25. COMMISSION DE PHOTOMÉTRIE STELLAIRE

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MAGNITUDES

1. Much material extending our knowledge of stellar magnitudes has accumulated during the last four years. In the appendix to this report will be found a list of recent catalogues, a summary of the discussion made at Mt Wilson by Seares and the formulae that he finds for the reduction of these catalogues to a fundamental system, until such time as a more extended discussion shall have furnished definitive corrections.

For convenience the following symbols are used:

C Colour indices inferred from HD spectra. Numerical values in Table I.
C_I, C_Y, C_G Colour indices of the Polar Standards (Rome Report, *Trans. I.A.U.* **1**, 71, 1922) and of the Yerkes and Göttingen actinometries, the last revised to agree with the PD general catalogue.
c Colour coefficient. The product cC gives the correction which reduces a stellar magnitude from one colour system to another.
G Groningen Pv magnitudes. *Publication* No. 44. See Appendix, section 5.
GA Main catalogue of the *Göttingen Aktinometrie*.
GAP Polar catalogue of the *Göttingen Aktinometrie*.
Gr *Greenwich photographic magnitudes of stars brighter than* 9·0 *between* + 75° *and* + 90°, 1913; *between* + 65° *and* + 75°, 1914.
HP Miss Payne's measures of Pg magnitude north of + 80°. *H.B.* No. 881. See Appendix, section 3.
HS Harvard Standard Regions. See Appendix, section 2.
IPg, IPv International photographic and photovisual Polar Standards, Rome Report, 1922.
L Leiden Pg magnitudes north of + 80°. *B.A.N.* No. 210. Measures by A. de Sitter; not the combination with other catalogues. See Appendix, section 4.
NPS North Polar Sequence.
PD General catalogue of the Potsdam Durchmusterung.
PDP Potsdam Polar Durchmusterung. See Appendix, section 1.
S Simeis photographic magnitudes by S. Beljawsky, *Bulletin de l'Observatoire central Nicolas à Poulkovo*, 1915.
Y *Yerkes Actinometry*, + 73° to + 90°, 1912. By J. A. Parkhurst.
Y_2 *Yerkes Actinometry*, Second Series, + 75° to + 60°, 1931. By A. S. Fairley. See Appendix, section 6.

COLOUR INDICES

2. *Colour Index and Spectral Type.* The relation between colour index and spectral type is still in a very unsatisfactory state. The difficulties are partly observational, partly instrumental, and partly inherent in the problem in that most of the data on spectral types do not distinguish between giant and dwarf stars of the same type. On the observational side the difficulties are those of determining accurate

Pg and Pv magnitudes, if the colour is to be found from the difference Pg – Pv; or those of standardization and of eliminating the gradation effect, if effective wave-lengths or exposure ratios are to be used. There are also complications arising from systematic differences in spectral classification. The instrumental difficulties have their origin in differences in the photographic plates and filters used, in the absorption of the mirror or in the absorption and colour correction of the objective, and in the colour perception of the observer, in case observations are made visually. Inability to distinguish between giant and dwarf stars, especially those of types G and K, means that the correlation of colour with spectrum will depend on the percentage of stars of different luminosities, and hence on the apparent magnitudes of the stars used to establish the relation.

Although much remains to be done, certain recent results are very helpful, especially in their bearing on the characteristics of various systems of magnitudes.

3. *Harvard Standard Stars. H.B.* 881, p. 18, gives details for the relation of the colour indices of HS stars to HD spectra. Smoothed values are in the second column of Table I.

TABLE I

Mean Colour Index and HD Spectrum.

HD	HS	Ross and Zug	MW (C)	HD	HS	Ross and Zug	MW (C)
B8	– 0·10	—	– 0·06	G5	+ 0·78	+ 0·80	+ 0·78
A0	0·00	0·00	0·00	8	0·95	0·97	0·95
2	+ 0·08	+ 0·12	+ 0·04	K0	1·03	1·10	1·07
5	0·17	0·26	0·12	2	1·20	1·21	1·20
F0	0·26	0·38	0·22	5	1·45	1·47	1·40
5	0·35	0·41	0·35	M	+ 1·67	+ 1·73	+ 1·65
G0	+ 0·57	+ 0·55	+ 0·54				

4. *Comparison Stars for Eros.* (*a*) Yerkes observations by Ross and Zug (*A.N.* **239**, 289, 1930). Colour indices for 607 stars, photographic magnitudes 7 to 11. (*b*) Mount Wilson observations by Seares, Sitterly, and Joyner (*Mt Wilson Contr.* No. 415, Tables IV, V, XI; *Astrophysical Journal*, **72**, 311, 1930). Values for 359 stars, Pg mags. 5 to 11. The mean values for A0 stars in these two series are – 0·15 and – 0·14 mag., respectively. About a hundred additional early-type stars on the Yerkes photographs were subsequently measured by Carr. Among them are 44 A0 stars, 32 fainter than Pg mag. 8·0. The mean colour index for the 44 A0 stars is – 0·04; for 12 stars having $m < 8{\cdot}0$, – 0·11; for 32 fainter stars, – 0·02. The A0 stars in both (*a*) and (*b*) suggest a similar dependence of mean colour on magnitude. The colours of the later-type stars, however, are in both cases the same for all magnitudes. The results, corrected by + 0·15 and + 0·14, respectively, are in the third and fourth columns of Table I.

From G0 on, the agreement for HS, R and Z, and MW is good, and since the last two series depend on polar comparisons with IPg and IPv standards, all three are in general accordance with the international colour system. The irregularities from A2 to F5, probably instrumental in origin, illustrate the difficulties involved in establishing a sharply defined system.

5. *Colour Equivalents of* 191 *Stars near the North Pole. Bulletin Astronomical Institutes of the Netherlands*, **4**, 115 (No. 140), 1927. By N. W. Doorn.

Stars north of + 80°, mostly brighter than Pg 7·5. Doorn's own measures of effective wave-lengths were combined with other colour equivalents: (1) CI from Yerkes Actinometry, (2) Greenwich effective wave-lengths, (3) CI from Göttingen Aktinometrie, (4) Poulkovo Pg combined with Kharkow Vis., (5) Greenwich Pg combined with Harvard Vis. All six series were reduced to the Yerkes colour system and combined into mean values, which in general have a mean error of $+ 0{\cdot}05$ mag.

6. *Untersuchung über Sternfarben. Veröffentlichungen der Universitäts-Sternwarte zu Bonn*, No. 23, 1930. By Bernhard Sticker.

An extensive investigation of the dependence of colour on absolute magnitude for stars of different spectral types, based on Göttingen colour indices of 1673 stars for which either spectroscopic or mean parallaxes are known, preceded by a discussion of the relation of colour to type, its dependence on galactic latitude (complicated by what seems to be a systematic error in right ascension in the GA) and on apparent magnitude. The adopted mean relation between colour and type (mostly HD spectra) depends on practically all the stars in the GA. An analysis of several frequency functions for colour index reproduces the sequence of preferential colour indices found at the Cape (Leiden Report, *Trans. I.A.U.* **3**, p. 151, 1928). The contention that such analyses have physical significance is vigorously criticized by Kienle (*Zeitschrift für Astrophysik*, **3**, 1, 1931) and by Öpik (*H.B.* 885, 1931).

7. *On the Relation of Absolute Magnitude to Colour, Spectrum and Proper Motion. Publications de l'Observatoire de Tartu*, **27**, No. 1, 1929. By E. Öpik.

