25. COMMISSION DE PHOTOMETRIE STELLAIRE

Report of Meetings

Meeting of Commission 25, 18 August 1961
Joint Meeting with Commission 37, 21 August 1961

PRESIDENT: R. H. Stoy.
SECRETARY: R. H. Hardie.

Professor Hertzsprung and Professor Stebbins were welcomed to the meeting of the Commission. Copies of *Lowell Observatory Bulletin* No. 113 and of Part VII of Volume XVII of the *Publications of the United States Naval Observatory* were distributed to Members of the Commission, and their contents were briefly explained by Hoag and H. L. Johnson. These publications give the results of the joint work of the Lowell and U. S. Naval Observatories on galactic clusters.

The following Organizing Committee was agreed in terms of the new Constitution of the Union:

President: V. B. Nikonov

Vice-President: A. W. J. Cousins

Organizing Committee: H. Haffner, R. H. Hardie, G. E. Kron, K. Osawa, J. M. Ramberg, E. Rybka and A. G. P. Velghe.

DRAFT REPORT

The *Draft Report* was adopted with only a few minor corrections. A number of topics arising from it were then discussed.

The first of these was the convertibility of observed ultra-violet, blue colours. Cousins pointed out that simple transformations of the form

$$(U - B)_a = \alpha(U - B)_b + \beta$$

are only possible when the observational equipments involved are closely matched. In nearly every practical case, the relation between $(U - B)_a$ and $(U - B)_b$ is multi-valued for spectral types A and F. The ambiguity can sometimes be avoided, however, by using a transformation of the type

$$(U - B)_a = f_1(U - B)_b + f_2(B - V)_b$$

If the differences between the two systems involved are not large, linear functions will give satisfactory results. When the differences are larger and when it is possible to segregate the stars according to luminosity class and population type, a transformation of the form

$$(U - B)_a = k(U - B)_b + F(B - V)_{bo}$$

appears to be workable, k being the ratio of the slopes of the reddening lines in the two systems and $(B - V)_{bo}$ the unreddened colours.

Haffner asked if there was any reason for continuing with refractor $(U - B)$ colours such as those that had been determined at the Cape. Eggen emphasised that such colours now existed for many stars and thought that it would be unwise not to make use of them, especially as they had many of the same properties as the $(U - B)$ obtained with an aluminised reflector.

Stoy said that at the Cape both types of $(U - B)$ colours were being determined and that there was no intention of discontinuing $(U - B)$ observations with the refractors. For many purposes $(U - B)_c$ gave all the information that could be expected from a second colour and the observed refractor system had the great virtue of stability and consequent ease of reduction. It has been found that for normal stars conversions between the two systems could be made without serious loss of accuracy by the transformations that Cousins had mentioned.

The second topic to be discussed was the difficulty that had been encountered in reconciling the various series of photometric observations of Cepheids and super-giant stars. Schmidt mentioned that this matter had been investigated at the Bonn Observatory where Schmidt-Kaler had combined the observations of various observers to form a catalogue of 250 stars of types FO – M6, Ia – II. In the course of this work, which will be fully reported in the *Astronomische Nachrichten*, it had been found that transformations of the form

$$(B - V) = \alpha + \beta C + \gamma E_{B-V}$$

were needed and were adequate in that they gave residuals smaller than $0^m{\cdot}02$. The term depending on the interstellar reddening is probably due to small differences in effective wavelengths caused by different cut-offs in the ultra-violet. Such a term was also found necessary for the conversion of measures which had been nominally made on the U,B,V system. Thus, in the case of measures made by Hogg in Australia it was found that

$$(B - V) = (B - V)_{\text{Hogg}} - 0{\cdot}15\, E_{B-V}$$

Schmidt-Kaler's work has shown quite clearly that if one wants to get colour indices of heavily-reddened stars which will be reproducible with high precision, it is necessary to define highly-reddened standard stars and to determine the coefficient γ empirically. *It is therefore highly desirable that the Morgan-Johnson standard system should be supplemented by a number of considerably reddened stars of different spectral types.*

REPORTS AND DISCUSSION

Hogg reported briefly on some four-colour work done at Canberra using standard U,B,V filters plus a fourth filter B' which cuts out slightly more ultra-violet light than the normal B filter. It had been found that the $(B - B')$ colour varied rapidly with spectral type and luminosity class indicating that transformation difficulties did not result from differences in the U filter alone but were sensitive to the cut-off point of the B filter.

