportional to r^{-1}, r being the distance from the Sun. This was deduced on the assumption that the dust is in a stationary state. If we assume further that the extinction of light in the dust is proportional to its density we arrive at various conclusions; for example, the law of illumination of planets

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becomes $I \sim r^{-1-A}$, where A is constant, and the magnitudes of stars in the ecliptic must vary with the longitude of the Sun. It seems of interest to get some observational evidence bearing on these considerations.

Wrocław University Observatory:

Rybka reports progress with the reductions of his photovisual and photo-red observations made in the years 1937–42. The aim of the photovisual observations was to form a new photovisual system of magnitudes for stars brighter than about 8^{m} The observations were obtained in declination zones 5° distant from each other. 251 plates were taken altogether at Lwow Observatory in the declination zones from +90° to +50° and sixty plates were measured with the thermo-electric photometer. The first part of the catalogue contains photovisual magnitudes of 635 stars north of $\delta = +80°$ The magnitudes were published in *Contributions from the Wrocław Astronomical Observatory*, No. 3, where all details may be found. The system accords well with the *IPv* magnitudes.

The photo-red photometry of stars near the North Pole was also based on the observations made at Lwow Observatory. From twenty plates red magnitudes were determined for 172 stars brighter than about 8^{m} north of $\delta = +84°$ The mean wave-length of the photometry is near $\lambda 6100$. The new system has been compared with Harvard red magnitudes (*H.A.* **89**, no. 5) and with those of Burger and Nassau (*Ap. J* **103**, 25–34). It has been found that the red magnitudes published by Burger and Nassau contain systematic errors of the order of $0^{m}{\cdot}3$. The accordance of Rybka's magnitudes with those of Harvard is satisfactory. The relation of red magnitudes to those of *IPv* are represented by the formula

$$IPv - LwPr = -0^{m}{\cdot}012 - 0{\cdot}000\,(LwPr - 7^{m}{\cdot}0) + 0{\cdot}356\,C$$
$$\pm\ {\cdot}023 \pm\ {\cdot}013 \qquad\qquad \pm\ {\cdot}027$$

where *LwPr* denotes Rybka's red magnitudes and *C* the international colour indices taken from the *Mount Wilson Catalogue* of Seares, Ross and Joyner (*Carnegie Publ.* No. 532, 1941). The average mean error of one catalogue magnitude is $\pm 0^{m}{\cdot}036$. The results will soon be published in the *Contributions of the Wrocław Observatory*.

A photo-electric photometer incorporating a 1P21 multiplier photo-tube has been recently installed in the focus of the 8-inch refractor of the Wrocław Observatory. The second photometer will soon be installed in the focus of the 10-inch refractor at the branch of Wrocław Observatory at Białków. The photometric programme consists mainly in the determination of fundamental photo-electric magnitudes of stars in sequences associated with Selected Areas.

Rybka adds the following comments:

It is generally known that the state of photometry of bright stars is far from being satisfactory. The zero point of visual, photovisual and photographic photometries seems to be dependent on co-ordinates of stars and there are still other inconsistencies in the visual and photographic catalogues of magnitudes of bright stars.

The application of multiplier phototubes to stellar photometry gives an opportunity of determining the fundamental system of magnitudes and colours of stars with high accuracy. It is proposed to determine such a system in the Wrocław Observatory from observations which have already been started in Wrocław and will also be made in Białków using photo-electric photometers with 1P21 multiplier photo-tubes in two colours (blue and dark yellow). The magnitudes will be measured in sequences correlated with the Selected Areas. Each sequence will consist generally of ten stars, five stars of type A from 4^{m} to 8^{m} and five stars of type K also from 4^{m} to 8^{m} The observations have been started at the Pole and will be continued near Selected Areas in zones +75°, +60°, etc.

The extinction is to be determined very carefully For that purpose a constant light source is used. The extinction coefficient will be determined each night from extra-atmospheric magnitudes of the stars of types A and K situated along the parallel +51°, i.e. with the declination near the latitude of Wrocław

W. M. H. Greaves
President of the Commission

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Report of the Sub-Commission on Sequences of Magnitudes

(1) *General Remarks.* During the past five years there has been a great growth of photo-electric work, based on photomultipliers. At the same time it has been demonstrated that with proper care the in-focus photographic method can give remarkably good results, while for bright stars the Fabry method ('plages pupillaires') appears to be as accurate as most photo-electric procedures, and has the advantage of using very simple and reliable apparatus. With the best techniques, photo-electric or photographic, the ultimate accuracy is set more by the sky than by the instrument, but by repeating observations any painstaking observer can now reach *internal* standard errors of about $0^{m}\cdot01$, at least in favourable conditions.

Unfortunately no two observers, using different apparatus at different places, measure exactly the same quantity. A 'magnitude' is at best an empirically defined parameter. It should conform to the Pogson scale for stars of identical colour, but is otherwise purely conventionally defined by the North Polar Sequence. Some doubts have been expressed as to whether independent magnitude observations, internally consistent to $0^{m}\cdot01$, can be reduced to a common standard scale to this same order of accuracy. That is, can accurate measures made in any two colours be reduced to the international *pv* and *pg* scales with standard errors about $0^{m}\cdot01$? In the absence of space reddening is it possible to describe the radiation properties of the great majority of normal stars to about 1% over the wave-length range 4000–7000 A., by means of a *pv* magnitude and a colour index only? If not, what restrictions have to be placed on the choice of colours in the working magnitudes? Alternatively, how many other colour parameters are necessary? Should an extra parameter be introduced, measuring say the Balmer discontinuity?

At the moment it appears that if the working magnitudes are fairly close to the standard system, for example so that the corrections are of the order of one-tenth of the colour index, the reduction can be made with errors not greater than $0^{m}\cdot02$. This may cease to be true if strong space reddening is present, and there is probably greater uncertainty also if the corrections exceed 0·1 C.I., which might be the case, for example, if one of the working magnitudes is a red magnitude. At the other end of the accessible spectrum there are important advantages in avoiding wave-lengths shorter than about 3800 A., not merely in order to keep the colour corrections small, but because the observer then escapes some of the worst troubles from atmospheric irregularity, from the brightness of the night sky, and from any effect of the Balmer series, both lines and continuum, on his magnitudes. In any case it is of the greatest importance that the working magnitude systems, however they may be chosen, should always permit accurate reduction of the measures to a generally agreed standard system. Private inconvertible magnitude systems, however self-consistent, have a very limited sphere of usefulness; like inconvertible paper money, they may have some value at home, but are not generally acceptable abroad.

