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BRIGHT STAR OBSERVATIONS USING AN UNFILTERED 1P21 PHOTOTUBE

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BRIGHT STAR OBSERVATIONS USING AN UNFILTERED 1P21 PHOTOTUBE†

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ABSTRACT

There is a current need in space astronomy to calibrate accurately the magnitude of the brighter stars used as navigation guide stars in unfiltered tracking systems. In the past, these magnitudes have always been computed from observed narrow-band data since there have been few direct observations with these systems.

Photoelectric observations of bright stars have been made using the LPL (Lunar and Planetary Laboratory) 21 inch telescope and a calibrated 1P21 phototube, unfiltered. A color index, [m(S-4)-V] versus (B-V) calibration curve, was derived with the zero-point set for A0 stars. The measured magnitude over the response of the phototube is m(S-4) and V and (B-V) are the magnitude and color, respectively, in the UBV system. The calibration curve is linear between (B-V) = 0.00 and +1.00 and reaches limiting values of [m(S-4)-V] = -0.61 and +0.99 for (B-V) = -0.23 and +1.64, respectively.

A theoretical curve, based on a formula derived by Davenport, relating m(S-4) to the existing UBV measurements differed from the observed curve by ±0.05 mag (p.e.) with the later spectral classes having the larger differences. Line blanketing becomes important in these cooler stars and becomes increasingly difficult to take into account in the computed magnitudes. Both the observed and theoretical curves are discussed in detail as well as the errors expected in using this method to calibrate tracking systems.

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INTRODUCTION

There is a current need in space astronomy for a stellar calibration curve for the brighter navigational stars, in terms of the detector system, or in other words "How bright will a particular star appear to a particular star tracker?" To date, previous work on this problem included Aerobee flights conducted by NASA on four stars and Mariner, Surveyor, and Orbiter data on Canopus. In the past, the calibration curve for broadband systems, such as an unfiltered 1P21 phototube, has been computed from observational filter-band data (UBV).

OBSERVATIONS

Thirty-nine stars brighter than 3.0 magnitude (V) were observed using the 21 inch telescope of the Lunar and Planetary Lab, University of Arizona. The spectral response of the unfiltered 1P21 phototube was measured both before and after the observations in order to compare this information with the theoretical data.

The magnitude observed is designated m(S-4) to indicate that an (S-4) photosurface was used. The observations were reduced to zero air mass in the usual manner. It was found that the total extinction coefficient varied smoothly with the stellar color, reaching a maximum value of 0.31 for stars of the earliest spectral class. A color index, [m(S-4)-V], was derived for each star using the V values given by Johnson et al (1966). As is the usual case, the color index was set equal to zero for stars of spectral class, A0 V.

Figure 1 shows the observed calibration curve for a detector system using an unfiltered 1P21 phototube. The quantity, (B-V), is the standard color in the UBV system and the errors in the presently observed color index, [m(S-4)-V], are ± 0.03 mag (p.e.). The curve is quite linear between (B-V) = 0.00 and +1.00. This is to be expected as $\lambda_{eff}[m(S\text{-}4)] = 4600$ Å, $\lambda_{eff}[B] = 4400$ Å and $\lambda_{eff}[V] = 5500$ Å, i.e., m(S-4) can be thought of as approximating a very broadband B magnitude.

No effect due to the Balmer discontinuity is seen. This is the result of the sensitivity of the 1P21 falling off quite rapidly for $\lambda < 3600$ Å. Hence, the influence of the stellar ultraviolet is small when compared to the visible radiation which extends to