When the question of the constancy that could be expected from standard stars was raised, *Cousins*, reporting on recent E-Region observations, confirmed his previous statement that many stars are remarkably constant. Omitting stars previously noted as variable or suspected variable, there are only 19 out of 302 stars for which the newly determined magnitudes differ by more than $0^m{\cdot}01$ from those given in *Cape Mimeogram* No. 11. He pointed out, however, how dangerous it is to rely too much on the constancy of any particular star and said that several standard stars should be used for any particular piece of work. This point was emphasised by *Eggen* who thought that many more standards were needed in the northern hemisphere.

A written report received from *Serkowski* gave further information about the observed variations in brightness of the 'Ten-Year Standard' stars used at the Lowell Observatory in the study of the Sun as a variable star. Serkowski's diagram, which appears to include and revise the material given in *Lowell Bulletin* No. 96, indicates that for the sixteen stars in the diagram the total variation in magnitude is $0^m{\cdot}02$ or less. These variations are considerably smaller than those suggested in the original paper. The improved magnitudes and colours that Serkowski has found for eight of the primary standards of the U,B,V system are as follows:

HR	Star	V		ΔV	$B-V$		$\Delta(B-V)$	n
		m		m	m		m	
3249	β Cnc	3·534	±0·002	+0·014	+1·477	±0·001	−0·003	36
3454	η Hya	4·299	·002	−·001	−0·195	·001	·000	37
4456	90 Leo AB	5·947	·003		−0·159	·001		27
4550		6·448	·003		+0·753	·002		30
5685	β Lib	2·608	·003	−·002	−0·109	·002	−·001	28
5854	α Ser	2·640	·002	−·010	+1·170	·002	+·002	29
5947	ϵ Crb	4·144	·002	−·006	+1·231	·001	+·001	28
6092	τ Her	3·895	·003	+·005	−0·151	·002	+·001	29

ΔV and $\Delta(B\text{-}V)$ are the corrections which should be applied to the values given by H. L. Johnson and D. L. Harris in *Ap. J.*, **120**, 196, 1954. n denotes the number of nights. Only those nights were used on which at least 6 different primary standards were observed and an extinction coefficient determined. The errors given are mean errors.

Haffner reported on his work at the Boyden Observatory for the programme of fainter U,B,V standards that was formulated in 1957 at the Stockholm Symposium on the 'Co-ordination of Galactic Research'. Haffner concentrated on a pair of A and K stars of about the eighth photographic magnitude in each of the nine E Regions. Observations were made on 17 nights but the final results depend only on 10 nights which were selected for their good, homogeneous quality. On these nights the series of observations covered from 8 to 16 hours of right ascension and each E-Region pair was observed up to 6 times per night. The zero-points were determined from 18 Morgan-Johnson stars between declinations +15° and −30° which were observed close to the meridian and evenly distributed between the E-Region observations.

The Boyden values of V, $B-V$ and $U-B$ for the 18 E-Region stars are given in the following table. They are supposed to represent the Morgan-Johnson system within less than $0^m{\cdot}01$ and within the colour range of unreddened late B and early K stars. The weights p

E	Q	HD	α (1950)			δ		Sp.	V	$B-V$	$U-B$	p
			h	m	s	°	′		m	m	m	
1	46	7795	1	14	47	42	48	B9	7·842	−0·086	−0·326	9
	30	7706	1	13	58	42	16	K0	6·573	+1·205	+1·265	9
2	4	25653	4	00	39	44	48	A2	8·185	+0·132	+0·091	9
	27	25301	3	57	42	44	03	G5	6·830	+1·101	+0·977	9
3	5	46817	6	31	46	45	20	A0	8·030	+0·124	+0·059	8
	37	46652	6	30	53	45	16	K0	7·148	+1·069	+0·860	8
4	6	80484	9	16	45	44	25	A0	8·331	+0·092	+0·064	12
	30	80527	9	17	01	44	48	K0	7·182	+1·106	+0·934	12
5	2	105498	12	06	07	44	39	A0	8·055	−0·024	−0·228	14
	27	105852	12	08	27	45	09	K0	6·609	+1·086	+0·836	14
6	4	128726	14	36	44	45	32	A0	8·057	+0·034	−0·077	17
	33	128413	14	34	56	45	39	K0	6·836	+1·168	+1·207	17
7	16	157477	17	22	02	45	13	A3	8·099	+0·242	+0·150	21
	32	157487	17	22	02	44	44	K0	7·64	+1·25	+1·14	—
8	8	191273	20	07	22	43	45	A3	7·828	+0·249	+0·104	14
	29	191117	20	06	38	44	03	K0	6·933	+1·023	+0·807	14
9	1	216009	22	46	57	44	41	A0	8·059	+0·045	+0·042	12
	30	216406	22	50	22	45	25	K0	6·858	+1·113	+1·063	12