Another question to which insufficient attention has yet been given is that of the constancy of radiation of a normal star. Only now is convincing evidence beginning to accumulate that many stars can be relied on to remain constant to $0^{m}\cdot02$ over periods of the order of two or three years (some N.P.S. stars for twenty years). There is a general belief that very red stars and very blue stars, of all absolute magnitudes, are less stable than the general body of stars. This view is supported by recent results from the Bright Star Programme of the Cape Observatory, from which Cousins has produced a preliminary list of stars found to vary more than $0^{m}\cdot05$, the standard error of measurement being $0^{m}\cdot015$ or less. Nearly all the discovered variables are of types earlier than B5, or later than M0; only four out of forty variables are of types A0 to K5, and of these two are known to be Cepheids. More information on this important question is needed, and should soon appear if present technical progress is maintained. Until, however, we are sure that most stars, not extreme in any known physical characteristic, vary less than $0^{m}\cdot03$ over periods of the order of a century, it is unwise to sink much effort in programmes of magnitude determination with the aim of reducing errors to $0^{m}\cdot01$.

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(2) *The North Polar Sequence.* However valuable it may be to make spectroscopic or other detailed examination of the radiation of individual stars, practical limitations (lack of light, enormous numbers) confine us to something near the present magnitude system for very many purposes. Our basic standards are contained in the North Polar Sequence, defining the two international magnitude scales, 'photographic' and 'photovisual', denoted respectively by *pg* and *pv* in this report. Some workers, notably W Becker,* have stressed the limitations of this system, viewed in relation to the general physical problems of stellar radiation, and have advocated other schemes offering advantages of various kinds. While it may be freely admitted that the existing system is far from ideal, so that exploration of other possibilities is to be encouraged, the very large amount of time and labour already invested in it makes any change inadvisable except after the most exhaustive technical examination and discussion. The general feeling of the Sub-Committee is that the time is not yet ripe for any very radical change in the standard system.

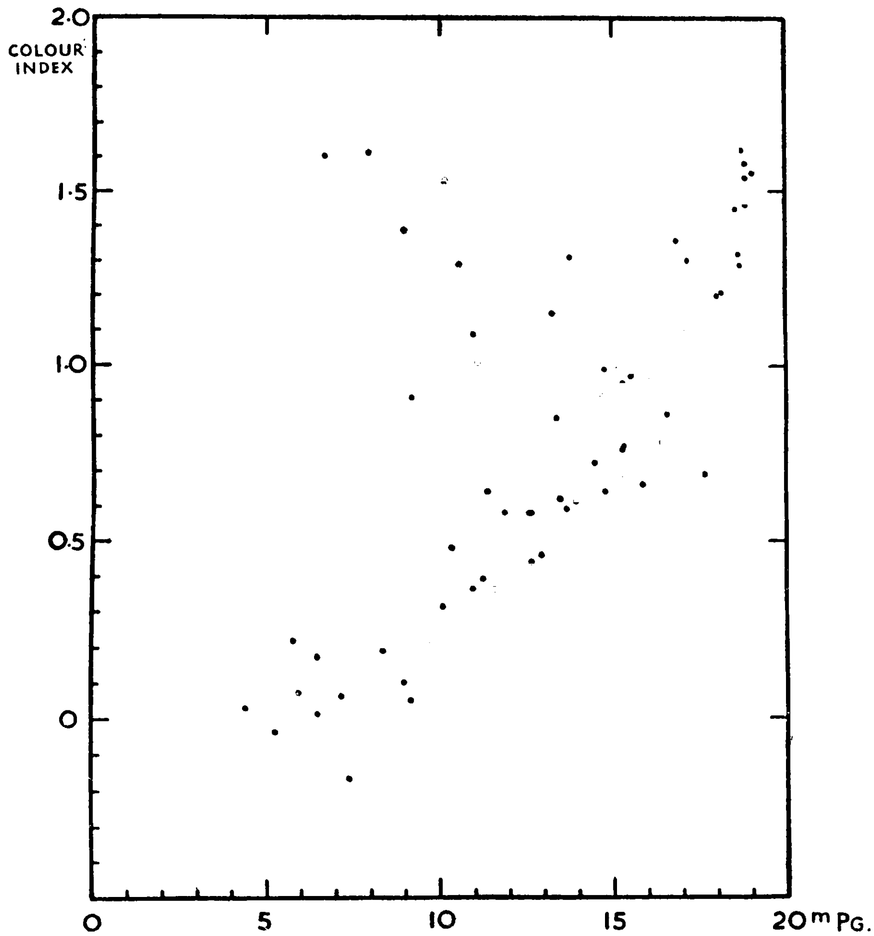

Fig. 1. Colours and apparent magnitudes of N.P.S. stars.

In so far as the N.P.S. provides the conventional definition of zero point and of colour characteristics, it cannot be challenged. It should, however, conform to the Pogson scale, within say $0^m.01$, for any group of stars of identical colour. (Another question obtrudes itself here: Can the energy distribution within the spectrum of a star brighter than 8^m, say, be matched sufficiently exactly by that of any star fainter than 18^m? Does the physical significance of the colour index change gradually with apparent magnitude?) Since the 1938 work of Stebbins and Whitford, there has been reason to believe that the original N.P.S. magnitudes contain an appreciable scale error in the vicinity of 6^m. Recent photo-electric measures by several independent observers have confirmed this,

* See pp. 361, 362.