Derived from 4500 colour indices reduced to a homogeneous system, including all northern stars having Harv. Vis. $< 5{\cdot}00$, a few fainter northern stars, a few in southern declinations, and all in the GA. Results are tabulated for each star, along with HD, MW and Victoria spectra, the spectroscopic absolute magnitude, and values of M derived from colour, spectrum and proper motion.

The colour system is defined by

$$C = m_L - \tfrac{1}{2}(m_P + m_H),$$

where m_L is Leiden Pg (Hertzsprung, *B.A.N.* No. 35, 1923), m_P is PD, and m_H is Harv. Vis. The relations between mean colour and HD spectra (*loc. cit.* Table 39) show clearly for types beyond F5 the dependence of colour on M.

Miscellaneous Investigations

8. Numerous undertakings, completed or in progress, can be mentioned only briefly. Brill (Berlin-Babelsberg, *Veröffentlichungen*, **9**, Part 2, 1931) has begun a detailed photographic-photometric investigation of 137 bright stars by a method which permits the simultaneous observation, on the same plate, of the intensity of two spectral regions.

A catalogue of 1800 Pg magnitudes and effective wave-lengths of stars in Praesepe, by Vanderlinden, is ready for publication (Prel. acct. *Mém. de l'Acad. royale de Belgique* in 4°, Ser. II, **10**, 1929). A similar catalogue for M 67 is soon to be published; also for a group of stars of large proper motion. Vanderlinden has also begun a programme of magnitudes, colours, and spectra for stars near the galactic circle.

The measures on the IPg system of stars in the zone $+ 60°$ to $+ 65°$ by Bergstrand (Leiden Report, *Trans. I.A.U.* **3**, p. 150, 1928) are two-thirds finished. The catalogue will probably be completed during 1933.

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In continuation of the work on Astrographic Zones (*ibid.* p. 151), Bemporad has investigated the magnitudes of stars common to 72 pairs of plates, and for 3179 stars finds a mean deviation of $\pm$ 0·19.

Mount Wilson Pv magnitudes and colour indices to a limit of 15·5 to 16 in 42 Selected Areas are finished, except for certain control plates. Publication has been delayed in order that tests involving exposure ratios and spectral types might be applied.

E. S. King and Ruth L. Ingalls have determined red magnitudes for 37 bright stars by King's extra-focal method from panchromatic plates exposed behind a red filter (*H.A.* **85**, No. 11, 1930). Relative to King's Pg system the resulting colour indices for K0 and M stars are 1·77 and 2·81 respectively (0 for A0).

Lindblad and Malmquist, with the new equipment at Stockholm, are beginning detailed investigations of special fields, in which the determination of magnitudes and colours will have an important part. In certain regions the limit for photometric observations will be pushed to the seventeenth magnitude.

The observatory of Poulkovo will reduce to the standard photometric system the estimates of visual magnitude in northern Selected Areas made by Okulicz (*Plan of S.A.* Third Report, p. 8).

For the southern Areas Becker will determine provisional Pg magnitudes for the stars whose spectra he classifies. The limit is 12 Pg in fields $4^\circ \times 4^\circ$.

Those who have experienced the difficulties of visual photometric observations will admire the way in which apparently many of these have been overcome in an improved form of stellar photometer, proposed by Gehlhoff and Schering and further improved by Hopmann (*Veröffentlichungen der Universitätssternwarte zu Leipzig*, Heft III, 1932).

Finally, everyone engaged in photometric investigations will appreciate the convenience and value of the contributions to the *Handbuch der Astrophysik*, Bd II, 2 on *Photographische Photometrie* by Eberhard and on *Visuelle Photometrie* by Hassenstein.

An Extension of the List of Polar Standard Magnitudes

9. Data are now available by means of which the number of Polar Standards between the fifth and eighth magnitudes may be increased to about 150 for both the photographic and photovisual (or visual) systems. The appendix summarizes the derivation of the systematic corrections to existing catalogues which will reduce them to the NPS system and clear the way for the formation of the additional standards. Further details will be printed elsewhere.

Spectrophotometry

10. This report presents no detailed account of recent investigations in spectrophotometry; the emphasis is intentionally placed on the status of the problems of magnitudes and colours as the principal objective of the Commission at this time. The Commission has in the past frequently emphasized the importance of spectrophotometric observations and again gives expression to that opinion by suggesting that the Union may well consider the desirability of organizing a separate commission, or at least a sub-committee of one of the existing Commissions, to give its whole attention to the rather specialized problems and technique of this field of investigation.

General Remarks

11. In many particulars the final remarks of the Leiden Report, 1928, are appropriate here. Could the existing catalogues be freed from systematic errors and brought to a common standard, an immense amount of material would then be available for the discussion of important questions. For example, the correlation of colour indices with spectral types in different parts of the sky would certainly throw light on the question of selective absorption. For this and other purposes the precision in respect to accidental error is ample; the obstacle lies in the present lack of homogeneity in the data. Various investigations already under way, notably at the Harvard Observatory, have been planned with the prospective utilization of such data in mind. The reduction formulae given in the Appendix are also a contribution to this end. The additional Polar Standards, which will be prepared and published as soon as possible, should also be helpful in standardizing observations already accumulated, as well as in providing new data on stars brighter than the eighth magnitude. With such standards available, it will, for example, be a simple matter to trace to its origin the dependence of Göttingen colour indices on right ascension, or to test the homogeneity of a suspected catalogue.

The Commission insists again on the vital importance of the standardization of all equipment on the international system. In case the magnitude scale is independently established in the course of an investigation, its relation to the Polar Standards should also be determined, as a means of defining the results and eventually of testing and revising the standards themselves.

F. H. Seares

President of the Commission

(APPENDIX TO REPORT OF COMMISSION 25)

Magnitudes

1. *Photometrische Durchmusterung der BD-Sterne von 7·5 bis 9·5, + 80° bis + 90°* (PDP). *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, **26**, Part 2 (No. 85), 1927. Observations by Müller, Kron and Kohlschütter, reduced and published by W. Hassenstein.

A catalogue of visual magnitudes, also including measures of selected stars north of + 73° and of NPS stars to $m = 12{\cdot}2$. The abundant material on Polar stars permits a comparison* with the IPv scale. The relative colour equation seems to be negligible, the scale differences small. In the mean

$$\text{IPv} - \text{PDP} = -0{\cdot}13 - 0{\cdot}01\text{C} \quad (\text{PDP 6 to 12}). \qquad \ldots\ldots(1)$$

When reduced to the same system—that of Müller for the years 1909–1916—the results in the PDP and the PD are closely accordant.

After correction for zero-point, the scale differences (unit, 0·01 mag.), with PD measures included, are

PDP	2·1	5·2	6·3	7·7	8·9	9·8	10·5	11·1	12·1
IPv − PDP	+7	0	+2	+7	0	−5	−2	−2	+2

Through the PDP we find for the PD catalogue the important relation

$$\text{IPv} - \text{PD} = -0{\cdot}22 + 0{\cdot}11\text{C}_{\text{I}} \quad (\text{PD} = 7{\cdot}35). \qquad \ldots\ldots(2)$$

* Seares, *Mt Wilson Contr.* No. 431; *Astrophysical Journal*, **74**, 131, 1931.

