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Recalibration of the $uvby\beta$ photometry-based distance scale of OB-type stars using the revised *Hipparcos* parallaxes

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Abstract. The absolute visual and infrared magnitudes of moderately evolved OB-type stars are directly calibrated as a function of Stroemgren four-color and Hβ photometric indices using the trigonometric parallaxes from the new reduction of *Hipparcos* data. The resulting calibrations have an average accuracy of ~ 0.4 mag and, when applied to members of young open clusters, yield distances that are fairly consistent with those determined using the M_V–$(B-V)$ zero-age main-sequence fitting procedure.

Keywords. stars: distances, stars: luminosities, supergiants, stars: kinematics

1. Introduction

The dramatic improvement in the accuracy of trigonometric parallaxes of bright OB-type stars provided by the new reduction of the *Hipparcos* data (van Leeuwen 2007) allows recalibration of the absolute magnitudes of close-to-main-sequence blue stars from scratch, without having to resort to open cluster membership probabilities. We derive the trigonometric-parallax-based V- and K-band absolute-magnitude calibrations for moderately evolved O–B9-type stars. We use these calibrations to redetermine the distances to a number of young open clusters and associations and study the kinematic behavior of the young stellar population in the extended solar neighborhood.

2. Calibration

Our working sample consists of 458 OB-type stars with accurate parallaxes ($\sigma_\pi/\pi \leqslant 0.1$) in the revised *Hipparcos* catalog (van Leeuwen 2007) and complete, homogenized $uvby\beta$ data available from the catalog of Hauck & Mermilliod (1998). (All known binaries and emission-line stars have been excluded.) We calibrate the absolute magnitudes of these stars by fitting them to a function of the photometric indices c_0 and β in the Stroemgren system, which depend mostly on temperature and luminosity, respectively. The parameter c_0 is the dereddened index $c_1 = (u-v)-(v-b)$, and the β index characterizes the strength of the Hβ line in the stellar spectrum. Fig. 1 shows the c_0–β diagram for the sample stars. The solid line shows the locus of the zero-age main sequence (ZAMS) and the vertical bar, $\Delta\beta = \beta - \beta_{\rm ZAMS}(c_0)$, the vertical offset of the star's β index from the ZAMS locus. The latter quantity characterizes the degree of the star's evolution away from the ZAMS. Fig. 2 shows the β–$\Delta\beta$ diagram for the same stars.

We computed the trigonometric parallax-based absolute magnitudes,

$$M_V = V_0 + 5\log\pi - 10$$

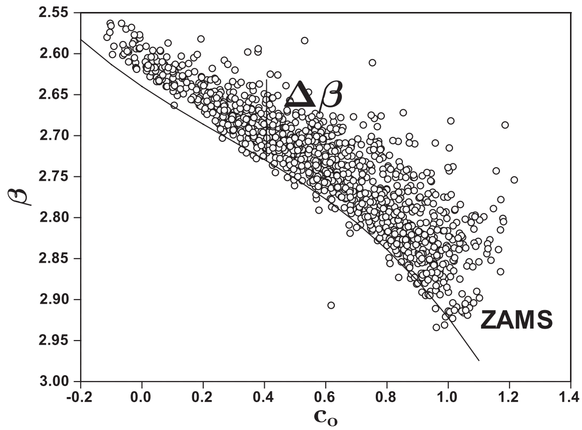

Figure 1. β–c_0 diagram for 458 OB-type stars with revised *Hipparcos* parallaxes, published *uvbyβ* data, and characterized by fractional errors $\sigma_\pi/\pi \leqslant 0.1$. The β and c_0 indices are mostly luminosity- and temperature-dependent, respectively. $\Delta\beta$ is the vertical distance of the star from the ZAMS locus.

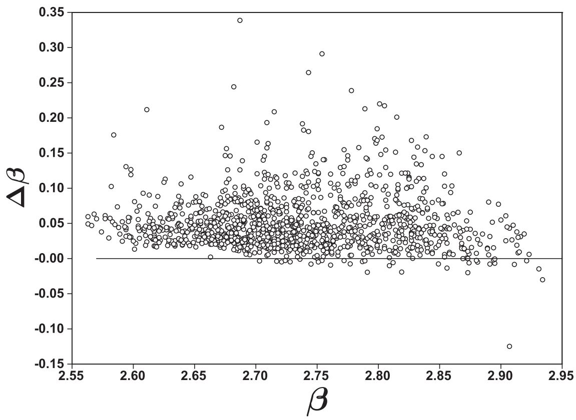

Figure 2. $\Delta\beta$–c_0 diagram for 458 OB-type stars with revised *Hipparcos* parallaxes, published *uvbyβ* data, and characterized by fractional errors $\sigma_\pi/\pi \leqslant 0.1$.