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Table I

N.P.S.	B.D.	Interim values *pg*	Interim values *pv*	Interim values C.I.	Original N.P.S. *pg*	Original N.P.S. *pv*	Cambridge *pg*	Cambridge *pv*	Cox *pg*	Cox *pv*	Eggen *pg*−0·03	Eggen *pv*	Stebbins and Whitford *pg*−0·09	Stebbins and Whitford *pv*	Stebbins, Whitford and Johnson *pg*	Stebbins, Whitford and Johnson *pv*
1	86° 269	4·20	4·31	−0·11	(4·39)	(4·39)	4·19	4·33	4·18	4·31	4·20	4·30	4·25	—	—	—
2	85° 383	5·07	5·22	−0·15	(5·22)	(5·30)	5·08	5·23	5·06	5·22	5·09	5·21	5·07	—	—	—
3	86° 344	5·65	5·54	+0·11	(5·76)	(5·58)	5·64	5·54	5·65	5·52	5·69	5·56	5·64	—	—	—
4	86° 272	5·83	5·74	+0·09	(5·95)	(5·82)	5·81	5·75	5·82	5·72	5·85	5·74	5·85	—	—	—
5	88° 4	6·42	6·46	−0·04	(6·46)	6·46	6·41	6·46	6·43	6·47	6·43	6·44	6·40	—	—	—
6	89° 13	7·13	7·07	+0·06	(7·15)	7·08	7·15	7·12	7·13	7·09	7·08	6·99	7·11	—	7·15	7·09
7	88° 64	7·35	7·53	−0·18	(7·37)	7·56	7·38	7·54	7·30	7·47	—	—	7·36	—	—	—
8	88° 9	8·33	8·13	+0·20	8·30	8·13	8·32	8·12	8·41	8·12	8·30	8·06	8·33	—	—	—
9	88° 13	8·99	8·85	+0·14	8·93	8·84	8·98	8·86	9·01	8·83	9·06	8·89	8·98	—	—	—
10	89° 3	9·17	9·05	+0·12	9·15	9·05	9·16	9·04	9·21	9·05	9·18	9·04	9·14	—	9·17	9·05
11	89° 18	9·78	9·60	+0·18	9·77	9·57	9·73	9·62	—	—	9·80	9·61	9·78	—	—	—
12	89° 25	10·08	9·79	+0·29	10·08	9·79	10·05	9·80	—	—	10·10	9·78	10·07	—	—	—
13	89° 29	10·51	10·32	+0·19	10·55	10·35	10·49	10·33	—	—	—	—	10·50	—	10·51	10·27
1*r*	87° 51	6·62	5·03	+1·59	(6·67)	(5·08)	6·67	5·02	6·60	5·03	6·58	5·04	6·63	—	—	—
2*r*	88° 112	7·90	6·35	+1·55	(7·92)	6·35	7·90	6·37	7·89	6·34	7·86	6·38	7·90	—	7·90	6·34
3*r*	88° 76	8·88	7·51	+1·37	8·92	7·54	8·86	7·54	8·86	7·47	—	—	8·89	—	—	—
4*r*	88° 114	9·24	8·24	+1·00	9·18	8·28	9·20	8·22	9·25	8·21	9·25	8·27	9·22	—	9·27	8·22
5*r*	89° 22	10·21	8·61	+1·60	10·18	8·63	10·22	8·61	10·24	8·59	—	—	10·19	—	—	—
6*r*	89° 9	10·51	9·26	+1·25	10·51	9·25	10·51	9·27	—	—	—	—	10·49	—	—	—
7*r*	89° 35	10·96	9·86	+1·10	10·98	9·86	10·95	9·86	—	—	—	—	10·94	—	—	—
8*r*	89° 31	11·41	10·43	+0·98	11·44	10·46	11·37	10·44	—	—	—	—	11·41	—	11·43	10·41
2*s*	88° 71	6·46	6·26	+0·20	(6·50)	6·30	6·46	6·28	6·48	6·27	6·43	6·22	6·48	—	—	—
3*s*	87° 107	6·62	6·33	+0·29	(6·64)	6·33	6·59	6·34	6·62	6·32	6·63	6·33	6·63	—	—	—
4*s*	89° 12	10·32	9·85	+0·47	10·31	9·82	10·31	9·83	—	—	10·33	9·89	10·30	—	—	—
6*s*	89° 26	11·39	10·69	+0·70	11·37	10·70	11·43	10·68	—	—	—	—	11·38	—	—	—
Taking interim values as standard and units $0^m{\cdot}01$,																
Mean residual with regard to sign ...					+0·8	−0·8	+0·7	−0·7	−0·4	+1·2	−0·3	+0·4	+0·4	—	−1·1	+1·3
Mean residual without regard to sign					2·6	1·6	2·0	1·3	2·1	1·6	2·5	2·5	1·4	—	1·1	2·0
Number of stars					14	20	25	25	17	17	17	17	25	—	6	6

SOURCES.

Cambridge: Unpublished photo-electric measures by Redman and Yates.

Cox: Unpublished photo-electric measures by Cox at the Goethe Link Observatory.

Eggen: *Ap. J.* **111**, 65, 1950. An arbitrary zero correction $-0^m{\cdot}03$ has been applied to the *pg* measures.

Stebbins and Whitford: *Ap. J.* **87**, 237, 1938. An arbitrary zero correction $-0^m{\cdot}09$ has been applied to the *pg* measures. The *pv* values seem to be less accurate and have not been used.