From different sources we also find

$$
\begin{aligned}
\text{PDP} - \text{PD} &= -0{\cdot}06 + 0{\cdot}06C_I \qquad (a)\\
&= -0{\cdot}06 + 0{\cdot}10C_I \qquad (b)\\
&= -0{\cdot}08 + 0{\cdot}09C_I \qquad (c)\\
&= -0{\cdot}07 + 0{\cdot}14C_I \qquad (d).
\end{aligned}
$$

(*a*) From 118 stars common to PDP and PD.
(*b*) From 112 of the same stars, differently grouped.
(*c*) From comparisons with 217 Harvard observations in *H.A.* 24.
(*d*) From comparisons with HP, 134 stars in PD and 75 in PDP.

The mean is

$$\text{PDP} - \text{PD} = -0{\cdot}07 + 0{\cdot}10C_I \qquad (\text{PD} = 7{\cdot}35). \qquad \ldots\ldots(3)$$

Combined with (2), (3) gives

$$\text{IPv} - \text{PDP} = -0{\cdot}15 + 0{\cdot}01C_I \qquad (\text{PDP} = 7{\cdot}35). \qquad \ldots\ldots(4)$$

2. *Photovisual Magnitudes in Harvard Standard Regions* (HSPv). *Harvard Annals*, **89**, No. 1, 1931. By Cecilia H. Payne.

Sequences of 15 to 20 stars (819 in all) in each of the 48 Harvard Standard Regions and at the South Pole; approximate limits 6·5 and 11·0. Revised Pg magnitudes (HSPg) referred to the international NPS standards are also given.

Photovisual results for zones E, F, and for the South Pole, are by Miss Payne, from objective-grating photographs made with the 10-inch Metcalf (MF) telescope, standardized, in part, by means of the IPv scale. The North Pole and zones A and B are from an unpublished investigation by Miss Leavitt, based on observations with the 16-inch Metcalf (MC) telescope and reduced by Miss Payne to the IPv standards. Zones C and D were included in both investigations. The provisional zero-point was fixed by the condition that the colour index of the A0 stars in zone C should be zero. All photovisual results are on the MF colour system.

Results by Miss Payne and Miss Leavitt for the same stars in zones C and D (values marked as uncertain not included) show a mean difference of $\pm$ 0·14 mag. For half the regions the mean difference arises from accidental error and zero-point difference; for the others a scale divergence of the form

$$\text{P} - \text{L} = a\,(\text{L} - b)$$

also enters, in which a ranges from + 0·1 to + 0·2 and b from about 7·5 to 8·6.

After allowance for a scale correction of + 7 per cent., the photovisual data by Miss Leavitt for stars at the North Pole give the relations

$$\text{MF} - \text{MC} = -0{\cdot}06 - 0{\cdot}14C_I, \qquad \ldots\ldots(5)$$

$$\text{IPv} - \text{MF} = +0{\cdot}08 + 0{\cdot}04C_I. \qquad \ldots\ldots(6)$$

Comparisons of results for zones A and B and for zone C with the PD and the GA give

	(A, B)		(C)		
HSPg − GA	= − 0·02 − 0·04C	(57 stars),	= − 0·12 − 0·02C	(42 stars),	(7)
HSPg − PD	= − 0·29 + 1·14C	(56 ,,),	= − 0·36 + 1·10C	(42 ,,),	(8)
HSPv − PD	= − 0·32 + 0·10C	(53 ,,),	= − 0·36 + 0·07C	(42 ,,),	(9)

which refer to a mean photovisual magnitude of about 7·5. Since the stars available for comparison cover an interval of but little more than a magnitude, scale divergence cannot be tested. All these comparisons are direct, except the first for (A, B), which was obtained by reducing the PD magnitudes to GA values with the aid of the mean colour indices (mean GA – PD for each spectral type). The accordance of the colour coefficients for (A, B) and (C) is satisfactory. The zero-point differences (A, B) – (C) are + 0·10, + 0·07, and + 0·04. Since the zero-points for HSPg and HSPv apparently coincide ((C) = 0 for A0 stars; cf. *H.B.* 881, p. 18), the mean,

$$(\text{A, B}) - (\text{C}) = +\,0{\cdot}07, \qquad \ldots\ldots(10)$$

may be adopted. Adjusting the constant terms in (7), (8), and (9) to satisfy (10) and using mean colour coefficients, we find for (C)

$$\text{HSPg} - \text{GA} = -\,0{\cdot}10 - 0{\cdot}03\text{C}, \qquad \ldots\ldots(11)$$
$$\text{HSPg} - \text{PD} = -\,0{\cdot}36 + 1{\cdot}12\text{C}, \qquad \ldots\ldots(12)$$
$$\text{HSPv} - \text{PD} = -\,0{\cdot}38 + 0{\cdot}08\text{C}. \qquad \ldots\ldots(13)$$

To obtain corresponding results for (A, B), add + 0·07.

The supplementary relations, from equation (2) and from Table IV*,

$$\text{IPg} - \text{GA} = +\,0{\cdot}06 - 0{\cdot}05\text{C}, \qquad \ldots\ldots(14)$$
$$\text{IPg} - \text{PD} = -\,0{\cdot}22 + 1{\cdot}11\text{C}, \qquad \ldots\ldots(15)$$
$$\text{IPv} - \text{PD} = -\,0{\cdot}22 + 0{\cdot}11\text{C}, \qquad \ldots\ldots(16)$$

combined with (11), (12) and (13), then give for (C),

$$\text{IPg} - \text{HSPg} = +\,0{\cdot}16 - 0{\cdot}02\text{C}, \qquad \ldots\ldots(17)$$
$$\text{IPg} - \text{HSPg} = +\,0{\cdot}14 - 0{\cdot}01\text{C}, \qquad \ldots\ldots(18)$$
$$\text{IPv} - \text{HSPv} = +\,0{\cdot}16 + 0{\cdot}03\text{C}. \qquad \ldots\ldots(19)$$

To obtain results for (A, B) add – 0·07. Equation (18) checks (17); (19) referred to (A, B) becomes

$$\text{IPv} - \text{HSPv} = +\,0{\cdot}09 + 0{\cdot}03\text{C}, \qquad \ldots\ldots(20)$$

which is checked by (6), derived from Miss Leavitt's observations on NPS stars. In the mean

$$\begin{array}{lll} & \text{(C)} & \text{(A, B)} \\ \text{IPg} - \text{HSPg} = & +\,0{\cdot}15, & +\,0{\cdot}08 - 0{\cdot}02\text{C}, \qquad \ldots\ldots(21) \\ \text{IPv} - \text{HSPv} = & +\,0{\cdot}16, & +\,0{\cdot}09 + 0{\cdot}03\text{C}. \qquad \ldots\ldots(22) \end{array}$$

These results are all internally consistent, as shown, first, by the colour coefficients for (A, B) and (C); second, by the zero-point differences for these zones; third, by the check equations for (17) and (19); and finally, by the difference, equation (21) *minus* equation (22):

$$\text{C} - \text{C}_{\text{HS}} = -\,0{\cdot}01 - 0{\cdot}05\text{C}, \qquad \ldots\ldots(23)$$

which is in harmony with the general condition that colour indices should be zero for A0 stars.

3. *Photographic Magnitudes of Bright Stars North of* + 80° (HP). *Harvard Bulletin*, No. 881, p. 9, 1931. By Cecilia H. Payne.