and

$$M_K = K_0 + 5\log\pi - 10$$

for our sample stars. V_0 and K_0 are the dereddened apparent magnitudes and π is the revised *Hipparcos* trigonometric parallax. The corresponding smoothed contour maps are shown in Figs 3 and 4. We subsequently fitted the individual, derived absolute magnitudes with polynomials in β and $\Delta\beta$ to derive the revised calibrations,

$$M_V = +0.18 + 10\Delta\beta + 9.6(\beta - 2.75) - 62(\beta - 2.75)^2$$

$$-32(\beta - 2.75)\Delta\beta + 123(\beta - 2.75)^3 \pm 0.40 \quad (2.1)$$

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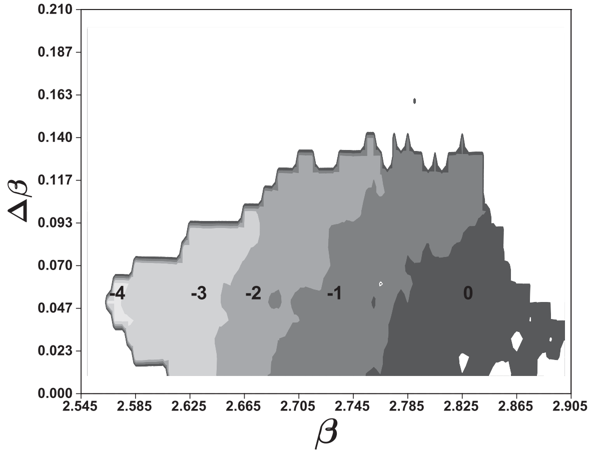

Figure 3. Dependence of the absolute magnitude M_V on β and $\Delta\beta$.

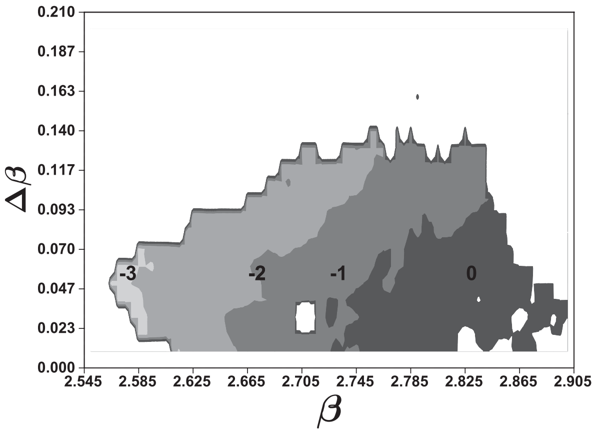

Figure 4. Dependence of the absolute magnitude M_K on β and $\Delta\beta$.

and

$$M_K = +0.48 + 12\Delta\beta + 7.0(\beta - 2.75) - 55(\beta - 2.75)^2$$
$$-38(\beta - 2.75)\Delta\beta + 120(\beta - 2.75)^3 \pm 0.39. \tag{2.2}$$

To test our calibration, we used Eq. (2.1) to compute the absolute V-band magnitudes of OB-type members with published $uvby\beta$ photometry in several young open clusters and estimated the corresponding average photometric distance moduli. The results are summarized in Table 1. The table's columns include the cluster name, the average distance modulus based on Eq. (2.1), and the M_V–$(B-V)$ ZAMS-fitting-based distance modulus from the catalog of Dambis (1999).

Finally, we compute a rotation-curve solution based on published radial velocities (Barbier-Brossat & Figon 2000), revised *Hipparcos* proper motions, and photometric distances to 810 OB-type stars with radial-velocity errors $\leqslant$ 10 km s^{-1}. The inferred kinematic parameters (average heliocentric velocity components U_0, V_0, and W_0; velocity-dispersion tensor components σ_U, σ_V, and σ_W; angular rotation velocity, Ω_0; Oort's constant A; and the second derivative of the angular rotation velocity, Ω''), are listed in Table 2.

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Table 1. Distances to several young open clusters determined using the revised calibration, Eq. (2.1).

Cluster	$(m-M)_0$ (mag)	$(m-M)_0$ (mag; Dambis 1999)
NGC 869	11.25 ± 0.12	11.36
NGC 884	11.61 ± 0.09	11.50
NGC 2244	10.71 ± 0.08	10.77
NGC 2362	10.72 ± 0.15	10.53
NGC 3293	12.30 ± 0.10	11.67
NGC 4755	11.31 ± 0.10	11.38
NGC 6231	10.96 ± 0.10	10.74
IC 4665	7.60 ± 0.10	7.57
IC 4724	8.91 ± 0.11	8.62
$\langle\Delta(m-M)_0\rangle = +0.13 \pm 0.08$ mag		

Table 2. Rotation-curve solution for OB-type stars with distances based on the revised calibration, Eq. (2.1).

U_0 (km s^{-1})	V_0 (km s^{-1})	W_0 (km s^{-1})	σ_U (km s^{-1})	σ_V (km s^{-1})	σ_W (km s^{-1})	Ω_0 (km s^{-1} kpc^{-1})	A (km s^{-1} kpc^{-1})	Ω'' (km s^{-1} kpc^{-3})
−8.4 ± 0.6	−12.8 ± 0.5	−8.0 ± 0.2	16.3 ± 0.4	11.9 ± 0.3	5.9 ± 0.2	26.3 ± 1.2	13.5 ± 0.7	+1.75 ± 0.24

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