given in the last column have been calculated from the number n of observing nights ($5 \leqslant n \leqslant 7$) and the number z of observations per night ($z \leqslant 6$). The internal mean errors of unit weight are $\pm$ 0^m·018, $\pm$ 0^m·015 and $\pm$ 0^m·015 respectively for V, $B - V$ and $U - B$. The K star selected as standard in E 7 proved to be variable. It was therefore omitted from the final list and replaced by Q'_i32 for which the Cape data reduced to the Boyden system are given.

Schmidt explained his proposal to revive a project which, in one form or another, has been suggested several times in the past. This is to establish comprehensive magnitude sequences in conveniently placed areas. These would be especially useful for photographic photometry and for the inter-comparison of photometric systems, while for photo-electric photometry they would be very much more convenient than standards scattered all over the sky. Schmidt suggested the following desiderata for the choice of stars and areas:

1. Areas should be observable from both hemispheres and at all times of the year. This means that there will have to be a number of areas in the equatorial belt and well separated in right ascension.

2. Each area should be small enough to be covered by a single photographic exposure. This limit will depend on the instrument concerned, but a diameter not exceeding 2° or 3° is indicated.

3. The stars selected must be observable by both small and large instruments. The upper limit of brightness could be about 7^m and the lower 16^m.

4. All spectral types and luminosity classes should be represented in the sequences.

5. One or more of the areas should be in regions of obscuration so as to provide material for determining how colour excess affects the transformations between different colour systems.

Willstrop said that Redman had raised the question of the provision of faint standards in restricted areas that could be used for calibrating Schmidt camera plates because the conditions at Cambridge were not often suitable for photo-electric photometry in which stars are compared consecutively. It was therefore not practicable at Cambridge to adopt the ideal method of establishing a photo-electric sequence in each Schmidt field investigated. He thought that the construction for the Royal Observatory, Edinburgh, of a twin 16-inch reflector especially designed for the measurement of sequences was greatly to be welcomed.

Velghe stressed the need for the establishment of photo-electric R and I standards for use in investigating low temperature stars in the Milky Way. He suggested that these standards should be set up in the Selected Areas of the Special Plan and said that it was imperative that the particular R and I system chosen must be such that it could be reproduced photographically.

The relative merits of the R,G,U and U,B,V Systems for separating out various types of stars were briefly discussed. *Willstrop* said that Argue using the Cambridge Schmidt had found that both systems separated out some types of stars but not others. As R,G,U standards were not readily available, Argue had reverted to the use of U,B,V. *Steinlin* agreed that there were cases where the U,B,V System is able to sort out types of stars which the R,G,U could not and *vice versa*. The latter system was particularly useful for sorting out late-type giants and dwarfs. Steinlin thought that it was probable that there was no single three-colour system which fulfils all purposes and it was necessary to select the most suitable for the particular object in view. *Schmidt* said that at Bonn they were trying to compare the relative potentialities of the two systems by investigating in both a large number of stars brighter than magnitude 13 in a Milky Way field for which spectral types and luminosity classes were also being determined. Work on the establishment of R,G,U standards in the North Polar Area had been suspended until the results from this test of the two systems were known.

Walraven described the new five-colour photometric equipment of the Leiden Southern Station and showed some photographs of it. He discussed the properties of the various colour systems and indicated how in the case of the Magellanic Clouds they might be used for sorting out foreground stars from genuine Cloud members.

Rybka reported on the progress at the Cracow Observatory with the reduction of the Harvard and Potsdam visual photometries to the Morgan-Johnson V system. Each combination of observer plus instrument needs its own set of systematic corrections and in some cases the colour corrections required are surprisingly large. Unfortunately, reliable colours are available for relatively few stars in the northern hemisphere but is has been found that in most cases colour indices sufficiently accurate for applying systematic corrections to the visual observations can be deduced from the difference between the photographic and photometric magnitudes given in the Henry Draper Catalogue. The mean error of a colour index so derived appears to be about $\pm 0^{m}\cdot 16$.

Stoy spoke briefly on the work at the Cape for the 'General Catalogue of Magnitudes' that had been proposed at Moscow. Apart from the collection of much of the published photo-electric data on to cards, the principal progress had been the consolidation into a single list and on to a single system of the various series of photo-electric observations that had been made at the Cape since 1948. This list, which is available as *Cape Mimeogram* No. 12 or as *Royal Observatory Bulletin* No. 64, gives V magnitudes and $(B - V)$ colours for 4950 stars. $(U - B)_c$ colours are given for 3940 of these stars. Many of the stars have been observed in more than one series of observations and for these the results from the individual series are given separately except for the E-Region stars.

