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The Visual Absolute Magnitude of the Central Objects in Be Stars

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Abstract. Using the circumstellar envelope parameters (mean temperature, extent and opacity) derived by fitting theoretical energy distributions to those observed in a sample of 20 Be stars, we estimate the respective magnitude difference $\Delta V = V - V_*$ of the continuum flux excess produced by their circumstellar envelopes. Using then the HIPPARCOS parallaxes of these stars and the ISM E(B-V) colour excesses derived with the surrounding normal B stars, we estimate the visual absolute magnitude of the central objects in the program Be stars. In most cases the results obtained are in good agreement with the absolute magnitudes obtained from the photospheric (λ_1, D) components derived in the BCD spectrophotometric system. There are, however, strong discrepancies in 4 program stars which deserve further studies. The magnitude excess seems to be $\Delta V \lesssim 0$ for the higher effective temperatures only. There is no correlation between ΔV and $V \sin i$, as would be expected if the circumstellar envelopes were strongly flattened.

1. Introduction

The visual absolute magnitude M_V in normal B stars is an indicator of their temperature and their evolutionary stage. Apart from this information, in Be stars the absolute magnitude may also give indications on the effects produced on their energy distribution by the high stellar rotation. Assuming we can ignore the backwarming effect on the photosphere of the central stars produced by the circumstellar envelope (CE) and using the CE model we presented in other contributions in this issue, we derived from the observed energy distributions of a sample of 20 Be stars the excess/deficiency in the V magnitude $\Delta V = V - V_*$, where V_* is the apparent visual magnitude of the central star. In this paper we would like show only the difficulties related to the determination of reliable individual ΔV excesses. These uncertainties should be taken into account in those studies which aim at showing any possible incidence of the rotation on the magnitude and/or on the energy distribution of central stars without the CE.

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Table 1. The magnitude excess ΔV and the absolute magnitude M_V of the central objects of program Be stars

HD	$\log T_{\rm eff}$	$d_{\rm HIPP} \pm \sigma$ pc	$\Delta V \pm \sigma$ mag	$(M_V \pm \sigma)_{(\lambda_1,D)}$ mag	$(M_V \pm \sigma)_{\Delta V}$ mag
10144	4.215	44±1	$+0.13 \pm 0.11$	-1.46 ± 0.19	
			-0.01 ± 0.03		
28497	4.380	483±191	-0.25 ± 0.01	-2.60 ± 0.14	-2.71 ± 0.86
37490	4.290	498±233	$+0.08 \pm 0.11$	-3.13 ± 0.30	-3.26 ± 0.50
37795	4.090	82±4	$+0.09 \pm 0.04$	-1.15 ± 0.16	-1.26 ± 0.20
48917	4.322	800±358	$+0.28 \pm 0.08$	-3.27 ± 0.26	-4.77 ± 0.99
50013	4.362	242±29	-0.44 ± 0.04	-3.88 ± 0.30	
			-0.45 ± 0.02		
56139	4.336	283±47	$+0.16 \pm 0.02$	-2.43 ± 0.30	-3.60 ± 0.39
			$+0.26 \pm 0.03$		-3.38 ± 0.37
58978	4.447	435±132	-0.26 ± 0.04	-3.76 ± 0.19	-2.55 ± 0.67
			-0.44 ± 0.01		-2.34 ± 0.67
63462	4.415	758±385	-0.36 ± 0.01	-4.42 ± 0.34	-5.06 ± 1.11
			-0.38 ± 0.01		-5.01 ± 1.11
66194	4.318	316±47	$+0.12 \pm 0.04$	-2.40 ± 0.14	
68980	4.431	300±46	-0.26 ± 0.01	-3.85 ± 0.23	-3.52 ± 0.34
83953	4.198	152±15	-0.09 ± 0.01	-1.12 ± 0.32	-1.24 ± 0.28
91465	4.243	152±11	$+0.20 \pm 0.11$	-2.81 ± 0.11	-2.82 ± 0.17
			$+0.10 \pm 0.07$		-2.80 ± 0.18
105435	4.334	121±11	$+0.25 \pm 0.04$	-2.94 ± 0.20	-3.02 ± 0.16
110432	4.367	301±51	-0.62 ± 0.01	-3.93 ± 0.26	
			-0.43 ± 0.02		
120324	4.323	162±19	$+0.20 \pm 0.51$	-2.60 ± 0.20	
			$+0.05 \pm 0.13$		
120991	4.354		$+0.22 \pm 0.13$	-3.50 ± 0.31	
124367	4.204	149±13	$+0.12 \pm 0.06$	-1.46 ± 0.23	-1.25 ± 0.27
148184	4.362	150±17	-0.48 ± 0.02	-2.96 ± 0.28	-2.56 ± 0.30
209409	4.132	117±11	$+0.17 \pm 0.09$	-0.82 ± 0.11	-0.90 ± 0.25

2. Flux excess determination

The magnitude difference $\Delta V = V - V_*$ can in principle be obtained by studying the long-term component of the V magnitude variation of Be stars as a function of some photospheric tracer not perturbed by the circumstellar matter. Among the best of such indicators is the Balmer discontinuity. Nevertheless, for hot Be stars the circumstellar medium can be strongly ionized with tiny true absorptions (bb+ff), so that at any moment the Balmer discontinuity closely reflects the underlying stellar photosphere, though the V magnitude is strongly absorbed due to electron scattering. We then used an analytical representation of the CE, so as to take into account CE continuum emission, electron scattering and true absorption in the visible continuum spectrum. This representation also takes into account the flattening of the CE and the consequent aspect angle effect on the observed apparent energy distribution. We looked then for a fit of the observed energy distributions in Be stars. The data are from Kaiser (1987) and Dachs et al. (1989) relating to 20 Be stars. A number of these objects were observed several times. This procedure led us to estimate the following parameters of the CE: R = the mean extent of the region in the CE producing the studied flux excess; τ_V = the total continuum opacity (bb+ff + electron scattering); $T_{\rm env}$ = the mean temperature of the region. Using these parameters

