Kinematics of OB-associations and the new reduction of the *Hipparcos* data

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ABSTRACT

The proper motions of OB-associations computed using the old and new reductions of the *Hipparcos* data are in good agreement with each other. The Galactic rotation curve derived from an analysis of the line-of-sight velocities and proper motions of OB-associations is almost flat in the 3-kpc neighbourhood of the Sun. The angular rotation velocity at the solar distance is $\Omega_0 = 31 \pm 1$ km s^{-1} kpc^{-1}. The standard deviation of the velocities of OB-associations from the rotation curve is $\sigma = 7.2$ km s^{-1}. The distance scale for OB-associations should be shortened by 10–20 per cent. The residual velocities of OB-associations calculated for the new and old reductions differ, on average, by 3.5 km s^{-1}. The mean residual velocities of OB-associations in the stellar-gas complexes depend only slightly on the data reduction employed.

Key words: Galaxy: kinematics and dynamics – open clusters and associations: general.

1 INTRODUCTION

The original data from the *Hipparcos* satellite were obtained in the form of time moments for transitions of stars through the diffraction grating which were then transformed into the angular positions along the scan direction (Kovalevsky 2002). A better understanding of the peculiarities in the rotation of the satellite and increased computer power allowed van Leeuwen (2007) to abandon the intermediate reduction on the great circle, which was one of the sources of noise. A global iterative solution resulted in a factor of 4 improvement in the accuracy of the astrometric data for bright stars ($m_V < 8$ mag) (van Leeuwen 2007).

In this paper, we compare the proper motions, parallaxes and residual velocities of OB-associations derived for the old (Hipparcos 1997) and new (van Leeuwen 2007) reductions of the *Hipparcos* data. We also determine the parameters of the Galactic rotation curve and improve the distance scale for OB-associations. A good agreement between the old and new results is indicative of high quality of the astrometric data obtained for bright stars.

OB-associations are large groups of high-luminosity stars, though the sky-plane size of most of them does not exceed 300 pc. They often have several centres of concentration. The catalogue of Blaha & Humphreys (1989) of stars of OB-associations includes 91 groups located within 3.5 kpc from the Sun. There are several partitions of high-luminosity stars (OB stars and red supergiants) into OB-associations (Blaha & Humphreys 1989; Garmany & Stencel 1992; Mel'nik & Efremov 1995), but all partitions used the photometric data obtained by Blaha & Humphreys (1989). We do not use the partition by Garmany & Stencel (1992) because it covers only a

restricted interval of Galactic longitudes 55°–150°. Our own partition (Mel'nik & Efremov 1995) is also unsuitable for kinematical studies: the compact centres of OB-associations derived by using the cluster analysis method include only few stars with known kinematical data. All associations considered here are unbound objects. The new partition (Mel'nik & Efremov 1995) clearly shows that even compact centres of OB-associations have very large velocity dispersions to be bound objects.

Blaha & Humphreys (1989) derived distances for OB-associations by averaging distance moduli of individual stars. Membership in the associations is based on positions, spectral type, luminosity and resulting photometric distance. The above authors used their own calibration which differs little from the previously published ones (see comments in Humphreys & McElroy 1984).

The mass measurements of proper motions of blue stars became available due to the inclusion of a list of OB stars into the *Hipparcos* input catalogue (de Zeeuw et al. 1999). The mean visual magnitude of the stars of OB-associations with known proper motions is $m_V = 7.3$ and 7.8 mag in the areas $0 < r < 3.5$ and $1.5 < r < 3.5$ kpc, respectively. Thus, they are bright enough, and we can expect a conspicuous increase in the accuracy of their astrometric data.

2 RESULTS

2.1 Proper motions of OB-associations

The OB-associations have quite reliable distances, which are accurate, on the average, to 6 per cent without the allowance for the uncertainty of the zero-point of the distance scale (see the Appendix). Table 1, available in full as Supporting Information in the online

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Table 1. Sample of the line-of-sight velocities and proper motions of OB-associations. The full table is available as Supporting Information.