Hall said that Serkowski is preparing a short catalogue of stars for which the polarisation has been reasonably well determined. This will extend the list he gave in *Lowell Observatory Bulletin* No. 105 of 'Suggested Standards of Polarisation'.

Discussing extinction, *Rybka* stressed its variability with time and direction. In general it is not sufficient to determine it for a given night and then assume that it is constant throughout the night all over the sky. For accurate work the extinction has to be determined at the time and for the part of the sky in which the observations are being made. This can be done if there are stars in that vicinity for which accurate magnitudes and colours are known. It is to meet this need that the Crimean and Cracow Observatories are determining accurate magnitudes and colours for pairs of stars near each of the Kapteyn Selected Areas. The stars are about the sixth visual magnitude and one of each pair is of spectral type B5 – A5 and the other G5 – K5. Observations on the U,B,V System for 230 stars have been completed at the Crimean Observatory by Nekrasowa and will shortly be published. There is a need to extend this work to the southern Kapteyn Areas and also, possibly, to fainter pairs of stars in each Area.

Speaking on behalf of the Pulkovo astronomers *Rybka* appealed for photometric help in connection with their programme for determining absolute proper motions in 300 areas containing galaxies. Magnitudes are required for about 10 stars in each area. The areas are mostly $2^{\circ} \times 2^{\circ}$ and the range of magnitude to be covered is from 10 to 14. The accuracy desired for the individual magnitudes is not large ($\pm 0^{m}\cdot 1$) but it is essential that these magnitudes should be on a homogeneous system with systematic errors well below this limit. Observatories willing to help should contact Professor A. N. Deutsch at the Pulkovo Observatory.

Joint meeting of Commissions 25 and 37

The chief speakers at the joint meeting of Commissions 25 and 37 were *Walker* and *Haffner* who both discussed the problem of the most suitable photometric system for work on clusters. *Walker* reviewed the desiderata for the ideal system and concluded that the *U,B,V* photometry satisfied these more closely than do other three-colour systems now available. He thought that in theory some narrowing of all three colours might be desirable in order to avoid band-width effects when reducing observations to the standard system. In practice, however, this was unlikely to be worth the trouble involved, especially as the effects in question are small and can be fully evaluated by using sufficient standard stars. Walker, therefore, advocated that the present definition of the *U,B,V* System be retained but that the existing standards should be checked carefully for variability and that, in addition, there should be set up a number of accurate faint standards suitable for use with large telescopes.

Haffner said that although spectro-photometry was to be regarded as the only precise approach to an understanding of stellar radiation, it was not always practicable and that for some problems one had to be content with integrated light methods. This was particularly the case for cluster work, especially when the faintest stars were involved. For such work, he strongly recommended the use of the *U,B,V* photometry both for reasons of continuity and of its practicability. The instrumental system should be kept as close to the standard system as possible and its relation to the standard system frequently checked. A satisfactory control needs a five-dimensional system of standard stars—spectral type, luminosity class, reddening, right ascension and declination. Much has still to be done to establish a convenient system of standards, though the number available is steadily increasing in both hemispheres, particularly as a result of the photo-electric sequences that have been set up near clusters. Photographic observations should be made as closely as possible on the system of the photo-electric standards being used to calibrate them. For the brighter stars ($6^m - 12^m$) work in colours *additional* to *U*, *B* and *V* is to be welcomed.

Tifft emphasized the fact that the width of the *U,B,V* bands made it necessary, when making accurate transformations, to take into account terms depending on the band-width squared and that these terms had to be carefully calibrated. He also pointed out that the poorly defined ultra-violet limit of the *U* band might lead to trouble when the time came to compare existing results with observations made outside the atmosphere. He thought, therefore, that it would be worth while to experiment with a system involving slightly narrower and more precisely defined band-widths than the present *U,B,V* System, even though the present system was very satisfactory and would, undoubtedly, continue to be used for many purposes.

King, referring to a remark made by Walker, said that the fact that narrow-band measurements might be hard to reproduce photographically was not a valid criticism against their use. The information contained in a number of narrow bands is intrinsically more than that contained in a single band. It should, therefore, be possible to synthesize from photo-electric measures made in several narrow bands magnitudes suitable for use in calibrating photographic observations.