CALIBRATION OF INTERMEDIATE-BAND PHOTOMETRIC PARAMETERS AND *V* Sin *i* EFFECTS

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Calibration of four-color and Hβ photometry, in terms of intrinsic color and absolute magnitude, for the B-, A- and F-type stars is about finished, though still subject to small changes. The data for the bright stars in the northern and southern hemispheres and for a number of the brighter open clusters were used in obtaining these calibrations. Some of the data have been published; much more of it will be going to press shortly. The calibration is interesting not only for itself and its applications, but because deviations from it may be due in part to rotational velocity effects.

For the A stars (β between $2^{m}.880$ and $2^{m}.700$) the calibration for intrinsic color may be expressed simply as $(b-y)_0 = 2.943 - 1.0\beta - 0.1\ \delta c_1 - 0.1\ \delta m_1$. δc_1 and δm_1 are determined as the difference between the observed value and the value of c_1 and m_1 for a given β. The standard relations are given in condensed form in Table I. All bright stars observed within the limits of β and having δc_1 less than $0^{m}.280$ were used in obtaining the calibrations. In other words, about 500 stars. The 25 largest residuals were all positive (in the sense that positive indicates reddening) and, if these are

TABLE I

Standard relations, A and F Stars (Preliminary)

β	$(b-y)_0$ $\delta c_1 = 0$ $\delta m_1 = 0$	m_1	c_1 (Z.A.) June '69	M_v (Z.A.) June '69
$2^{m}.880$	$0^{m}.063$	$0^{m}.207$	$0^{m}.93$	$2^{m}.3$
$2^{m}.860$	$0^{m}.083$	$0^{m}.207$	$0^{m}.89$	$2^{m}.4$
$2^{m}.840$	$0^{m}.103$	$0^{m}.208$	$0^{m}.85$	$2^{m}.5$
$2^{m}.820$	$0^{m}.123$	$0^{m}.206$	$0^{m}.82$	$2^{m}.6$
$2^{m}.800$	$0^{m}.143$	$0^{m}.203$	$0^{m}.78$	$2^{m}.7$
$2^{m}.780$	$0^{m}.163$	$0^{m}.196$	$0^{m}.74$	$2^{m}.8$
$2^{m}.760$	$0^{m}.183$	$0^{m}.188$	$0^{m}.70$	$2^{m}.8$
$2^{m}.740$	$0^{m}.203$	$0^{m}.181$	$0^{m}.66$	$2^{m}.9$
$2^{m}.720$	$0^{m}.223$	$0^{m}.176$	$0^{m}.60$	$3^{m}.1$
$2^{m}.700$	$0^{m}.243$	$0^{m}.172$	$0^{m}.54$	$3^{m}.3$
$2^{m}.680$	$0^{m}.265$	$0^{m}.170$	$0^{m}.48$	$3^{m}.5$
$2^{m}.660$	$0^{m}.294$	$0^{m}.171$	$0^{m}.43$	$3^{m}.7$
$2^{m}.640$	$0^{m}.324$	$0^{m}.178$	$0^{m}.38$	$3^{m}.9$
$2^{m}.620$	$0^{m}.356$	$0^{m}.193$	$0^{m}.34$	$4^{m}.3$
$2^{m}.600$	$0^{m}.390$	$0^{m}.216$	$0^{m}.30$	$4^{m}.6$

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omitted, the rms scatter for one star is $\pm 0\overset{m}{.}013$. By fitting a normal curve to the negative residual tail, a dispersion of $\pm 0\overset{m}{.}011$ results (for one star). I interpret the slightly higher red tail as due to small values of reddening. Therefore the rms scatter for one star (which is equal then to the cosmic scatter since all stars were included) is $\pm 0\overset{m}{.}011$. This cosmic scatter includes the effects of spectroscopic binaries, metallic line stars, effects of rotation, etc. The calibration fits the observed unreddened clusters to $0\overset{m}{.}003$. There is little or no rotational velocity effect apparent in the calibration, and the relation of the $(b-y)_0$, β, and δc_1 to MK spectral types is quite good.

The absolute magnitude calibration may be expressed as $M_v = M_v$ ($\delta c_1 = 0$, in other words 'zero age main sequence')$-8\delta c_1$. This calibration was obtained by using the slopes of absolute magnitude vs. β relations for open clusters and fitting the zero point by trigonometric parallax stars. The factor 8 was determined by stars within clusters and from cluster to cluster. The observed values for cluster stars were corrected for this before the shape fitting was made. The Hyades were not used in the calibration. The rms scatter is estimated to be $0\overset{m}{.}3$ for one star.