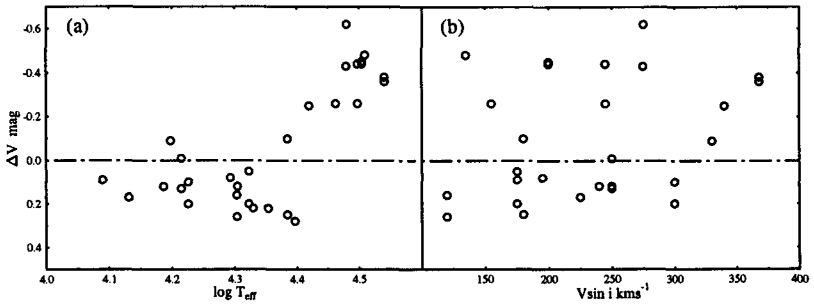

Figure 1. (a) ΔV visual magnitude excess as a function of $\log T_{\rm eff}$. (b) ΔV magnitude excess against $V \sin i$.

we can then give a representation of the flux excess at $\lambda = 0.56\mu$m as follows:

$$\Delta V = f(R, \tau_{\rm V}, T_{\rm env}) \tag{1}$$

3. Results and discussion

Table 1 presents the set of stars studied, the parallaxes obtained with the Hipparcos satellite and the magnitude differences calculated from (1). We also give the absolute magnitude $(M_{\rm V})_{(\lambda_1,D)}$ obtained from calibration of the Balmer discontinuity (λ_1, D) parameters, and the absolute magnitude of the central star as seen without the CE: $(M_{\rm V})_{\Delta V}$. This last was derived using (1) for all those stars for which we had absolute calibrations of fluxes (15 stars) and Pogson's relation:

$$(M_{\rm V})_{\Delta V} = V - \Delta V - R_V \times E(B-V) + 5 - 5 \times \log d_{\rm HIPP}. \tag{2}$$

For most studied Be stars the calibrated absolute magnitude $(M_{\rm V})_{(\lambda_1,D)}$ and $(M_{\rm V})_{\Delta V}$ are in agreement within a mean error $\delta M_{\rm V} = \pm 0.16$ mag (11 stars). Discrepancies are however high for HD 48917, HD 58978 and HD 63462, where the errors of parallaxes are also about 40%. There is still HD 56139, where disagreement amounts to a troublesome 1 mag! In this star a $\Delta V \gtrsim 0$ was obtained, though a $\Delta V \lesssim 0$ would be expected according to its low $V \sin i$ and if its CE were flattened, as assumed in most models of CE in Be stars. Unless we have made an error of about 4 subspectral types in classifying this object, no other apparent reason can easily explain such a high discrepancy. However, such an error in spectral classification implies that the Balmer discontinuity of the central star was determined with an error higher than 4 times the mean error made in the BCD classification system, which seems unlikely.

Fig. 1(a) shows ΔV against $\log T_{\rm eff}$. We see that from our small set of stars the dependency of ΔV with $T_{\rm eff}$ does not vary monotonically. Be stars with $T_{\rm eff} \lesssim 25000$ K have systematically $\Delta V \gtrsim 0$ and those with higher temperatures have $\Delta V \lesssim 0$. In Table 2 we report mean total opacities (bf+ff+e-scattering) of the CE at $\lambda 0.56\mu$m and the mean extent of the region that produces the

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ΔV difference for stars with $\Delta V \gtrsim 0$ and with $\Delta V \lesssim 0$. Even when there is a slightly higher mean opacity in those CE with $\Delta V \lesssim 0$, we see that the clearest difference between both groups of stars is depicted by the mean extent of the CE: Be stars with $\Delta V \lesssim 0$ have, as a mean, the more extended CE.

Table 2. Mean parameters of CE producing $\Delta V < 0$ or $\Delta V > 0$

$\Delta V \lesssim 0$	$\Delta V \gtrsim 0$
$\overline{\tau_V} = 0.91 \pm 0.40$	$\overline{\tau_V} = 0.73 \pm 0.56$
$\overline{R/R_*} = 4.1 \pm 1.8$	$\overline{R/R_*} = 1.3 \pm 0.2$

Fig. 1(b) shows ΔV against $V\sin i$. The lack of correlation with $V\sin i$ for the whole set of stars, as well as for each group with $\Delta V \lesssim 0$ and $\Delta V \gtrsim 0$ separately, may imply that the regions producing the ΔV excess or deficiency are not flattened enough to produce any clear dependency with the aspect angle.

Finally, the magnitudes $(M_V)_{\Delta V}$ seem to be systematically slightly brighter than $(M_V)_{(\lambda_1,D)}$. Nevertheless, the differences are of the order of uncertainties. The sample of stars studied is rather small, so that the relations obtained between ΔV, $T_{\rm eff}$ and $V\sin i$ are only preliminary. More definite conclusions will perhaps be derived once we have finished the calculations planned for the whole set of 200 program Be stars.

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