Results for stars selected from the programme for the determination of the magnitudes of all stars brighter photographically than 8·25 and used for comparison

* Equation (14) applies properly to GAP. Its use here is as much a test of the formula itself as it is a check on (15).

with similar results by A. de Sitter (see section 4); derived from polar comparisons with the IPg standards made with a 3-inch Ross lens, stopped to $1\frac{1}{2}$ inches. Extra-focal exposures measured with a Schilt photometer. Accordance with the international system may be tested by the comparisons:

$$\text{HP} - \text{PD} = -0{\cdot}23 + 1{\cdot}11\text{C} \quad (134 \text{ stars, PD} = 7{\cdot}0), \qquad \ldots\ldots(24)$$

$$\text{HP} - \text{PDP} = -0{\cdot}16 + 0{\cdot}98\text{C} \quad (75 \text{ stars, PDP} = 7{\cdot}3), \qquad \ldots\ldots(25)$$

$$\text{HP} - \text{GAP} = +0{\cdot}06 - 0{\cdot}07\text{C} \quad (119 \text{ stars, GAP} = 7{\cdot}2). \qquad \ldots\ldots(26)$$

From equations (2) and (4) and a provisional correction for GAP, afterwards verified by Table IV, we obtain

$$\left.\begin{aligned}\text{IPg} - \text{HP} &= +0{\cdot}01 + 0{\cdot}00\text{C}\\ &= +0{\cdot}01 + 0{\cdot}03\text{C}\\ &= +0{\cdot}01 - 0{\cdot}02\text{C}\end{aligned}\right\}. \qquad \ldots\ldots(27)$$

4. *Photographic Magnitudes of Stars brighter than 7·5 between declination + 80° and the Pole* (L). *Bulletin of the Astronomical Institutes of the Netherlands*, **6**, 65 (No. 210), 1930. By A. de Sitter.

Photographs with the 10·5 cm. objectives of a double camera, provided with moving plate holders. The scale was established by means of an objective grating, the zero-point being fixed by the IPg magnitudes of 10 NPS standards. Relations with five other catalogues, HD, GAP, YPg, Gr, and S, expressed by linear formulae involving Doorn's colour indices (see section 5, p. 137 above), were used to reduce the magnitudes in all these catalogues to the same system, namely the scale of L, the IPg zero-point, and the colour system of GAP. The characteristics of de Sitter's own measures appear from the discussion in sections 10–12.

5. *Photovisual Magnitudes for the Selected Areas at* + 75° (G). *Publications Kapteyn Astronomical Laboratory*, No. 44, 1929. From plates taken at the McCormick Observatory by Alden and van de Kamp; discussed by van Rhijn and Bok.

The catalogue includes 509 stars, magnitudes 9–13, in S.A. 2 to 7, referred to the IPv scale by polar comparisons. The consistency of the zero-points was checked by zone-comparison photographs. Fifty-eight of the stars have been observed at Mount Wilson. Although the number is small, these stars show in all six Areas a scale divergence of the form $\text{MW} - \text{G} = a\,(\text{G} - 11)$, in which a is $+0{\cdot}2$ or more; for S.A. 2, in the interval $\text{G} = 10{\cdot}5$ to $12{\cdot}5$, $a = +0{\cdot}8$. This large divergence requires further investigation. In the meantime the following details may be noted: Mount Wilson colours for S.A. 2 seem to be normal. On the other hand, the mean colour indices found by comparing G with *H.A.* **101** (75 stars reduced to the IPg scale) are large and increase rapidly from G = 12 mag. onwards. At 12·5 the mean colour index is 2·1. Further, the star ratios from counts of stars grouped according to various magnitude scales are:

m	11·0	11·5	12·0
G	3·0	2·9	3·8
Gron. Pub. **43**, Table I, Pg	2·6	2·5	2·3
MWPg	2·4	2·4	2·4
MWPv	2·0	2·0	2·0

The ratios from MWPv are not very reliable because of the small number of stars. It is clear, however, that those from G are abnormally large.

6. *Yerkes Actinometry*, Second Series, + 75° to + 60° (Y_2). *Astrophysical Journal*, **73**, 125, 1931. By Arthur S. Fairley.

An extension of the *Actinometry* of Parkhurst (Y), giving the photographic magnitudes of 2354 stars to $m = 8{\cdot}25$ (limit for Y = BD 7·5). A comparison with Y by Eberhard (*Vierteljahrsschrift der A.G.* **66**, 321, 1931), based on 123 stars common to both catalogues, shows a relative colour coefficient of zero and scale differences as follows (unit = 0·01 mag.):

m	< 6·0	6·1–6·5	6·6–7·0	7·1–7·5	7·6–8·0	> 8·0
$Y_2 - Y$	+ 23	+ 4	+ 7	+ 9	+ 2	− 5

Within the interval $m = 6$ to 8 the difference is chiefly one of zero-point, with a mean value of + 0·055 mag. There is, however, a large variation with right ascension:

RA	0^h–3^h	3–12^h	12^h–$20{\cdot}5^h$	$20{\cdot}5^h$–24^h
$Y_2 - Y$	+ 14	+ 7	− 17	+ 10

The catalogue also includes HR visual magnitudes and HD spectra.

7. *Photographic Magnitudes of Stars brighter than* 14·0 *in* 40 *of Kapteyn's Selected Areas.* Determined at the Royal Observatory, Greenwich, by P. J. Melotte under the direction of Sir Frank Dyson, 1931.

Based on polar comparisons made with the 26-inch refractor, reduced originally with the standards of *H.C.* 170 and subsequently revised in accordance with *H.A.* **71**, 224 and *H.B.* 781. The catalogue also includes magnitudes of 395 stars within 1° of the Pole. Comparison of catalogue magnitudes for 36 NPS stars with the IPg standards gave

$$\text{IPg} - \text{Gr} = -\,0{\cdot}04 + 0{\cdot}10C_I. \qquad \ldots\ldots(28)$$

Except for four bright stars at the beginning of the magnitude interval covered by the catalogue, whose deviations may be regarded as a slight scale divergence, a better representation is given by

$$\text{IPg} - \text{Gr} = -\,0{\cdot}13 + 0{\cdot}23C_I. \qquad \ldots\ldots(29)$$

The large colour coefficient here given for the 26-inch refractor is that found from 33 NPS stars in the preparation of the Rome Report, 1922, and checked by an independent computation for 53 stars of *H.A.* 48, which led to 0·25.

Comparisons of these Gr magnitudes have been made for all 40 Areas with the results of the *Mount Wilson Catalogue.* For 9 of the Areas unpublished MWPv magnitudes are available, and hence also colour indices. These permit an additional determination of the colour coefficient of the Greenwich refractor. The result confirms in the mean the second of the above formulae, in zero-point as well as in colour coefficient. The large difference in colour system complicates the comparison for the remaining Areas. In general, however, the agreement seems to be poor.

8. *Photovisual Magnitudes of Southern Stars, with revised values for Northern Stars. Harvard Annals,* **85**, No. 10, 1928. By Edward S. King.

A revision and extension of King's well-known results for bright stars obtained from extra-focal exposures, together with a revision of his colour indices. The new list includes 123 stars brighter than about the third magnitude.

9. *Mount Wilson Catalogue of Photographic Magnitudes in Selected Areas* 1–139 (MWC). Carnegie Institution of Washington Publication 402. *Papers, Mount Wilson Observatory,* **4**, 1930. By Seares, Kapteyn, and van Rhijn, assisted by Mary C. Joyner and Myrtle L. Richmond.

Magnitudes on the IPg system of 67,941 stars to an average limit of about 18·5. Full details may be found in the introduction to the catalogue.

10. The catalogues used in the discussion are Gr, S, HP, L, GAP, and YPg (photographic) and PD, PDP, and YPv (visual and photovisual). Harvard observations with the meridian photometer have not yet been included, partly because of the labour involved in segregating the measures by different observers, and partly because their reduction to the fundamental system will be facilitated by the use of provisional Pv standards derived from the PD, PDP, and YPv.

