SYNTHETIC uvby-β PHOTOMETRY OF HD 12856 AND HD 13890

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Abstract. Stromgren and Hβ colors have been measured from spectrophotometric observations of two Be stars without published photometry in Per OB1: HD 12856 (B0 pe) and HD 13890 (B1 III:pe). Stellar parameters and improved spectral types are then derived from the color indices and the calibrations of Jakobsen (1986a,b,c). These are compared with the parameters of normal B stars and they are used to estimate the evolutionary status of the stars.

The relations between Stromgren (uvby)-β colors and stellar parameters, such as effective temperature (T_e) and absolute visual magnitude (M_v), have been well calibrated for B (including Be) stars by Jakobsen (1986a,b,c). We have applied her calibrations to two Be stars in Per OB1: HD 12856 and HD 13890.

The colors for these two stars were measured from spectrophotometric observations taken at Kitt Peak National Observatory with the Intensified Reticon Scanner on the .9 m telescope, covering the spectral region 3200-8200 Å. The Stromgren and Hβ filters were approximated by Gaussians and the colors were derived by convolving the filter with the spectrum. The colors are given in Table 1, where $[c_1] = c_1 - 0.20(b-y)$, $[m_1]=m_1+0.32(b-y)$ and $[u-b]=(u-b)-1.56(b-y)=[c_1]+2[m_1]$. The intrinsic colors and color excess are given in Table 2. They were calculated with the method discussed by Crawford et al. (1970), which is independent of spectral subtype. The colors, intrinsic colors and color excess in the Johnson UBV system are listed in Table 3. The $(U-B)_0$ was calculated from the relation of Crawford et al. (1970): $(U-B)_0 = 1.242(U-B) - 0.894(B-V)$, where the coefficients follow a reddening slope of E(U-B)=0.72E(B-V).

Table 2

Intrinsic Colors and Color Excess

	$(b-y)_0$	c_0	m_0	$(u-b)_0$	E(b-y)
HD 12856	-0.136	-0.209	0.052	-0.376	-0.394
HD 13890	-0.112	0.040	0.076	-0.032	-0.318

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Table 1

uvby - β Colors

	(b-y)	m_1	c_1	β	$[m_1]$	$[c_1]$	[u-b]
HD 12856	0.258	-0.074	-0.130	2.556	0.009	-0.182	-0.164
HD 13890	0.206	-0.026	0.104	2.567	0.040	0.063	0.143

Table 3

Colors, Intrinsic Colors and Color Excesses in the UBV System

	V	(U-B)	(B-V)	V_o [c]	$(U-B)_o$	$(B-V)_o$	E(U-B)	E(B-V)
HD 12856	8.55[a]	-0.77[a]	0.24[a]	6.9	-1.17	-0.32	0.40	0.56
HD 13890	8.47[b]	-0.63[b]	0.19[b]	7.2	-0.95	-0.25	0.32	0.44

[a] Wildey 1964, [b] Schild 1986, [c] Slettebak 1968

Table 4

Stellar Parameters

	T_{eff} (°K)	B.C. (mag)	M_V (mag)	M_{bol} (mag)	$\log(L/L_\odot)$	$R/R_\odot$
HD 12856	31,000±900	-2.938±0.278	-4.6±0.5	-7.5±0.6	4.89±.39	10
HD 13890	24,800±2100	-2.468±0.363	-4.3±0.5	-6.8±0.6	4.61±.41	11

SYNTHETIC FILTER PHOTOMETRY OF HD 12856 AND HD 13890

As can be seen, the intrinsic colors of HD 12856 are too large for a B type star, they correspond to those of O type stars. Its $[c_1]$ index is smaller than that of a typical B0 III star, which means that its Balmer discontinuity is less pronounced. In fact, its spectrum shows a Balmer discontinuity in emission, rather than in absorption. Both HD 12856 and HD 13890 show β indices lower than normal B stars of the same spectral type, as expected because of the $H\beta$ line in emission. T_e is derived from Jakobsen's (1986a) calibration as a function of color index (for luminosity classes III-V):

$$10^5/T_e = 6.057[c_1] + 3.6475$$

or

$$10^5/T_e = 5.30[u-b] + 3.25$$

The temperature of HD 13890 suggests that it is a B1.5 III:pe star rather than a B1 III:pe. These calibrations are not applicable to HD 12856 because its large intrinsic colors would yield an exceedingly high temperature. As suggested by Jakobsen (1986a), the temperature of HD 12856 is estimated by using Stromgren indices representative of B stars of the same spectral class. Such indices are taken from Jakobsen (1986c).

Once the effective temperature is known, the B.C. is calculated from Jakobsen's (1986a) calibration:

$$\text{B.C.} = -5.228 + 0.811(10^5/T_e) - 0.313(10^5/T_e)^2$$

M_v is measured from V_0 in Table 2 and the distance modulus of Crawford et al. (1970) to h and χ Persei ($= 11.5 \pm 0.5$ mag). Having calculated these quantities, the bolometric magnitudes, luminosities and stellar radii are found. Table 4 lists all these parameters.

The M_v and M_{bol} of HD 12856 are comparable to those of a normal B0 III star, while HD 13890 is more luminous than a normal B1.5 III star by ~ 0.5 mag. When placed on an HR diagram, HD 12856 is found to be in that part of the diagram where stars are still burning hydrogen in the core, although it is more evolved than a main sequence star. HD 13890 lies very close to the evolutionary tracks (without mass loss) of a 15 $M_\odot$ star, near the end of the hydrogen burning phase and the beginning of core contraction.

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DISCUSSION FOLLOWING TORRES

Doazan:

The way you proceed for determining the position of Be stars in an HR diagram does not take into account the intrinsic excess of the Be stars relative to normal B stars in the Paschen and Balmer continua. Such an effect may be quite large, of the order of 1 or even 2 magnitudes. Therefore, you should first correct your observations for these effects before trying to locate the stars on evolutionary tracks.

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