

SECONDARY STANDARD STARS IN THE FOUR-COLOR SYSTEM

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Now that larger telescopes are being used to make photometric measures of very faint stars, fainter standard stars are needed. Most of the stars listed in the standard star list of Crawford and Barnes (1970) are too bright, even for a 1.5 m telescope. Over the past two decades observations have been made of B, A and F-type stars in the magnitude range $V = 6$ to 13 in the northern and southern hemispheres in a program of four-color photometry of field and blue horizontal-branch stars. An earlier list of secondary standards was published in Philip and Philip (1973). The present paper reports on over twice as many standard stars and the secondary standards are increased by about 20%. The number of observations per star is substantially increased.

Over eighty standard stars from Crawford and Barnes have been used as standards in these observing runs. The zero point differences for the group of stars relative to the standards are 0.000, +0.002 and -0.001 in $(b-y)$, c_1 and m_1 respectively (in the sense P - CB). The rms errors of a single observation are ± 0.003 , 0.005 and 0.006 in $(b-y)$, c_1 and m_1 respectively.

The fifty secondary standards include Population I stars and field horizontal branch stars. The four prototype FHB stars (HD 2857, 86986, 109995 and 161817) have been measured an average of over 100 times each and are among the best measured stars in the new standard star list. In Fig. 1 a plot is shown of the delta $(b-y)$ magnitude for HD 161817 over a period of 17 years. The rms error is ± 0.009 mag. and no trend can be seen in the residuals. This behavior is typical for the FHB stars in the secondary standard star list; these stars exhibit a very stable nature.

Four plots (Figs. 2 - 5) show the distribution of the primary and secondary standards in the $(b-y)$, (c_1) and $(b-y)$, (m_1) planes. In the standard list, the great majority of the stars are main sequence Pop I stars. In the secondary standard star list there is a

prominent group of FHB stars whose indices fall away from the main sequence. In Fig 6a, b and c the differences in $(b-y)$, c_1 and m_1 between Philip and Crawford-Barnes are shown. There are no differences greater than ± 0.02 and most of the differences are smaller than ± 0.01 . In Fig. 7a, b and c the rms errors of the secondary standard stars are plotted. The typical average rms error is near ± 0.015 with the largest rms error falling under ± 0.03 mag.

The details concerning these stars are being prepared for publication in a journal article. The four-color photometric indices will be presented in two tables; the first will list the indices for the Crawford-Barnes standards and the second will list the indices for the secondary standards. Those who would be interested in obtaining the list of secondary standards prior to publication can obtain it on request.

REFERENCES

- Crawford, D. L. and Barnes, J. V. 1970 *Astron. J.* 75, 978.
 Philip, A. G. D. and Philip, K. D. 1973 *Astrophys. J.* 179, 855.

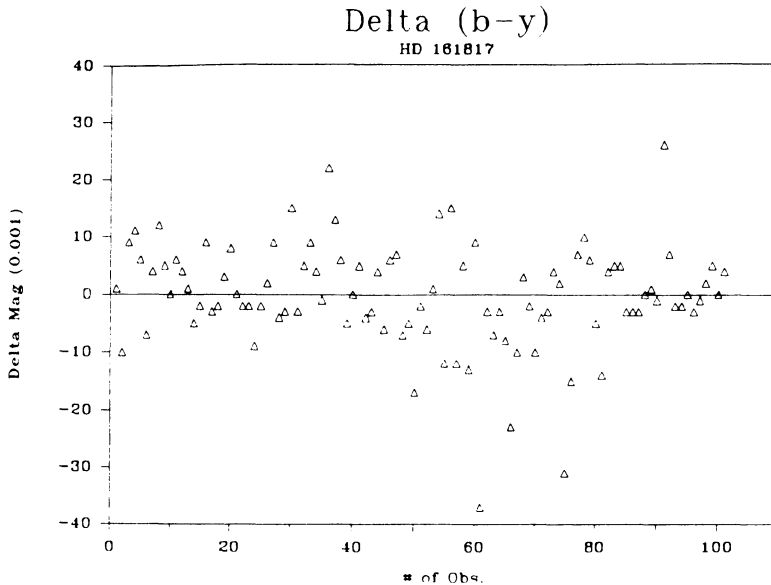


Fig. 1. Delta (b-y) for observations made over a 17 year period of HD 161817.