The inclusion of colour equations in the discussion is important. The colour equivalent used provisionally is the colour index C inferred from the HD spectral type. The adopted values for each type are those found at Mount Wilson, on the international system, from observations of comparison stars for Eros, corrected by a constant such that for A0 stars C becomes zero (section 3, p. 137, Table I). Later, the systematic relations between the different catalogues and the magnitudes of the standards themselves should be revised on the basis of colour indices derived from provisional values of the Pg and Pv standards.

The relations between the various systems of magnitudes are based on differences for individual stars, expressed in the form

$$m_1 - m_2 = \Delta m + \mathrm{c}C, \qquad \ldots\ldots(30)$$

where m_1 and m_2 are the magnitudes in any two catalogues, Δm the scale difference, and c the relative colour coefficient. Means of these differences for groups of stars having different values of C, all within a small interval in m_2 (usually 0·5 mag.), give for that interval values of Δm and c. Similar means for other intervals in m_2 extend the comparison over the entire range in magnitude. The unit for Δm and c is 0·01 throughout the discussion and in all the tables.

11. To understand the treatment of the photographic data, place the symbols Gr and S at the centres of two squares, and at the corners of each square write in succession the symbols for the other photographic catalogues, H, L, GAP, YPg, in the counter-clockwise direction around the squares. The sides and diagonals (δ) and the semi-diagonals (Δ) of the squares then represent the corrections established by 14 different comparisons made among the six catalogues. A fifteenth comparison, S − Gr, connects the two squares with each other. The diagrams also represent a network of closing conditions used to adjust the "observed" differences, which later must be connected with the IPg system at the Pole.

To avoid too much complexity, the adjustment was made in steps: first, the sum of the semi-diagonals against the diagonals; second, the semi-diagonals and sides of each square separately (Gr net and S net); third, the two nets against each other, in this case a simple mean, checked by the fifteenth comparison, S − Gr.

The essential conditions are expressed by the closure of the four triangles included between the sides and the semi-diagonals of the squares. The observed relations for the triangular circuits are

$$\Delta_n - \Delta_{n+1} + \delta_n = \phi_n \quad (n = 1, 2, 3, 4), \qquad \ldots\ldots(31)$$

where ϕ is the closing error. The adjustments, which were made by the standard formulae for conditioned observations, give corrected differences satisfying the conditions

$$\mathrm{D}_n - \mathrm{D}_{n+1} + \mathrm{d}_n = 0 \quad (n = 1, 2, 3, 4). \qquad \ldots\ldots(32)$$

The algebraic signs in these formulae correspond to differences formed in the counter-clockwise direction along the sides of the squares and from the centre outward, and to a counter-clockwise circuit around the triangles.

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Since the systematic relations are defined by mean scale differences and colour coefficients for narrow intervals of the argument m_2, the adjustment formulae must be applied separately to the results for each of these intervals, once to obtain the corrected scale difference, and once to obtain the colour coefficient. It is important to note that all adjustments, and in fact all combinations of systematic relations throughout the entire discussion, must be made for corresponding values of a common argument. This necessarily involves much reduction back and forth from one argument to another, and requires the use of smoothed values of the observed data for Δm and c, obtained most conveniently by graphical methods.

The number of differences involved in a comparison is usually about 140. Gr − YPg and S − YPg are exceptions, with totals of 493 and 283, respectively. For the entire series of 15 comparisons the total is 2853. With the exception of Δm for Gr − YPg, all the differences enter into the adjustment formulae with equal weights. For this one difference the adjusted results are sensibly those derived from the curve of smoothed values. Doubtless the data differ in excellence, but since homogeneity of scale and colour, as well as accidental errors, is involved, differential weighting must be deferred until the provisional results are revised.

The adjusted results are given in Table II, the Gr net above, the S net below, with values of Δm on the left and of c on the right in each column. That the closing conditions are satisfied may be verified by substituting the values of D and d into equations (32).

TABLE II

Adjusted Differences in Scale (figures on left in each column) and Colour for Six Photographic Catalogues (unit = 0·01 mag. in scale; 0·01 in c).

m	D_1	D_2	D_3	D_4	d_1	d_2	d_3	d_4
Gr	Gr − HP	Gr − L	Gr − GAP	Gr − YPg	HP − L	L − GAP	GAP − YPg	YPg − HP
5·25	+ 9 − 2	+ 10 − 1	+ 17 − 20	+ 22 − 11	+ 1 + 1	+ 7 − 19	+ 5 + 9	− 13 + 9
5·75	+ 3 − 1	+ 3 0	+ 11 − 20	+ 12 − 10	0 + 1	+ 8 − 19	+ 1 + 10	− 9 + 9
6·25	− 5 − 1	− 4 + 1	+ 3 − 18	0 − 10	+ 1 + 2	+ 7 − 19	− 3 + 8	− 5 + 9
6·75	− 13 + 1	− 10 + 3	− 6 − 12	− 11 − 7	+ 3 + 2	+ 4 − 15	− 5 + 5	− 2 + 8
7·25	− 19 + 4	− 13 + 6	− 12 − 4	− 15 − 5	+ 6 + 2	+ 1 − 10	− 3 − 1	− 4 + 9
7·75	− 21 + 6	− 13 + 8	− 17 + 6	− 16 − 6	+ 8 + 3	− 4 − 3	+ 1 − 11	− 5 + 11
S	S − HP	S − L	S − GAP	S − YPg	HP − L	L − GAP	GAP − YPg	YPg − HP
5·25	− 6 + 61	− 4 + 62	+ 4 + 41	+ 8 + 51	+ 2 0	+ 8 − 21	+ 4 + 9	− 14 + 11
5·75	− 6 + 45	− 5 + 47	+ 2 + 26	+ 4 + 36	+ 1 + 2	+ 7 − 21	+ 2 + 10	− 10 + 10
6·25	− 4 + 31	− 4 + 33	+ 2 + 14	0 + 22	0 + 2	+ 6 − 19	− 2 + 8	− 5 + 9
6·75	− 3 + 18	− 1 + 20	+ 4 + 3	− 1 + 10	+ 2 + 2	+ 5 − 17	− 5 + 6	− 2 + 8
7·25	0 + 5	+ 4 + 7	+ 6 − 4	0 − 2	+ 5 + 2	+ 1 − 11	− 5 + 2	0 + 7
7·75	+ 1 0	+ 11 + 4	+ 6 0	+ 1 − 9	+ 10 + 4	− 5 − 4	− 5 − 9	0 + 9

12. To connect these results with the IPg system, consider first the colour coefficients. Equations (27), section 4, show that the coefficient of HP relative to IPg is sensibly zero. Further, there is reason to believe that c for HP does not vary with the magnitude. Hence for IPg − HP we adopt for all magnitudes the value c = 0. The values of c under the headings Gr − HP and S − HP in Table II, with their signs reversed, are accordingly the coefficients for IPg − Gr and IPg − S, respectively; and these, combined with the data in the following columns of the table, give in succession two independent determinations of the coefficients of L, GAP, and YPg relative to IPg, one through Gr, the other through S. The systematic differences between these results are in Table V; the final mean values of c

for all the catalogues, in Table IV. The large values of c for S are in harmony with the known characteristics of the instrument used.