For the F stars, these same types of equations hold, though the coefficients are slightly different. The rms scatter for one star is about $0\overset{m}{.}015$, larger than for the A stars, but still quite usable for determining intrinsic colors of individual stars. The range of β is $2\overset{m}{.}720$ to $2\overset{m}{.}600$. Near G0 the stars with values of δc_1 greater than $0\overset{m}{.}100$ were omitted. The coefficient of β becomes larger as β gets smaller and the coefficient of δm_1 becomes larger as β gets smaller. In the absolute magnitude calibration the factor times δc_1 is 11. This is determined both from data for trigonometric parallax stars and from observations in NGC 752. The rms scatter appears to be $0\overset{m}{.}3$.

For the B stars a simple relation for intrinsic color that fits the observations quite well is $(b-y)_0 = -0.116 + 0.097 c_0$. ($c_0$ is the value of c_1 corrected for interstellar reddening.) The effects of reddening on c_1 are about 20% those on $(b-y)_0$ and so one iteration using the above equation accurately determines both the reddening on c_1 and on $(b-y)$. The rms scatter as estimated from nearly unreddened stars and a few galactic clusters that appear unreddened appears to be $0\overset{m}{.}01$ for one star. The effects of reddening on m_1 are 30% those on $(b-y)$ and on $(u-b)$ are 1.7 times those in $(b-y)$. The calibration appears to fit the clusters quite well and also appears to fit luminosity classes III and II within the above rms scatter.

The calibration for absolute magnitude is given in terms of a relation between β and absolute magnitude, and it appears that a small correction for spectral type or δc_0 or $\delta\beta$ is necessary. The observational errors in β of about $\pm 0\overset{m}{.}010$ would yield an error in absolute magnitude from this source alone ranging from between $0\overset{m}{.}2$ for the late B's to $0\overset{m}{.}7$ for the early B supergiants. As an example of the dispersion expected on the average, for the stars in h and χ Persei observed to the 15th magnitude, the average β is $2\overset{m}{.}610$ and the formal rms scatter for one star is $\pm 0\overset{m}{.}5$. The calibration itself was obtained by fitting the shape of the relation from the observations in clusters and then fitting the zero point by the 'known' distance moduli of the α Persei and Pleiades clusters. The relation between the observed values and the MK spectral types is very good.

Effects of $v \sin i$ must be reasonably small: of the order or less than $0\overset{m}{.}2$ in M_v. Other factors affect the dispersion equally or even larger, for example, unresolved double stars, peculiar stars, age differences, and the 'Hyades anomaly' in the F-type stars. Unfortunately I have been unable to thoroughly analyze the data for $v \sin i$ effects, but in the α Persei and Pleiades clusters, for the A stars where there should be little or no differential age effect, I have applied individual reddening corrections to the stars and find that the clearest correlation with $v \sin i$ is in the parameter δc_1. δc_1 when plotted against $v \sin i$ shows a linear slope of about $0\overset{m}{.}04$ in δc_1 for 100 km/sec difference in $v \sin i$. This is valid over a range from 0 to 250 km/sec. Small individual differences with spectral type and between the clusters exist but these have not yet been looked at in detail.

The calibrations will be published within the next year, and in the meantime are available on request as well as are the data on the clusters. I am especially open to suggestions of important things to look for in the data and of ways to analyze the data in light of theory and from the experience of spectroscopists.

Discussion

Faber: What was the spectral type of the reddest stars observed in the α Per cluster, and did you detect any change in the slope of the relation between δc_1 and $v \sin i$ dependent upon spectral type?

Crawford: G0 is the latest spectral type. The slope seems the same for different types, but there may be some small differences that I haven't seen yet.

Buscombe: I hope the *photometric* data will be published in the form of *photometric* parameters. It is unfortunate that a trend to convert by an unpublished transformation to a *spectroscopic* parameter (equivalent width) has begun to creep into the photometric literature.

Crawford: The observed data – $(b-y)$, m_1, c_1, V, β – will be published, of course.

Deutsch: Dr. Strömgren has found that δm_1 appears to correlate with $v \sin i$ in the A stars. Can you comment on this effect and its interpretation?

Crawford: The Am stars have negative δm_1's and low velocities. If these data for these stars are omitted, there appears to be little effect left, certainly not as large as in δc_1. The question is: what are the independent parameters?