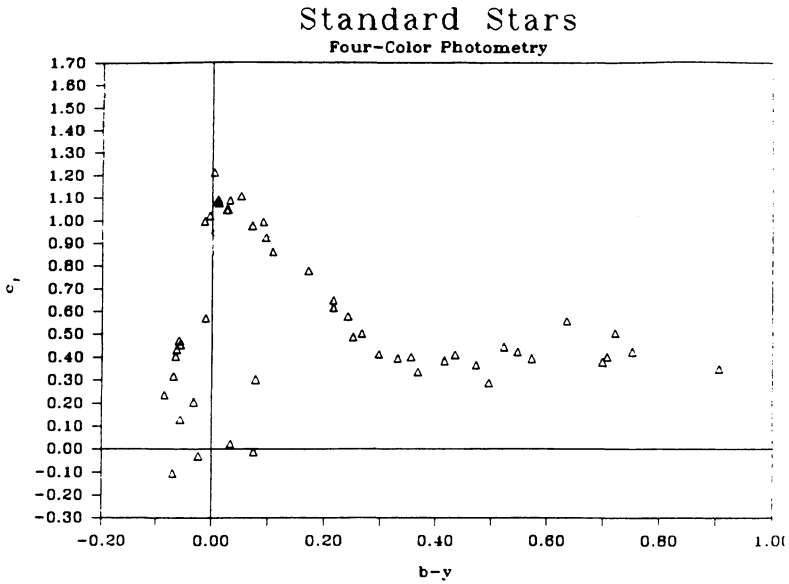


Fig. 2. The distribution of the standard stars in the c_1 , $(b-y)$ plane.

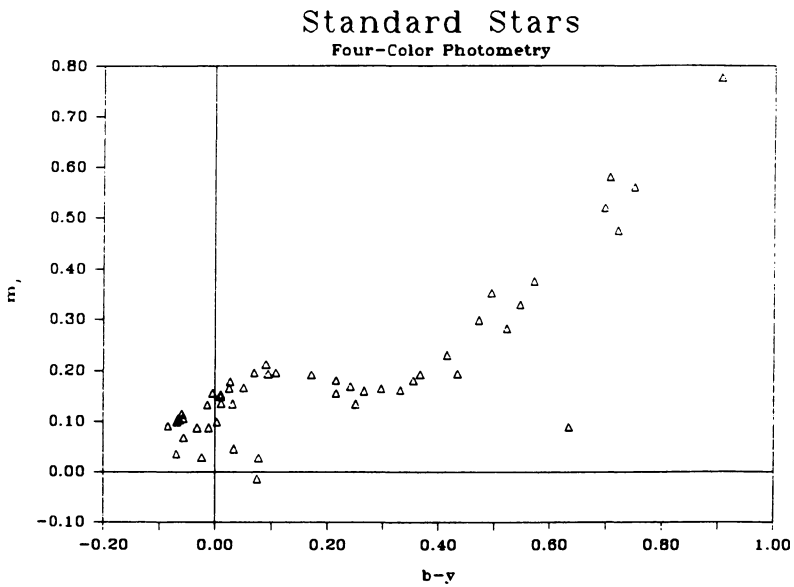


Fig. 3. The distribution of the standard stars in the m_1 , $(b-y)$ plane.