TABLE III

Connection of Gr and S Scales with the IPg System.

m	IPg − Gr	IPg − S	IPg − HP	IPg − L	IPg − GAP	IPg − YPg	IPv − YPv	IPv − PD
				Provisional Scale Corrections from NPS Stars				
5·25	− 2	0	0	+ 2	+ 7	+ 13	+ 3	− 27
5·75	+ 2	0	0	+ 2	+ 7	+ 11	+ 5	− 25
6·25	+ 5	+ 1	0	+ 2	+ 7	+ 9	+ 7	− 24
6·75	+ 9	0	0	+ 2	+ 7	+ 7	+ 8	− 22
7·25	+ 12	− 4	0	+ 2	+ 7	+ 5	+ 9	− 21
7·75	+ 15	− 5	0	+ 2	+ 7	+ 3	+ 11	− 19
Gr				IPg − Gr				
5·25	− 2	—	− 9	− 8	− 10	− 8	− 7	− 8
5·75	+ 2	—	− 3	− 1	− 4	− 1	− 2	− 3
6·25	+ 5	—	+ 5	+ 6	+ 4	+ 9	+ 8	+ 4
6·75	+ 9	—	+ 13	+ 12	+ 13	(+ 18)*	(+ 17)*	+ 12
7·25	+ 12	—	+ 19	+ 15	+ 19	+ 19	+ 20	+ 18
7·75	+ 15	—	+ 21	+ 15	+ 24	+ 18	+ 20	+ 22
S				IPg − S				
5·25	—	0	+ 6	+ 6	+ 3	+ 5	+ 5	+ 4
5·75	—	0	+ 6	+ 7	+ 5	+ 7	+ 6	+ 5
6·25	—	+ 1	+ 4	+ 6	+ 5	+ 9	+ 8	+ 5
6·75	—	0	+ 3	+ 3	+ 3	+ 8	+ 8	+ 3
7·25	—	− 4	0	− 2	+ 1	+ 5	+ 6	0
7·75	—	− 5	− 1	− 9†	+ 1	+ 2	+ 4	0
Gr			Residuals: Mean IPg − Gr *minus* Individual					
5·25	− 6	—	+ 1	0	+ 2	0	− 1	0
5·75	− 4	—	+ 1	− 1	+ 2	− 1	0	+ 1
6·25	+ 1	—	+ 1	0	+ 2	− 3	− 2	+ 2
6·75	+ 4	—	0	+ 1	0	(− 5)*	(− 4)*	+ 1
7·25	+ 6	—	− 1	+ 3	− 1	− 1	− 2	0
7·75	+ 5	—	− 1	+ 5	− 4	+ 2	0	− 2
Z.Pt	+ 1		0	+ 1	0	− 1	− 1	0
S			Residuals: Mean IPg − S *minus* Individual					
5·25	—	+ 5	− 1	− 1	+ 2	0	0	+ 1
5·75	—	+ 6	0	− 1	+ 1	− 1	0	+ 1
6·25	—	+ 5	+ 2	0	+ 1	− 3	− 2	+ 1
6·75	—	+ 5	+ 2	+ 2	+ 2	− 3	− 3	+ 2
7·25	—	+ 6	+ 2	+ 4	+ 1	− 3	− 4	+ 2
7·75	—	+ 5	+ 1	+ 9†	− 1	− 2	− 4	0
Z.Pt		+ 5	+ 1	+ 1	+ 1	− 2	− 2	+ 1

* Rejected. † Half Weight.

The derivation of the scale errors relative to the IPg system is based on the observations of NPS stars given in each of the catalogues. It was expected that both Gr and S would give excellent connections with the IPg system, since both include NPS stars well outside the magnitude interval here considered, and for Gr especially, the measures are numerous and the accidental errors small. The dozen or so NPS stars occurring in each of the other catalogues cover a shorter range in magnitude. Individually, the connections established through these stars are not of high weight; the collective mean, however, should be reliable because the errors of the Polar Standards themselves are small, while the relatively large errors affecting the catalogue values for these stars are minimized by the combination of results by several different observers.

Table IV

Adopted Corrections for Six Catalogues of Photographic Magnitude*.

m†	IPg − Gr	IPg − S	IPg − HP	IPg − L	IPg − GAP	IPg − YPg‡
5·25	− 8 + 2	+ 5 − 61	0 0	+ 1 + 1	+ 9 − 19	+ 13 − 9
5·75	− 2 + 1	+ 6 − 45	$+0^5$ 0	+ 1 + 2	+ 9 − 19	+ 9 − 9
6·25	+ 6 + 1	+ 6 − 31	+ 1 0	+ 2 + 2	+ 8 − 17	+ 6 − 9
6·75	+ 13 − 1	+ 5 − 18	+ 1 0	+ 3 + 2	+ 8 − 14	+ 3 − 8
7·25	+ 18 − 4	+ 2 − 5	$+0^5$ 0	+ 5 + 2	+ 7 − 9	+ 2 − 8
7·75	+ 20 − 6	0 0	0 0	+ 8 + 3	+ 5 − 1	+ 2 − 10

* The first term of each entry is the scale correction; the second, the colour coefficient. Thus for Gr = 5·25, in hundredths of a magnitude, IPg − Gr = − 0·08 + 0·02C. Values of C in Table I.

† *m* indicates Gr, S, HP, etc.

‡ Additional values: 8·25, + 5 − 11; 8·75, + 15 − 11. Obtained by extrapolations of results from Gr and S adjustments, controlled by direct comparison S − Gr for faint stars.

Table V

Systematic Difference between Corrections Obtained through Gr and S Adjustments.

m	HP		L		GAP		YPg		Mean Syst.	Mean Diff.
5·25	+ 2	0	+ 1	0	0	+ 2	0	+ 1	+ 1	+ 1
5·75	+ 1	0	0	− 1	+ 1	0	0	0	$+0^5$	0
6·25	− 1	0	0	0	+ 1	0	0	0	0	0
6·75	− 2	0	− 1	0	− 1	0	− 1	0	− 1	0
7·25	− 3	0	− 2	0	− 2	− 2	+ 1	− 2	-1^5	− 1
7·75	− 2	0	− 4	− 2	− 2	− 2	+ 3	− 2	− 1	− 2

The mean result, however, may further be strengthened by utilizing YPv and PD measures of NPS stars. Compared with the standards, these catalogues give corrections of the form IPv − YPv and IPv − PD. To the first of these forms apply the difference $C - C_Y$. The result is

$$(\mathrm{IPv} - \mathrm{YPv}) + C - C_Y = \mathrm{IPg} - \mathrm{YPg}.$$

A correction to YPg has therefore been derived from the correction to YPv. Were we to substitute into this formula the magnitudes and colour indices of individual stars, nothing would be gained; the calculated differences on the right would then be just those given directly by the photographic data. The derivation of IPg − YPg becomes independent, however, if for the parenthesis we use smoothed values of the photovisual correction and for $C - C_Y$ substitute values of $-C_Y$ for Ao stars of corresponding magnitudes, a substitution permissible for all but the red stars. The point of the artifice is that the values of C_Y for Ao stars of different magnitudes are an expression of the relation of the YPg and YPv scales which depends on all the stars of this type for which colours are known. In fact, stars of neighbouring

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types, for example, B9 and A1 to A3, may also be included, with the result that the relation between YPg and YPv becomes well determined. The relation used depends on 185 stars. A similar procedure derives IPg – GAP independently from IPv – PD. The colour indices of A0 stars necessary for the two transformations are

m	5·25	5·75	6·25	6·75	7·25	7·75
C_Y	– 14	– 3	0	0	+ 2	+ 5
C_{GAP}	– 34	– 32	– 30	– 28	– 26	– 24

where the argument m is, in turn, YPg and GAP.