Stebbins, Whitford and Johnson: *Ap. J.* **112**, 469, 1950.

and it appears possible now to draw up a list of revised magnitudes from which most, if not quite all, of this error has been eliminated. This has been done in the accompanying Table 1. The 'interim values' here are put forward as a basis for discussion, their colour system and zeros have been adjusted as closely as possible to the original N.P.S. for $8{\cdot}0 < m < 11$ *pg*, and $6{\cdot}0 < m < 10{\cdot}5$ *pv*, and to the 1950 measures of Stebbins, Whitford and Johnson.*

The discovery and correction of this scale error has raised the question of re-defining the zeros of the international *pg* and *pv* scales. Before Table 1 had been drawn up it had been suggested by Lick and Mount Wilson observers that the zeros be defined by the stars N.P.S. 6, *2r*, 10, *4r*, 13, *8r*, 16, 19, and *12r*, for which the Stebbins, Whitford and Johnson measures agree fairly closely with the original N.P.S. values, and that the S.W.J. values be adopted. The interim values of Table 1 differ in their zeros from the S.W.J. values by about $0^{m}{\cdot}01$ in each scale, although it will be seen on examining the scatter in the observations that the differences are barely significant.

		m
pg:	interim values—original N.P.S. ($m \nless 8{\cdot}0$, 14 stars)	$+0{\cdot}008 \pm 0{\cdot}009$
	interim values—S.W.J. 1950 (6 stars)	$-0{\cdot}011 \pm 0{\cdot}007$
pv:	interim values—original N.P.S. ($m \nless 6{\cdot}0$, 20 stars)	$-0{\cdot}008 \pm 0{\cdot}005$
	interim values—S.W J. 1950 (6 stars)	$+0{\cdot}013 \pm 0{\cdot}010$

Dr Vyssotsky dissents from the proposal to define the *pg* and *pv* zeros by the nine stars just named, believing it more nearly rigorous to confine standard zero-point stars to a small range in magnitude and colour. He suggests for the zero point:

Star	N.P.S.	*pg* m	*pv* m	*C*
89° 7	—	10·28	9·99	0·29
18	11	9·76	9·61	0·15
25	12	10·07	9·81	0·26
29	13	10·55	10·40	0·15
38	—	9·88	9·75	0·13

And for the determination of colour equation:

89° 2	—	10·85	9·15	1·70
9	6*r*	10·53	9·22	1·31
28	—	10·27	8·68	1·59
31	8*r*	11·46	10·45	1·01
35	7*s*	11·00	9·85	1·15

Six of these stars are in Table 1. The values quoted here are from the Seares, Ross and Joyner Catalogue; the 'interim values' are probably to be preferred.

Stoy and Cousins are of the opinion that the 'interim values' for the N.P.S. stars cannot be regarded as definitive, even if there is general agreement with regard to their zeros and colour characteristics. They point out that although South African work on the E regions is not regarded as finished, the various series of observations made independently at Pretoria, Bloemfontein and the Cape fit together better than do the measures quoted in Table 1. They urge that further precise observations be made on the N.P.S., preferably at observatories other than those already partaking in the work.

Apart from the matters just discussed, there is the question of the adequacy of the selection of stars available in the N.P.S. There is no doubt that the sequence would be much increased in usefulness and effectiveness if it could be extended to cover a wider selection of colours at all magnitudes. The existing distribution of colour index with regard to magnitude is illustrated in the accompanying figure, which shows clearly the increasing preponderance of red stars with diminishing brightness. This tendency for fainter stars to be redder is doubtless present to a greater or less degree in all star fields, but equally certainly there are many fields possessing quite ordinary stars which cannot be matched in both colour and brightness in the N.P.S. For example, there are

* *Ap. J.* **112**, 469, 1950.

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fields rich in 8^m–10^m stars of negative colour index, while such stars appear almost non-existent near the Pole. We may also note that there are no N.P.S. stars fainter than 15^m which are bluer than a naked-eye G5 star or redder than a naked-eye M star. To what extent do we need faint stars outside this colour range?

Ideally the photographic observer would like 10 to 20 stars in each step of one magnitude, with colour indices well distributed over at least $-0{\cdot}2$ to $+1{\cdot}5$. The needs of the photo-electric observer are a little less exacting, although greater than is sometimes supposed, since he needs a thorough check on the linearity of his apparatus and an accurate determination of his colour corrections. The area of sky immediately around the Pole does not contain as comprehensive a population sample as we wish, but it is nevertheless highly desirable that the N.P.S. should be extended as far as is practicable to include many more stars. This task has been well started for stars brighter than 11^m by Seares, Ross and Joyner,* whose magnitudes are believed to possess a high order of internal accuracy, although their exact relation to the N.P.S. needs re-checking. The S.R.J. Catalogue contains many more stars than are needed for amplifying the N.P.S., although even here very blue stars are rare.

(3) *Non-Polar Standard Sequences.* While our primary standards may be at the Pole, we need non-polar sequences too, partly on grounds of convenience, partly because of accessibility for southern observers, and partly because there is evidence that guiding difficulties (and perhaps instrumental flexure also) can give rise to serious systematic magnitude errors at the Pole when in-focus photography is used. Schmidt telescopes seem particularly susceptible to such trouble, presumably because of the fine images they give.

In so far as any exist, our secondary standards are contained in the following areas: (i) the Harvard Standard Regions, (ii) the Kapteyn Selected Areas, (iii) certain special areas, notably in open clusters such as the Pleiades, Hyades, Praesepe, etc. Most of the magnitudes contained in these have been determined photographically, although there is now a rapidly growing volume of photo-electric work involved too.

The general situation is: (*a*) Some of the older measures are known to be inaccurate, with both accidental and systematic errors running above $0^m{\cdot}1$, sometimes above $0^m{\cdot}25$. (*b*) Some newer measures have high internal consistency, but have not yet been linked accurately to the N.P.S. An important case is that of the Harvard E Regions, which have been intensively studied in recent years in South Africa, notably at the Cape and Radcliffe Observatories. Work at the Cape and Cambridge Observatories which will fill this particular gap is now approaching completion. (*c*) Some measures have high internal consistency. but cannot be reconciled precisely with others apparently equally reliable. There have been several instances of disagreement between photo-electric and photographic measures; a number of these have been explained by admitted observational errors, but in some cases (e.g. the Pleiades) the differences remain greater than can be considered satisfactory In part the trouble may be one of differing colour systems, which re-emphasizes the importance of choosing working magnitude systems whose colour characteristics allow an accurate reduction to the standard system.

There is at present no unanimity as to what areas should be used as 'key areas', i.e. should be standardized with a precision equal to that of the N.P.S., and on the N.P.S. system. There is a considerable concentration of work in progress at declinations $+15°$ and $-45°$ and in the open clusters. As far as the southern sky is concerned, it is agreed that the nine Harvard E Regions should be key areas, although not all observers are convinced that these by themselves will be sufficient south of the equator.