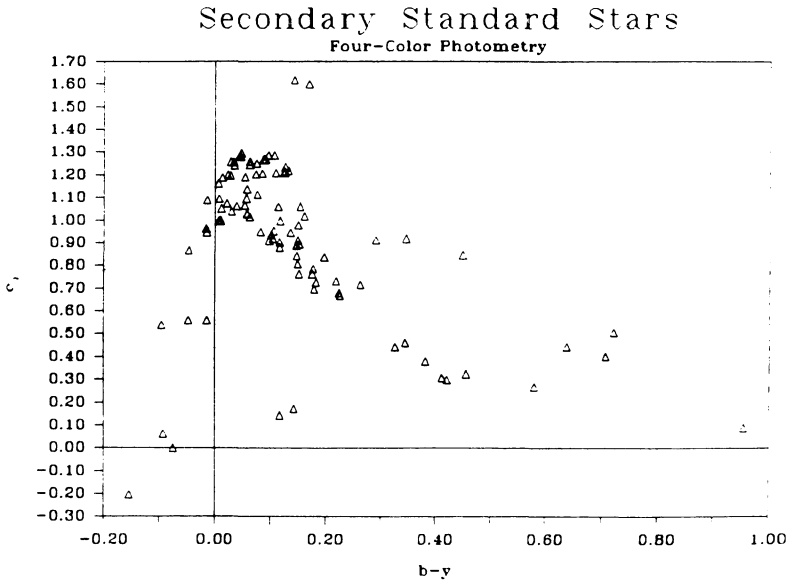


Fig. 4. The distribution of the secondary standard stars in the c_1 , $(b-y)$ plane.

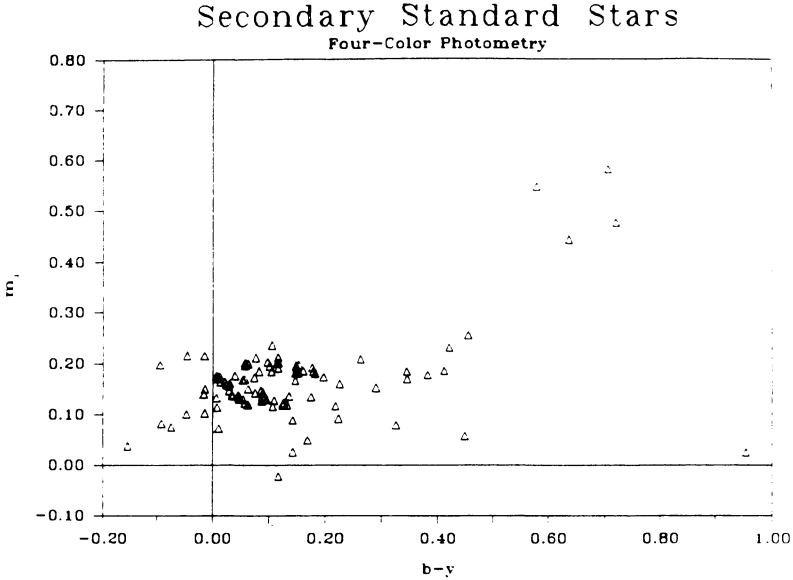


Fig. 5. The distribution of the secondary standard stars in the m_1 , $(b-y)$ plane.

