APPENDIX

REPORT OF THE COMMITTEE ON PHOTOMETRIC STANDARDS

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In view of the high precision which is now both possible and desirable in photometric observations, it is extremely important for the co-ordination of galactic research that all observers adopt a uniform photometric system. It is likewise important for reasons which have already been discussed at the Dublin meeting of the I.A.U. [1] that such a system should include a measurement of the ultra-violet, as well as the usual yellow and blue regions. The zero-point and scale of the system should be set up photo-electrically and standards on the system should be made available that would be suitable for the observation of faint objects of all kinds and in all parts of the sky.

To implement these needs, the committee makes the following recommendations:

I. *Photometric System.* It is recommended that the U-B-V system of Johnson and Morgan [2] be adopted. Improvements in the system could undoubtedly be made, both in the choice of the wave-length regions and in the filters used to define these regions. However, the greatest need is for *a* standard system *now*, and since the U-B-V system now has behind it a considerable weight of observations of a wide variety of objects, it is felt that this system should, at least for the present, be adopted in its present form.

In order to reproduce the U-B-V system, the following filters are recommended:

(*a*) For photo-electric observations with a 1 P 21 photo-multiplier or other photo-electric cell of similar spectral response, Johnson [3] has recommended the following filters: (1) V, Corning 3384 (Standard optical thickness) or 2 mm Schott GG 11. (2) B, Corning 5030 (Standard optical thickness) plus 2 mm Schott GG 13, or 1 mm Schott BG 12 plus 2 mm Schott GG 13. (3) U, Corning 9863 (Standard optical thickness) or 2 mm Schott UG 2.

(*b*) For photographic observations, the following plate and filter combinations have been found by Johnson and Sandage [4] to give no color equation to the U-B-V system: (1) V, Kodak 103aD plus 2 mm Schott GG 11. (2) B, Kodak 103aO plus 2 mm Schott GG 13. (3) U, Kodak 103aO plus 2 mm Schott UG 2.

Other filters—and plates—closely similar to these can also be found that will give linear transformations to the U-B-V system. However, whatever filters are used, the observer should in every case determine the conversion equation between his particular instrumental system and the U-B-V system, as discussed under Technique, below.

II. *Technique of Observation.* In order to avoid the problems of scale errors and to minimize the errors in the transfer of the zero-point of the system from one part of the sky to another, it is recommended that the use of *photographic* transfers be discontinued except where magnitudes of relatively low accuracy for statistical purposes *only* are required. Where a large number of faint stars are to be observed in a small area of the sky, as in the case of clusters, photo-electric transfers should be made to the area, and a photo-electric sequence set up within the area. Photographic photometry should be used only as an interpolation method for determining the magnitudes of the other stars in the field from those of the photo-electric standards. If the particular observatory does not have the facilities for setting up faint photo-electric standards, it is recommended that a qualified observer be sent to some other institution having such facilities to make the measurements. Representatives of the Haute-Provence and Mt Wilson observatories have indicated that guest investigators could arrange to make such observations at these institutions.

As indicated above, each observer should determine the transformation equations from his particular instrumental system to the U-B-V system, both for his photo-electric and photographic equipment. To determine the photo-electric conversion equation, about twenty stars from the lists of U-B-V standards [2, 3, 5] should be observed. These should cover a large range of colors and luminosity classes. One defect of the U-B-V system is that the standards are nearly all very bright, so that it is difficult to observe them with a large telescope and a photo-electric cell suitable for the observation of extremely faint stars. However, for calibration purposes, they can be observed by the use of objective screens (but not diaphragms, which could image the light on a different part of the cathode having a different sensitivity and color response from the average for the cathode as a whole) or by operating the cell at a reduced voltage. An objective screen will usually be found to have an absorption that depends slightly on wavelength, and this must be allowed for. Also, some types of photo-electric cells may show a change in color response with applied voltage, although this is not usually the case.

To determine the conversion equations, one should observe a field containing stars whose U-B-V magnitudes have already been determined

In order to discriminate between magnitude and color equations, these fields should not only contain a sequence of stars of different magnitudes, but stars of comparable magnitude and different color as well. At the present time, such fields include M 11 [6], M 67 [4], and NGC 7789 [7]. Once the photo-electric conversion equations have been determined, observations of a red and a blue standard on each night will give the zero-point of the conversion equation for that particular night. The photo-electric and photographic conversion equations should be carefully rechecked from time to time as there is the possibility that they may change with season, changes in the emulsion number, or the condition of the optical surfaces of the telescope.

III. *Standards.* In view of the foregoing recommendations, it is evident that what we require at the present time are photo-electric standards distributed over the entire sky. As indicated above, the standards on which the U-B-V system is based are not well suited for use with large telescopes since they are too bright to be observed with the same cell voltage and aperture used for fainter stars. Consequently, standards fainter than about 7th magnitude should be made available. Also, because of practical limitations of some telescopes, it is desirable to have standards located both north and south of the zenith. As an initial program, it is therefore recommended that the following standards be set up: A red and a blue standard of about 8th magnitude and another red and blue pair of about 10th magnitude should be set up in each of the following areas: (*a*) Decl. $= +45°$, Δ R.A. $= 4^h$. (*b*) Decl. $= 0°$, Δ R.A. $= 3^h$. (*c*) Decl. $= -45°$ (stars in the E regions). Standards in areas (*a*) and (*b*), above, will be set up by Hardie and Walker. The standards in (*c*) will be provided by Haffner in South Africa, who will make use of the extensive work already done in the E regions at the Cape Observatory. Haffner will also observe the stars in areas (*b*), to complete the tie-in between the northern and southern hemispheres.

In addition to the above areas, the red and blue stars, of about 8th to 12th magnitude, used by Baum as his fundamental standards in each of the nine selected areas 51, 54, 57, 61, 68, 71, 89, 94 and 107 in which he is setting up faint two-color photo-electric sequences, will be observed by Hardie and Walker.

References

[1] *Trans. I.A.U.* **9**, 338, *et seq.*, 1955.
[2] Johnson, H. L. and Morgan, W. W. *Astroph. J.* **117**, 313, 1953.
[3] Johnson, H. L. *Ann. d'Astroph.* **18**, 292, 1955.
[4] Johnson, H. L. and Sandage, A. R. *Astroph. J.* **121**, 616, 1955.
[5] Johnson, H. L. and Harris, D. L. *Astroph. J.* **120**, 196, 1954.
[6] Johnson, H. L. and Sandage, A. R. *Astroph. J.* **124**, 81, 1956.
[7] Burbidge, E. M. and Sandage, A. R. In the press.