In the northern sky, at $+15°$, work in progress is about equally divided between the Harvard C Regions and Kapteyn Areas. In addition, photo-electric work on S.A. 57, 61, and 68 by Stebbins and his colleagues, covering approximately 12^m–18^m, has recently appeared,† while important photo-electric measures are being published by Eggen,‡ dealing chiefly with the open clusters, but also including C4 and C12. The clusters are

* *Magnitudes and Colours of Stars North of* $+80°$. Washington, 1941.

† Loc. cit. ‡ *Ap. J.* **111**, 65, 81, 414, 1950.

usually observed with other purposes in mind and are not very suitable as key areas, unless large numbers of background stars are included, owing to the very close correlation between magnitude and colour in members of the cluster. It should be noted that areas at $+15^\circ$ form the most convenient stepping stones between the N.P.S. and the E Regions at -45°, and this is certainly a strong argument in their favour. It is doubtful whether the time is quite ripe for a final choice of northern key areas. Stoy has proposed that attention should at least for the present be concentrated on S.A. 68, C2, C4, C7, S.A. 85, and S.A. 89, a compromise policy designed to fit in with existing programmes. The results of a number of these programmes are likely to be published within the next three years, and more definite decision on these questions may be possible at the 1955 I.A.U meetings.

The best measuring techniques are still quite slow, so that even should no technical hitches be encountered the task of establishing some fifteen key areas is formidable, and certainly not to be undertaken lightly, especially since we expect finally a range of some 15^m to be covered in each. Prudence suggests a conservative policy: programmes should be framed with rather limited objectives, efforts should not be dissipated over too many areas, and the establishment of new colour systems should be discouraged, unless they are readily reducible to the existing standard system.

(4) *Recommendations*. The Sub-commission recommends:

I. That investigations be made to clarify the conditions under which accurate working magnitudes can be reduced to the standard *pg*, *pv* system with errors not exceeding $0^m{\cdot}02$. Evidence is required to settle the permissible colour ranges of the working magnitudes. More information is required concerning magnitudes of stars whose light is strongly reddened by interstellar matter, to find whether reduction to the standard system is thereby made more difficult, and to decide whether the standard *pg*, *pv* system should in such cases be supplemented by another colour parameter.

II. That the zeros of the international *pg* and *pv* scales be re-defined. There are three possibilities: (*a*) to use stars N.P.S. 6, 2*r*, 10, 4*r*, 13, 8*r*, 16, 19, 12*r*, taking either the original N.P.S. magnitudes or the photo-electric values of Stebbins, Whitford and Johnson (proposed by Lick and Mount Wilson observers); (*b*) to use stars 89° 7, 18, 25, 29, 38 for zero, and 89° 2, 9, 28, 31, 35 for colour, taking the magnitudes of Seares, Ross and Joyner (proposed by Dr Vyssotsky); (*c*) to use the 'interim values' for the twenty-five stars of the table in this report (proposed by Prof. Redman).

III. That every effort be made to extend the N.P.S. *pg* and *pv* scales to 23^m, the aim being to keep errors below $0^m{\cdot}03$.

IV That the N.P.S. in all magnitude ranges be extended as far as practicable to cover a greater range of colours, it being realized that an ideal population of stars is not available in this region.

V That key sequences be established in the E Regions at -45°, and that work aiming at linking these to the N.P.S. be encouraged.

VI. That in the northern sky work in the various standard fields at $+15^\circ$ should be encouraged, but that no immediate final decision should be made as to which northern areas are to provide key sequences. Meanwhile preference should where possible be given to S.A. 68, C2, C4, C7, S.A. 85, and S.A. 89.

R. O. Redman
President of the Sub-Commission

25. SUPPLEMENT TO THE DRAFT REPORT OF THE SUB-COMMISSION ON SEQUENCES OF MAGNITUDES

The Draft Report was circulated to members of the Sub-commission and to other workers known to be active in the field of stellar photometry. Their comments are summarized below.

A. W J. Cousins emphasizes that the important question in relation to the N.P.S. at present is systematic rather than accidental errors. He is of the opinion that additional stars should be included in the Sequence and also that mean magnitudes with standard errors less than $0^m.01$ must be obtained throughout before the N.P.S. can be regarded as defining an adequate magnitude system. He considers the nine stars of Recommendation II*a* are quite insufficient to fix colour, scale, and zero point.

A. N. Cox notes that he does not regard his magnitudes quoted in Table 1 as final. He thinks that any definitive system of N.P.S. magnitudes should be identical in colour and zero with S.W.J. stars. In any final discussion he would probably wish to revise the weighting of the observations quoted in Table 1.

Olin J. Eggen points out that his published magnitudes were not intended as standard magnitudes. He estimates the A.D. of the zero point of his colour system as $0^m.01$, and the A.D. of the individual magnitudes $0^m.03$ to $0^m.04$. He considers that were Vyssotsky's proposal accepted it would be essential to add more stars of intermediate colour, in order to be able to convert magnitudes not bearing a linear colour relation with one another. He also emphasizes the difficulty of using the N.P.S. as a standard area, because of variations of the extinction with azimuth. He has found extinction differences up to $0^m.1$ between directions east and west at the altitude of the Pole on apparently first class nights.

H. L. Johnson has forwarded a memorandum summarizing his programmes. In measuring ten bright stars as secondary standards, with mean magnitudes having internal errors below $0^m.01$, he has found no significant evidence for intrinsic variations in brightness. He supports Recommendation II*a* of the Report.

P Th. Oosterhoff does not feel satisfied with Recommendation II. He points out that van Rhijn (*Trans. I.A.U* **6**, 222, 1938) some years ago suggested that the N.P.S. zero be defined by the three stars N.P.S. 2, 4 and 5, but that any definition of this kind leads to practical difficulties, especially for the observer who is working in an entirely different magnitude range. He suggests rather that the Sub-Committee should concentrate on establishing a correct scale for the N.P.S. over its entire range, making Recommendation II redundant. Of II*a*, II*b*, II*c*, he prefers II*a*, but is certain that nine stars in a range 7^m will prove inadequate.