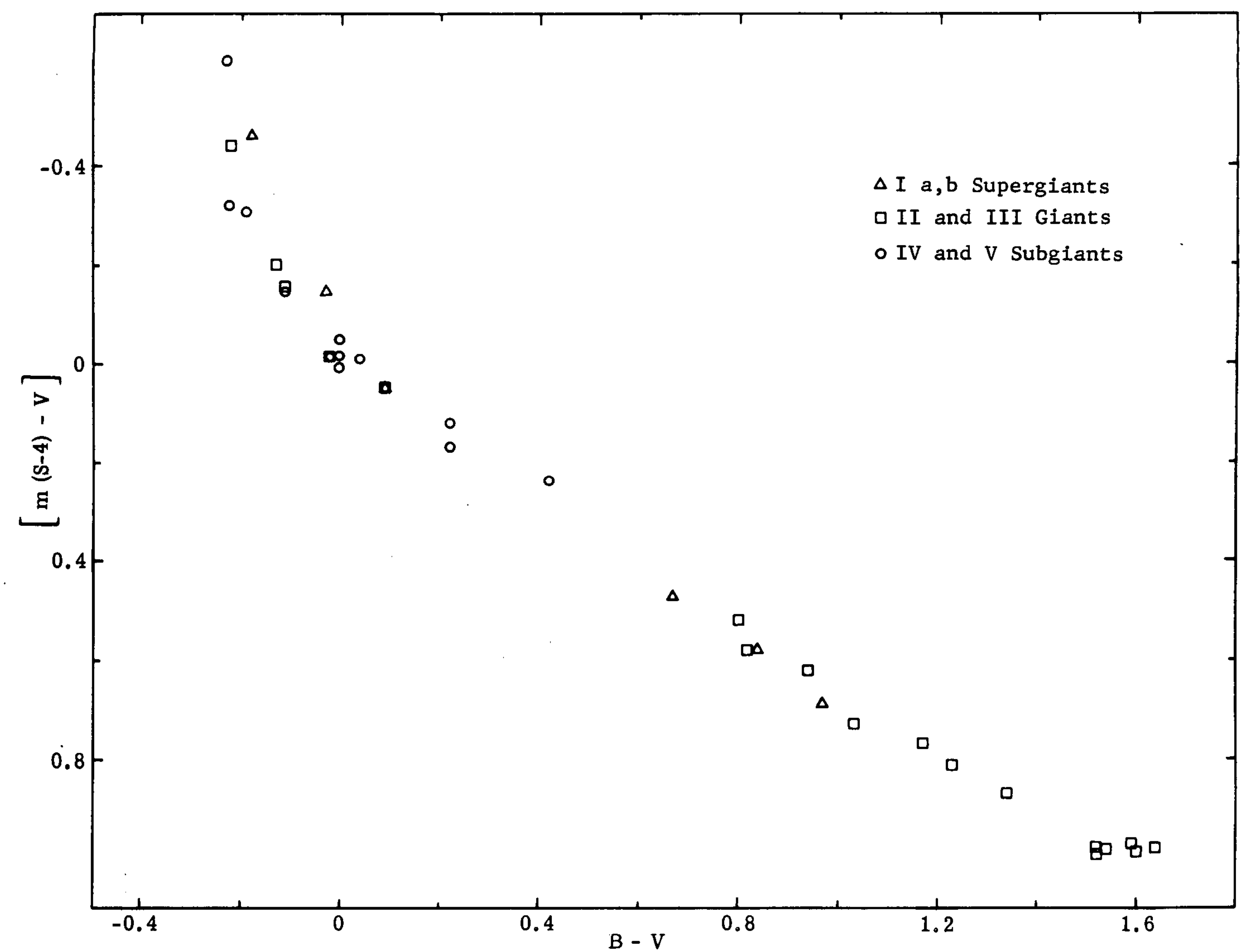

Fig. 1 Stellar Calibration Curve for Unfiltered 1P21 Photomultiplier Tube

7000 Å, the red limit of the tube. The color index, [m(S-4)-V], becomes progressively bluer as (B-V) $\rightarrow$ -0.23, reaching the limiting value -0.61. At (B-V) = +1.64, the red limit, [m(S-4)-V] = +0.99.

Stars of all luminosity classes (Ia,b, Supergiants; II and III, Giants; IV and V, Subgiants) seem to follow the same curve for (B-V) > 0.00. Again, this is a consequence of m(S-4) $\sim$ B. Two blue Supergiants, β Ori and κ Ori, appear to be bluer than the Giant and Subgiant stars of similar (B-V) by about 0.15 magnitude.

THEORETICAL COMPARISONS

Davenport, at Goddard Space Flight Center (unpublished), has derived a second order equation which can be represented in functional form as

$$m(S\text{-}4) = f[(U\text{-}V)^2, (B\text{-}V)^2, (U\text{-}V), (B\text{-}V), V] \quad .$$

The coefficients are determined from the measured spectral response of the phototube and the published responses of the UBV filters. The percent error between the observed m(S-4) values and the computed values is ± 0.05 mag with no systematic trend with color between $-0.2 < (B\text{-}V) < +1.5$. These differences become greater for $(B\text{-}V) > +1.5$ (later than K3) in the sense that the observed m(S-4) values are consistently fainter than the computed values. Line blanketing becomes important for these cooler stars and is not completely corrected for when UBV data is used to derive m(S-4).

A paper by Matloff (1967) has recently appeared in which the following function

$$m(S\text{-}4) = f(U, B, V)$$

is used to compute m(S-4). The weights for these three points are determined from the relative sensitivity of the 1P21 phototube read at the effective wavelengths of the UBV filters. The percent error in the differences (observed-computed) using Matloff's equation are slightly larger than the values derived from Davenport's equation, ± 0.07 mag versus ± 0.05 mag, respectively.

SUMMARY

Photoelectric data have been taken on bright stars in order to build up a calibration curve for detectors using (S-4) photocathodes. The calibration for other detector systems, such as (S-20) or silicon photosurfaces, should be derived by direct observation rather than depending on formulae which relate to filter-band data.

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