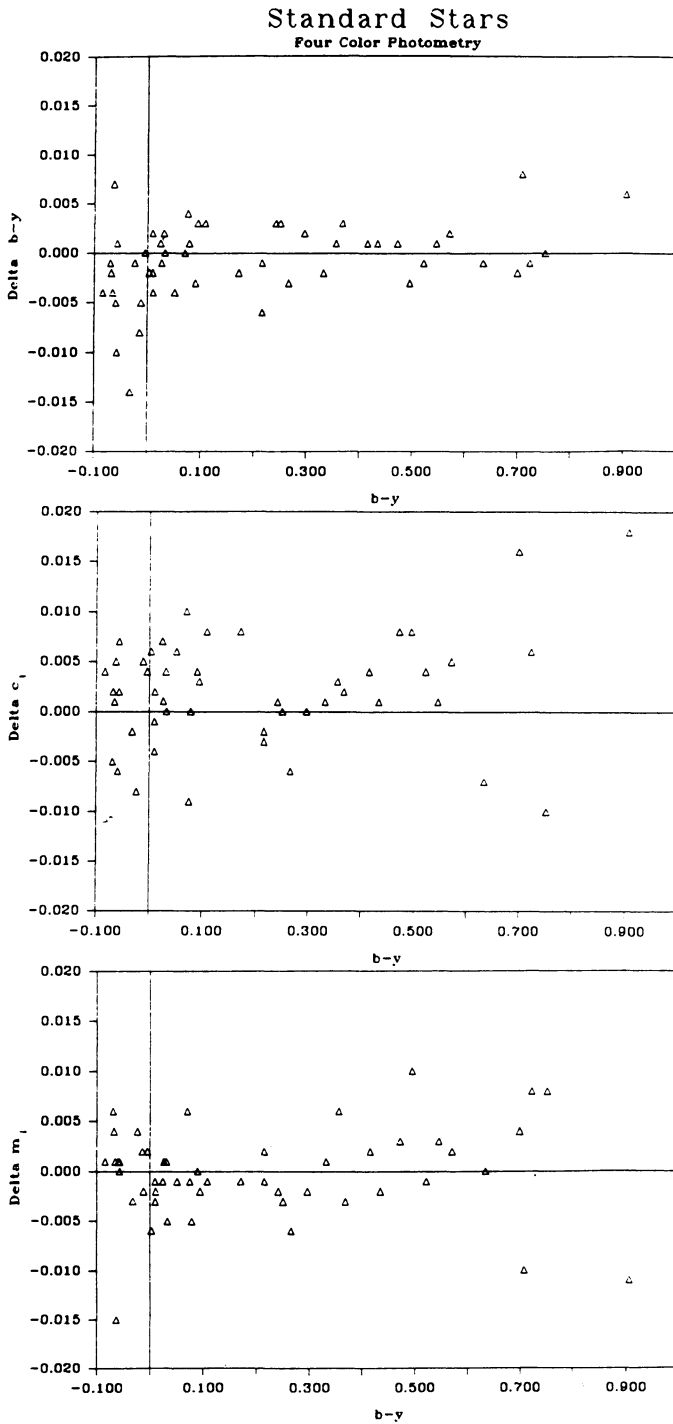


Fig. 6 Delta (b-y), c_1 and m_1 are plotted for the standard stars.

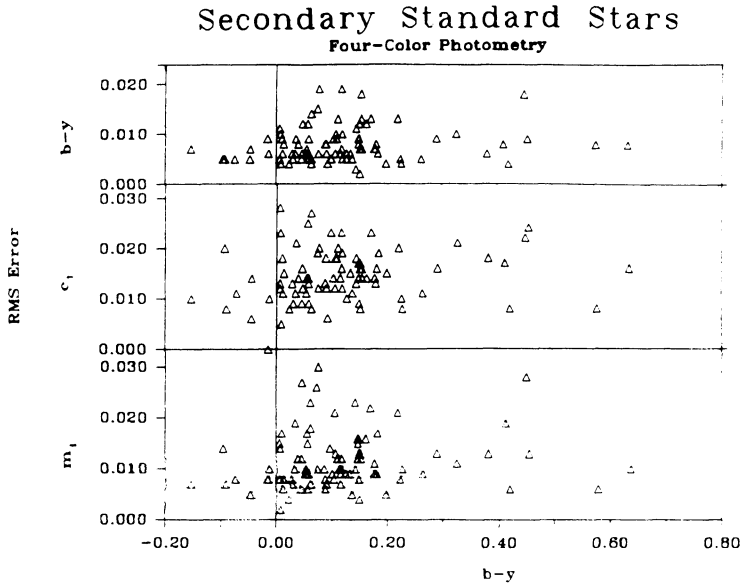


Fig. 7. The rms errors of the secondary standard stars.

DISCUSSION

JASCHEK: I would like to insist on the importance of providing detailed charts for all stars not contained in the BD or CoD, with proper scale, orientation and magnitude (for at least one star) clearly indicated.

PHILIP: When I published the finding lists of field horizontal-branch stars I made charts dotted from Schmidt spectral plates. These charts are fine for telescopes of 1 m but for large telescopes better charts are needed. As part of VVO Contribution No. 2 charts are being presented for the 60 FHB stars with reproductions from the Palomar Sky Atlas. The nearest BD or CoD star is marked on each chart. These charts will be published in 1985.

TOBIN: Many of your secondary standards are horizontal-branch stars. Is there any possibility that your indices might be systematically in error as a result of bandpass differences between your filters and those of Crawford and Barnes?

PHILIP: No. Up until the mid 1970's I used the No. 1 four-color filter set at Kitt Peak, which is the same set used by Strömgen and Crawford in setting up the system. When this filter set was "retired" I used a filter set obtained from Schott. These filters have been measured on the spectrophotometer at Kitt Peak and the shapes and the maxima of the filter transmission curves agree very closely with those of the No. 1 set.