P J. van Rhijn asks whether it is not desirable to add a few key areas at +45° declination. He also emphasizes the necessity for quickly clearing up the large differences between photographic and photoelectric magnitudes of faint stars in S.A. 57, 61 and 68, pointing out that until this is done the magnitudes of the fainter stars of the *Mount Wilson Catalogue of Selected Areas* are useless.

J. Stebbins agrees that the 'Interim Values' of Table 1 are probably better than the original N.P.S. figures, although he is not prepared to accept them as definitive. He mentions Eggen's recent revision of his N.P.S. measures (*Ap. J* **114**, 141, 1951) and also draws attention to work by Hassenstein (*A.N* **269**, 185, 1939) and Seares (*Ap. J* **94**, 21, 1941). He stresses the importance of settling the problem of the N.P.S., adding 'and let the residuals fall where they may'!

R. H. Stoy prefers Recommendation II*c* of the group II*a*, II*b*, II*c*, but emphasizes its interim nature. He points out that in so far as the establishment of the N.P.S. system in any other area of the sky is concerned there is *at present* no practical difference between the proposals. He questions the value of Recommendation III, pointing out that a prior task for the Sub-Committee is the examination of methods of establishing correct scales: 'Once a satisfactory method—or methods—is developed, it is only a matter of patient application to apply the method, and to set up scales wherever they may be wanted.' He believes that present photo-electric methods when used with proper care can be relied upon almost to the limit of the photometer. Beyond that point photographic methods must be used, but he is not satisfied that near the photographic plate limit we can yet be confident of finding really satisfactory sky corrections. Finally he asks whether the N.P.S. is to be retained as a *working* standard sequence, even if it keeps its position as the final *reference* standard (comparable with the standard metre).

A. E. Whitford is of the opinion that if a small number of stars have to be selected to define the zeros of the standard scales they should be chosen approximately in the middle of the range of intensities to be covered. He also points out that the interconnection between N.P.S. and Selected Areas must be done with stars 9^m–11^m, since there are rarely enough near 6^m. He thinks the S.W. J. stars must be regarded as having the same 'interim' status as the stars of Table 1, and is prepared to agree to the use of the latter. In his opinion Vyssotsky's stars cover too narrow a range to be entirely satisfactory: 'It is desirable to have stars well-distributed over as wide a range as possible in intercomparison of colour systems. This is particularly true when reddened stars or composite objects like clusters of galaxies are being considered. This issue has come up in comparing our older short base line colours with colours based on filters used with the photo-multiplier, as well as with various combinations of the six-colour filters. The conclusion is that for ordinary single stars with regions below 3800A excluded, linear transformations are very satisfactory. But for the other cases where the relative gradient curve is not a straight line, the six-colour observations have given a good guide as to the proper correction term. This comment applies to your first recommendation. I agree that further study at several observatories is desirable.'

To sum up, there seems to be general agreement with most of the Draft Report, except with the suggestion to revise existing N.P.S. magnitudes. The prevailing opinion is that a revision of some kind is necessary, but that the 'interim values' cannot be regarded as definitive. The Secretary of the Sub-Committee would prefer these 'interim values', as their name suggests, to be regarded as merely a second approximation, for stars brighter than 11^m, to the ideal system we are seeking. But at the same time he is strongly of the opinion that we must retain the N.P.S. as our final reference standard, even when it is not regarded as a good working standard, and that all attempts to attain an ideal standard sequence should leave the main structure of the original N.P.S. system as little changed as possible.

There is one final comment: on present evidence the original N.P.S. is extremely near a Pogson scale from about 7^m to 15^m, and some tribute should be paid to the first President of the Commission on Stellar Photometry, Dr F. H. Seares, who contributed more than any other man to this result. It is astonishing, not that a systematic error has been found over a quite limited range at the bright end of the scale, up to a maximum perhaps about $0^m{\cdot}2pg$ and $0^m{\cdot}1pv$, but that his work has stood up so well to testing by the best photo-electric methods. He observed by photographic methods only, at a time when photometric standards were much lower than they are now, and his results stand in conspicuous contrast to the great volume of stellar magnitude work down to 1940.

R. O. REDMAN
President of the Sub-Commission

Report of meeting. 8 September 1952

PRESIDENT: Prof. W M. H. GREAVES.

SECRETARY: Dr R. H. STOY

The Chairman, having briefly explained the scope and purpose of the meeting, invited Dr Stoy to speak on the first portion of the Report of Commission 25.

Dr Stoy said that he thought that the Report was an excellent summary of the present theory of what a magnitude should be and of how it should behave. The next step was to find out how actual magnitudes did behave in practice.

In this connexion he would like to present a short comparison of twelve different series of observations of stars in the E regions. Of these twelve series of observations, five had been made photo-electrically, four by the Fabry method and three by the use of in-focus photographic images. Four of the series had been made with the reflectors at Bloemfontein and Pretoria, while the remainder had been made with the refractors at the Cape. With the exception of the in-focus images which required corrections of the form $(m-m_0)$ $(c-c_0)$, the different series could all be reduced to the standard S system

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by the application of simple linear colour corrections which ranged from $-0{\cdot}19 \times$ S.C.I. to $+0{\cdot}14 \times$ S.C.I. When this reduction had been made, the average arithmetical divergence of the magnitudes in the individual series from the mean for all the series was considerably less than for the data given for the various determinations of the Polar Sequence magnitudes in Table I of Commission 25 *a*'s Report.

These results might be taken to indicate that two colours and linear transfers were adequate for normal photometry, but recent comparisons of the colours and magnitudes of bright stars as observed at the Cape with those observed elsewhere had shown that this was not the case.

A comparison of the Cape colours with those recently published by Schilt (*A.J* **55**, 9, 1951) indicated that the relationship between the Cape and Schilt colour indices was very far from linear and that the dispersion of the individual colours about the mean colour curve was very large for the blue stars but gradually decreased with increasing colour until for the red stars it was only about what might be expected from the accuracy of the observations.