The provisional scale corrections derived directly from the NPS stars are given in the first division of Table III, for which the argument is always the second term of any difference; for example, Gr for IPg – Gr, PD for IPv – PD, etc. The further procedure is to form, first, values of the correction IPg – Gr by combining each correction in the first division of the table with the appropriate difference from the Gr net in Table II; and, second, values of IPg – S by similar combinations with results from the S net. Thus

$$(\mathrm{IPg} - \mathrm{HP}) - (\mathrm{Gr} - \mathrm{HP}) = \mathrm{IPg} - \mathrm{Gr},$$
$$(\mathrm{IPg} - \mathrm{HP}) - (\mathrm{S} \quad - \mathrm{HP}) = \mathrm{IPg} - \mathrm{S}, \text{ etc.}$$

Here, as always, care must be taken with the argument to which the differences refer.

The results, in the second and third divisions of Table III, are satisfactorily accordant except in those cases for which the best agreement had been expected, namely, the Gr and S catalogues. In neither of these cases is the scale correction for the NPS stars (from direct comparison with the IPg values) the same as that derived for the other stars in the catalogue (from accordant comparisons with the Pole made through six other catalogues). The relations are best shown by the residuals given in the fourth and fifth divisions of Table III.

The adopted corrections for Gr and S in the second and third columns of Table IV are the direct means of the last six columns of the second and third divisions of Table III, with two values rejected and one given half weight. A combination of these corrections gives S – Gr, which should check with the results of a direct comparison of the two catalogues. The differences, Direct – Computed, are:

S	5·25	5·75	6·25	6·75	7·25	7·75	8·25
Scale	+ 13	+ 2	– 1	– 1	0	0	– 1
Colour Coeff.	—	—	—	+ 4	+ 5	+ 3	+ 1
No. stars	7	12	21	57	82	104	66

The agreement in scale, except for the group including only seven stars, is wholly satisfactory; that for colour less so, but still within the limits of uncertainty. The mean discordance of 0·03 in c is the closing error between the Gr and S nets, which may be adjusted to each other by forming the means of results obtained from them.

The final step is the combination of the adopted corrections IPg – Gr and IPg – S with the differences of Table II to obtain final corrections for the remaining four Pg catalogues. Here again independent results are given by the Gr and S nets; the systematic differences are collected in Table V, the final mean corrections in Table IV.

13. The data bearing on Pv magnitudes are summarized in Tables VI, VII and VIII. Table VI gives nine different determinations of the scale correction IPv − PD, obtained as indicated in the appended notes. The intermediate comparisons, YPv − PD, Gr − PD − C, S − PD − C, and HP − PD − C, used in these determinations and other details will be printed elsewhere. The results for the colour coefficient of the PD depend on rather slender data (Table VII), but are certainly of the right order of size and show the proper variation with magnitude. The adopted correction IPv − PD (Table VIII) is in good agreement with the well-determined relation, equation (2), section 2.

The correction adopted for IPv − YPv (Table VIII) was found by combining the photographic difference IPg − YPg in Table IV with Yerkes colour indices of A0 and K0 stars by a method which, in general, is the inverse of that used in connection with Table III to obtain IPg − YPg from IPv − YPv.

The Pv relations may be amplified in certain directions, notably by comparisons of Gr and S with PDP, and by a utilization of the Greenwich effective wavelengths. When calibrated on NPS colour indices, these colour equivalents may be combined with Pg magnitudes obtained with the corrections of Table IV to derive magnitudes on the IPv system. In this connection the *Catalogue of* 1156 *stars* by Fessenkoff, from observations made at Kharkow, should also be examined.

Table VI

IPv − PD Scale Difference from Various Comparisons.

PD	(1) NPS_1	(2) NPS_2	(3) YPv_1	(4) YPv_2	(5) Gr_1	(6) Gr_2	(7) S	(8) GAP	(9) HP	(10) Mean
5·25	− 27	− 26	− 24	—	—	—	—	− 21	(− 9)	− 24
5·75	25	26	25	− 19	− 18	− 23	—	20	16	22
6·25	24	26	26	25	20	27	− 24	20	20	24
6·75	22	25	26	21	23	27	26	19	22	24
7·25	21	16	20	24	24	28	24	− 18	22	22
7·75	− 19	− 15	− 19	− 22	− 25	− 26	− 20	—	− 20	− 21

Residuals: Mean IPv − PD *minus* Individual

PD	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
5·25	+ 3	+ 2	0	—	—	—	—	− 3	(− 15)
5·75	+ 3	+ 4	+ 3	− 3	− 4	+ 1	—	− 2	− 6
6·25	0	+ 2	+ 2	+ 1	− 4	+ 3	0	− 4	− 4
6·75	− 2	+ 1	+ 2	− 3	− 1	+ 3	+ 2	− 5	− 2
7·25	− 1	− 6	− 2	+ 2	+ 2	+ 6	+ 2	− 4	0
7·75	− 2	− 6	− 2	+ 1	+ 4	+ 5	− 1	—	− 1
Z.Pt	0	− 0^5	+ 0^5	0	− 0^5	+ 4	+ 1	− 4	− 3

Column

(1) Direct comparison of PD and NPS.
(2) Direct comparison IPv − YPv for NPS stars combined with YPv − PD.
(3) Adopted correction IPv − YPv (Table VIII) combined with YPv − PD.
(4) Adopted correction IPv − YPv (Table VIII) combined with YPv − PD for A0 stars.
(5) Adopted correction IPg − Gr (Table IV) combined with Gr − PD − C.
(6) Adopted correction IPg − Gr (Table IV) combined with Gr − PD − C for A0 stars.
(7) Adopted correction IPg − S (Table IV) combined with S − PD − C for A0 stars.
(8) Adopted correction IPg − GAP (Table IV) combined with GAP − PD for A0 and K0 stars.
(9) Adopted correction IPg − HP (Table IV) combined with HP − PD − C.

Table VII
IPv − PD Colour Coefficient.

PD	(3) YPv$_1$	(5) Gr$_1$	(8) GAP	(9) HP	Mean
5·25	—	—	—	+ 2	+ 2
5·75	—	0	—	2	1
6·25	+ 4	+ 2	+ 10	3	5
6·75	5	6	—	8	6
7·25	6	6	—	+ 14	9
7·75	+ 12	+ 3	—	—	+ 8

Numbers in column headings correspond to those in Table VI.

Table VIII
Adopted Corrections for YPv and PD*.

YPv	IPv − YPv		PD	IPv − PD	
5·25	+ 5	− 5	5·25	− 24	+ 1
5·75	+ 5	− 5	5·75	− 24	+ 2
6·25	+ 5	− 3	6·25	− 24	+ 5
6·75	+ 4	+ 1	6·75	− 24	+ 6
7·25	+ 4	+ 10	7·25	− 22	+ 8
7·75	+ 7	+ 20	7·75	− 21	+ 9

* See note * to Table IV.

The systematic corrections in Tables IV and VII are at least applicable to the stars from which they are derived, and should lead to a group of additional standards closely accordant with the NPS system. To what extent these corrections are applicable to other stars in the respective catalogues is a matter for further study, the results of which will depend on the homogeneity of the catalogues. For the GA, as distinct from the GAP which alone enters here, reservation must be made at once. As pointed out by Schwarzschild, the faint red stars in the GAP are affected by a systematic error, which in the present discussion appears as a rapid change in the colour coefficient. The values of c for the GAP may not therefore apply to the GA. Further, the Göttingen colour indices of stars of the same type are known to vary with the right ascension. This may indicate the influence of space absorption or of error in one or both of the magnitude scales. The probabilities point toward error in the GA scale, but in any case a variation in the reduction to the international system must be provided for somewhere.