A comparison of the same series of Cape colours with those determined by Johnson in his recent three-colour work on a number of stars in the equatorial zone showed a strictly linear relationship with $(B-V)$, and an average deviation of the individual colours only slightly greater than $0^{m}{\cdot}01$. On the other hand a comparison for these same stars of the Cape Fabry magnitudes with Johnson's showed that to achieve a comparable accuracy of transfer, it was necessary to use a linear relation involving both Johnson's $(B-V)$ and $(U-B)$ colour indices. The relation between $(B-V)$ and $(U-B)$ was not linear and the straight line of best fit—required if one was confined to two-colour work and linear reductions—left significant deviations for stars with spectral types earlier than A0.

The relation between the *S* system and the N.P.S. had been derived in several ways but there were discrepancies of the order of $0^{m}{\cdot}1$ between the various comparisons. These discrepancies seemed to be due, not to poor observations but to a fundamental uncertainty in the N.P.S. photographic magnitudes to which several observers had recently drawn attention and which seemed to arise from the inclusion of different ranges of ultra-violet light in the various series of observations. In fact it was becoming increasingly clear that in general, two-colour photometry was not able to define a magnitude system adequately precise for the needs of modern astronomical photometry.

The Chairman then invited Dr W Becker to explain his proposals for a three-colour system of photometry given in Section VI of the Report of the Commission.

Dr Becker said that excellent progress had been made in the past few years with the work of setting up photometric scales in standard fields. Moreover, since many observers are establishing their own scales by photo-electric observations, there will be in the future an increasing number of miscellaneous scale fields. In view of this situation he had the feeling that Commission 25 should pay attention to the special problem of the zero-point of the international scales and consider the question whether the time had come to organize a programme for the establishment of a fundamental system of magnitudes for zero-point stars. He imagined that such a system should consist of a large number of more or less extended groups of about five stars of the same magnitude and colour. These groups should not be more than about 20° apart, and if the stars in them were of about the 10th or 11th magnitude, they would be within the reach of the great majority of telescopes, both large and small.

With regard to the spectral regions for integral photometry, he was of the opinion that the international regions for m_{pg} and m_{pv} should not be changed, but should be reproduced as exactly as possible by all who wished to observe in these spectral regions. On the other hand there are problems which require photometry in spectral regions other than the international ones. (For example, the observation of the Balmer jump, especially in faint and condensed clusters of stars, the ultra-violet depression of the intensity depending on the spectral type and luminosity for late-type stars, etc.) In such cases the spectral regions for the integral photometry should be so chosen as to lead to the best astronomical results. The exact reproduction of any particular scale is of less importance for such astrophysical programmes. It therefore does not as yet seem necessary to fix such spectral regions by a general agreement. What does seem important is that any such investigation involving integral magnitudes should be started with a consideration of what spectral regions would be the most effective for the special purpose, the international regions or some others.

The Chairman next invited Dr Weaver to speak on his proposals for photo-electric magnitudes contained in Section VII of the Report.

Dr Weaver said:

1. The suggestions in Section VII of the Draft Report were made as a result of some rather unsatisfactory attempts to compare high precision photo-electric magnitudes and colours determined by different observers. The comparisons showed: (1) that the relations between the colours and the magnitudes of the systems compared were non-linear; (2) that it was apparently not possible to convert individual values on one system to another system with an accuracy comparable to that of either system even when non-linear transformations were made. These departures from the mean transformation curve seemed most pronounced for certain stars with spectral peculiarities, though this particular point needs more discussion and should be verified by further work.

The inclusion of different amounts of ultraviolet in the blue magnitudes of the systems being compared is certainly the cause of difficulty (1), and is no doubt involved in difficulty (2). However, other effects intrinsic in the stars may also be involved in (2). Both difficulties can be eliminated to a very large degree if all observers attempting to determine magnitudes on the international system will agree to observe in the same wave-length ranges and to establish their 'international system' by referring to a standard set of NPS stars. The phrase 'in the same wave-length range' does not imply that each observer will be forced to observe in precisely the same wave-length range. This is clearly impossible because of variations in the types of instruments, cells, filters, plates used by different observers. The phrase implies only that each observer will not depart far from the suggested range, and, in particular, that in the blue observations the ultra-violet to the shortward of, say, 3800 or 3900 A. will be eliminated. Under these conditions transformations from one system to another involve only small corrections, and such transformations can apparently be made very adequately. This does not appear to be the case if the corrections to be made are large.

2. It does not appear to me that this proposal for standardization of wave-length ranges and standard stars for observations on the international system is in conflict with a proposal of the type made by Prof. W. Becker, which deals with three-colour photometry, or with a proposal of the type made by Prof. Woolley, which involves very narrow wave-length regions. Such suggestions are concerned with photometric problems involved in special astrophysical investigations and are somewhat different from those generally considered in ordinary photometry. They are suggestions that might be considered jointly by the commissions on photometry and spectrophotometry.

The difficulty of extending 'monochromatic' or narrow-band magnitudes to faint stars would seem to preclude the *general* adoption of such systems for all purposes, and to put such magnitudes in a somewhat special class. The purpose of my proposal was to point out a present need for further standardization of magnitudes and colours of the ordinary sort on the 'international system' This suggested standardization must change as little as possible any existing work, such as the luminosity law, period-luminosity law, magnitude spectral-type relation, and so forth, and at the same time must permit the standard system to be applied to the faintest stars observable. It would also make different magnitude and colour systems convertible to a high degree of accuracy.

Prof. Strömgren then presented three relevant communications from Dr Harold Johnson setting out his proposals for a three-colour photometry in which the visual magnitude zero-point is based on the revised values of Stebbins, Whitford and Johnson for the N.P.S. and which returns to the original definition of the zero-points of the colours in terms of unreddened main-sequence stars of class A0.