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Colour Temperatures

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14. Since the Leiden meeting the relative spectrophotometric gradients for 24 stars have been published (*Monthly Notices*, **90**, p. 104, 1929). These stars have been extensively inter-compared and are intended for use as standards. The gradient for any other star in the northern hemisphere can now be determined by comparison with one or more of these.

To convert gradients into colour temperatures it is necessary to know the colour temperature corresponding to zero gradient. This can only be determined by comparisons between stars and a laboratory source. A series of such comparisons has been carried out. The necessary determinations of atmospheric reddening have been secured by comparing standard stars at different zenith distances (0° to 60°) and applying the gradients for these stars as previously determined. The laboratory source of light used was an Eastman Kodak Standard Acetylene Burner.

The copy for press for a volume containing the results of these and other observations is being prepared. The introduction to this volume contains a discussion on the effect of varying exposure times. The conclusion reached is that when small differences of colour temperature are being measured, a certain amount of latitude is permissible with exposure times, but when large differences are being measured (e.g. when an A type star is compared with a laboratory source) the same exposure time should be maintained for all spectra compared. This restriction is awkward when applied to plates taken at the telescope, but the colour differences can always be reduced to small quantities by the use of colour filters (e.g. the insertion of a suitable blue filter for the exposure on the laboratory source of light). This procedure requires that the absorptions of the filters at the relevant wave-lengths should be determined, but these determinations can be carried out in the laboratory under rigorous conditions, including constancy of exposure times.

When small differences of colour are being measured, and unequal exposure times are used, experience has suggested the desirability of adjusting the optical train (by the insertion of a colour filter if necessary) so that the densities at the ends of the spectral range used are not too widely different.

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15. The measurement of short dispersion objective prism spectra for the determination of the colours and temperatures of stars has been carried on with the Schilt microphotometer. The results for 400 northern stars are now available, and the deduced colours are being discussed for absolute magnitude effects, and also are being compared in some detail with the colour indices derived from a combination of the HPP and the HPvP magnitudes.

The following, submitted by Miss Payne, but arriving too late for incorporation in the body of the report, may not inappropriately be inserted at this point:

Heterochromatic Photometry. (*a*) Investigations of various combinations of plates and colour filters, using the 24-inch reflector and standardizing with a grating, have led to the definition of scales in ultra-violet (blue), yellow, orange, and red light. Ultra-violet and red scales, designed to be used as standards, have been set up in the Pleiades. The blue scale is the ordinary photographic scale, which has disadvantages as compared with one more nearly monochromatic; the orange scale appears to have so many disadvantages that it is not planned to investigate it further.

(*b*) The standardization of the various yellow magnitude scales that are associated with the numerous Harvard photographic instruments is a natural outcome of the experiments in heterochromatry.

(*c*) The heterochromatic method developed for the Pleiades will be extended in the near future to the investigation of special regions where the study of colours is important.

HARLOW SHAPLEY

16. In the determination of the corrections for reducing a catalogue of stellar magnitudes to a standard system, attention should also be paid to what may be called the statistical differences. These differences are due to the fact that the frequency function of the number of stars, common to two catalogues, generally varies with magnitude. The value of the statistical differences depends on the form of this frequency function, but is always proportionate to the square of the mean error of one magnitude.

In his work *Researches on the Structure of the Universe,* Pannekoek has first given formulae for computing the corrections, necessary to remove the statistical differences. Pannekoek makes the assumption that the frequency function of the star might be expressed as an exponential function, so that the number of stars will be perpetually increasing with increasing values of magnitudes.

S. Holm has later in *L.M.* **2**, no. 59, shown, that these statistical corrections might be easily computed for any form of the frequency function, even without knowing the exact mathematical expression for this function. As long as the number of stars is increasing with magnitude, the statistical differences will come out positive; if the number of stars is decreasing, those differences will show negative values.

Holm has applied his formulae to the magnitudes published in *H.A.* **44** and in *H.A.* **45**. Müller and Kempff have for these two catalogues found systematic differences ranging from $+0^{m}{\cdot}03$ for the brightest stars and then decreasing to $-0^{m}{\cdot}06$ for the faintest stars. Holm has shown that for stars with $m < 4{\cdot}0$ there exists no systematic difference between *H.A.* **44** and *H.A.* **45** and for all stars with $m > 4{\cdot}0$ there is only a small scale correction

$$H.A.\,\mathbf{44} - H.A.\,\mathbf{45} = -0^{m}{\cdot}02.$$

The given values are valid for all stars taken together without regard to colour.

Pannekoek has found similar results for other magnitude catalogues, issued by the Harvard Observatory. This makes it seem probable that the systematic differences between different Harvard Photometric Catalogues as deduced by Müller and Kempff are, at least partially, due to statistical causes. This applies especially to those differences which are dependent on magnitude. It is our intention to revise the comparison between the Harvard Photometric Catalogues of the Lund Observatory and try to find the real scale corrections. We suppose that beside the differences dependent on the colour of the stars there will only remain very small corrections.

How far the statistical differences might affect the values given by Seares in the report of this Commission is difficult, since only the final results are given. The values on page 144 concerning the difference $Y_2 - Y$ seem to indicate the existence of a statistical difference.

From the brief account of the method used by Seares in deriving the corrections published in the tables on p. 146 and following, it is impossible to decide if any statistical error might have been introduced or not in the computing of the catalogue differences. It is therefore to be desired that this question should be settled before Seares' tables are adopted as definitive.

K. LUNDMARK

17. In stellar photometry we need magnitudes corresponding to definite effective wave-lengths, which practically do not vary with the brightness and colour of the stars. Neither the visual nor the photographic magnitudes satisfy these elementary conditions to such a degree that they are fit for standard photometry. In both cases the active part of the spectrum is too broad.

The use of erythrosinesilver plates behind a yellow screen for the determination of "photovisual" magnitudes provides us with a system similar to the visual one in colour conception (Potsdam and the newer Harvard photometry) with the only important difference that the effective wave-length does not vary inconveniently with brightness and colour and can easily be reproduced with different instruments.

The problem is to establish a second system of "photographic" magnitudes having the same advantage in comparison with the one at present in use.

Owing to the strong and disturbing absorption of Hydrogen lines in many spectra it is natural to choose the active wave-lengths between two lines of Hydrogen. The interval of this kind best corresponding to usual photographic magnitudes is that between $H\gamma$ and $H\delta$. The middle of this interval has the effective wave-length 422mμ. Photovisually the spectral distribution of the action on the plate is represented by 550mμ $\pm$ 15mμ (mean deviation in the Gaussian sense). If this same distribution is wanted to be equally broad round 422mμ in the prismatic spectrum, the representation would be 422mμ $\pm$ 6mμ (mean deviation). In order to cut out this part of the spectrum one of the following ways may be chosen:

(1) In spectra of small dispersion made with an objective prism the region wanted is measured in the microphotometer. Any selection of wave-lengths is thus possible and can be made exactly as wanted, but the plate is additionally affected by much light not wanted, causing overlapping of stars and other trouble.

(2) The use of suitable colour-filters is possible, but the exact absorption may be difficult to reproduce and ordinarily such filters also absorb a considerable part of the light wanted.

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