The general plan for this photometry is set out in the first communication. Three standard regions, the Pleiades, Praesepe and I.C. 4665 have been selected and in these regions from 100 to 2000 stars are to be observed including many non-cluster members and ranging in magnitude from the brightest stars to about visual magnitude 15. These standard regions do not contain all of the necessary types of stars and it is doubtful if it is possible to find any region that does so. A list of 109 bright stars has therefore been selected so as to include very blue stars, red dwarfs, etc. Most of these 109 stars are in the 'central zone' between declination $+15°$ and $-15°$ and are therefore accessible from both the northern and southern hemispheres.

The second communication from Dr Johnson which is to be published in the *Astrophysical Journal* gives a discussion of the magnitudes and colour indices for about 300 stars selected by spectral type and luminosity class to be representative of the principal regions of the Hertzsprung-Russell diagram. The third communication, which is also to be published in the *Astrophysical Journal*, gives the magnitudes and colours for 133 physical members of the Praesepe cluster and for 17 non-members in the same field. A comparison with the photographic photometry of Haffner and Heckmann shows the latter work to be extraordinarily good.

The Chairman then called on Prof. Redman to present the Report of the Sub-commission on sequences of magnitudes.

Prof. Redman said that in his opinion the North Polar Sequence could not be abandoned at present. He agreed with Dr Weaver that any new magnitude systems should disturb the existing international *pg* and *pv* systems as little as possible. He pointed out that the Cape programme outlined by Dr Stoy had needed already perhaps about 20 man-years of work, and that a comparable amount of work might be needed for the suggested equatorial belt of standard stars.

Dr Baade agreed with Dr Stoy that the North Polar Sequence, although thoroughly confirmed with regard to scale in the interval from 6^m to 16^m by the photo-electric measures of Stebbins and Whitford, is on account of its location very inconvenient for transfers. For this reason work is under way at Mts Wilson and Palomar to replace the North Polar Sequence by precision sequences in the following Kapteyn Areas:

At $+30°$: S.A. 51, 54, 57, 61.
$+15°$: S.A. 18, 71, 89.
$0°$: S.A. 94, 107.

All measures are being made photo-electrically by Dr W. Baum. The sequences will cover the interval from 9^m to $19^m{\cdot}5$ and provide photographic magnitudes and colour indices on the international system. For transfers of the zero-point the stars nos. 6, 10, 4*r* and 2*r* are used; the last of these finally may drop out because there are indications that it is slightly variable. For three of the areas, S.A.'s 51, 57 and 68, which contain the sequences regularly used in our extragalactic work, it is planned to extend the scale beyond $19^m{\cdot}5$ as far as is possible, perhaps to 22^m. The work on all areas is far advanced and comparisons with Stebbins and Whitford who previously established m_{pg}'s and colour indices in the S.A.'s 57 and 68 down to $19^m{\cdot}3$, show that there is complete agreement between their data and those of Baum.

Dr Stoy had proposed photometric observations in three colour ranges in order to avoid the well-known difficulties if we want to transfer the data of one colour system into another and suggested the ultra-violet as the third colour range besides the usual photographic and photovisual regions. We have considered this possibility at the Mts Wilson and Palomar Observatories, but did not like it very much on account of the well-known extinction difficulties in this range. Instead of this we would propose another remedy, i.e. to cut out in future work the ultra-violet entirely and to restrict the photographic region to the range from $\lambda 5000$ to $\lambda 3900$ (for instance by a Schott GG 13-filter). The loss in limiting photographic magnitude would be negligible in general, but we would gain the advantage, as thorough tests by Baum have shown, that data from one colour range can be transferred to another which is not too far apart by strictly linear relations.

Dr Rybka then gave a short summary of his plan to establish a network of standard stars with 'extra-atmospheric' magnitudes, i.e. magnitudes from which the effect of atmospheric extinction had been completely removed and which could be used for determining the local instantaneous extinction. This plan calls for the determination near each Kapteyn Area of the accurate magnitudes as far as possible on the *IPg*, *IPv* system of two stars with visual magnitudes between $5^m.5$ and $6^m.5$, one of them being of class A (B5–A5), the second of class K (G5–K5).

Dr Stoy remarked that he thought Prof. Redman was grossly overestimating the amount of work needed to redefine the present unsatisfactory system of standard magnitudes. Much of the necessary work had already been done. No accurate series of observations would ever be wasted since they could be incorporated and would strengthen the finally adopted series of standard and working magnitudes.

Dr Kourganoff announced that about 200 mimeographed copies of a French translation of Prof. Parenago's paper on the magnitude scales and photometric catalogues could be obtained by applying to him c/o Institut d'Astrophysique, 98bis Boulevard Arago, Paris (14), France.

After the Chairman had briefly discussed the proposals of Dr Becker and Dr Weaver he moved a formal resolution that the Commission should resolve to recommend the appointment of a new Sub-commission on standards of stellar magnitude with the following terms of reference:

(1) To examine the conditions under which accurate working magnitudes can be referred to a standard *pg*, *pv* system with errors not exceeding $0^m.02$.

(2) To examine the desirability of re-defining the zero of the international *pg*, *pv* scales and if possible to bring forward specific recommendations.

(3) To examine and report on Dr Becker's proposals for the establishment of standard magnitudes at the same wave-lengths.

(4) To examine and report on Dr Weaver's proposals for the establishment of a standard photo-electric colour and magnitude system.

(5) To examine and report on the desirability and practicability of Dr Becker's suggestion that the I.A.U. should sponsor the construction and distribution of standard filters.

This recommendation was agreed to unanimously.

The Commission then decided to recommend the re-appointment of the Sub-commission on sequences of magnitudes and to charge it with the task of attempting to establish recommended key sequences in the E regions at $-45°$.

The following resolutions were then passed.

(1) Commission 25 recommends that work in the various standard fields at $+15°$ should be encouraged but that no immediate final decision should be made as to which northern areas are to provide key sequences. The Commission considers that in the meanwhile preference should be given to S.A. 68, C 2, C 4, C 7, S.A. 85 and S.A. 89.

(2) Commission 25 expresses its appreciation of the value of the photometric circulars issued from the Royal Observatory, Cape of Good Hope, and it hopes that it may prove possible to continue the issue of these circulars.

It was decided to take no action with respect to recommendations III and IV of the Report of the Sub-commission on sequences of magnitudes.