Association	l	b	r	V_r	σ_{vr}	n_{vr}	μ_{l1}	$\sigma_{\mu l1}$	μ_{b1}	$\sigma_{\mu b1}$	μ_{l2}	$\sigma_{\mu l2}$	μ_{b2}	$\sigma_{\mu b2}$	n_μ	N_t
Sgr OB5	0.0	−1.2	2.4	−15.0	19.0	2	0.1	1.7	0.1	2.2	−0.4	1.2	−1.2	2.2	3	31
Sgr OB1	7.6	−0.8	1.3	−10.0	12.1	37	−1.6	1.5	−1.3	1.1	−1.1	0.9	−1.1	1.3	29	66
Sgr OB7	10.7	−1.6	1.4	−6.1	17.1	3	0.0	0.3	−3.3	0.1	−0.9	0.3	−1.3	0.8	2	4
Sgr OB4	12.1	−1.0	1.9	3.5	10.8	9	−0.7	1.4	−0.8	2.5	−0.5	1.5	−1.7	1.8	3	15
Sgr OB6	14.2	1.3	1.6	−7.3	9.5	4	−0.3		−5.8		0.1		−6.2		1	5
Ser OB1	16.7	0.1	1.5	−5.0	21.6	17	−0.7	1.2	−0.8	2.6	−0.8	1.6	−0.1	1.8	12	43
Sct OB3	17.3	−0.7	1.3	3.3	17.0	8	−0.9	0.5	−0.6	1.0	−0.6	0.5	−1.5	1.1	3	10
Ser OB2	18.2	1.6	1.6	−4.0	14.5	7	−0.8	1.4	−1.4	0.9	−0.3	1.3	0.0	1.4	5	18
Sct OB2	23.2	−0.5	1.6	−11.0	40.2	6	−0.5	4.2	−0.6	1.6	−1.8	4.0	−0.1	2.4	6	13
Tr 35	28.0	−0.5	2.0	31.0		1	−3.2		−0.1		−3.7		1.8		1	9

version of this article, gives the line-of-sight velocities and proper motions of OB-associations based on the kinematical data of individual stars. We used the median estimations instead of mean values for velocities to reduce the influence of stars whose velocities deviate strongly from the mean value. For every OB-association from the catalogue by Blaha & Humphreys (1989) we give the mean galactic coordinates l and b, the mean heliocentric distance r, median line-of-sight velocity V_r, the dispersion of the line-of-sight velocities σ_{vr} and the number of stars n_{vr} with known line-of-sight velocity. We adopt the line-of-sight velocities from the catalogue by Barbier-Brossat & Figon (2000). We use only the velocities measured with errors of less than 10 km s^{-1}, which corresponds to the quality estimations A, B and C. Table 1 also gives the median proper motions of OB-associations along l- and b-coordinates, μ_l and μ_b. The data obtained for the reduction of 1997 (Hipparcos 1997) are denoted by subscript 1, whereas those based on the reduction by van Leeuwen (2007) are marked by subscript 2. For each OB-association we give the dispersions of proper motions, $\sigma_{\mu l}$ and $\sigma_{\mu b}$, as well as the number of stars n_μ with known proper motion. The last column gives the total number of stars with known photometric measurements, N_t, used to determine the distances for OB-associations. The distances listed in Table 1 agree with the short distance scale for classical Cepheids (Berdnikov, Dambis & Vozyakova 2000). They are equal to the distances from the catalogue by Blaha & Humphreys (1989), r_{BH}, multiplied by a factor of 0.8, $r = 0.8r_{BH}$ (Sitnik & Mel'nik 1996; Dambis, Mel'nik & Rastorguev 2001).

We determine the median proper motions for 64 OB-associations containing at least two stars with known proper motions and the median line-of-sight velocities for 70 OB-associations containing at least two stars with known line-of-sight velocities. The velocity of each OB-association is based, on average, on 12 line-of-sight velocities and 11 proper motions of individual stars.

Let us consider a sample of 64 OB-associations containing at least two stars with known proper motions. Fig. 1 shows the proper motions of OB-associations computed using the old and new reduction of the *Hipparcos* catalogue. It is immediately apparent that the new reduction does not bring dramatic changes into proper motions of OB-associations. The rms difference between the proper motions μ_{l1} and μ_{l2} derived for the old and new reductions is $\Delta_{\mu_l} = 0.58$ mas yr^{-1}, and the rms difference of the proper motions μ_{b1} and μ_{b2} is $\Delta_{\mu_b} = 0.62$ mas yr^{-1}. These deviations in proper motions translate into tangential velocity deviations of $\Delta_{tang} = 4.6$ km s^{-1}. That does not exceed the standard deviation of the velocities of OB-associations from the rotation curve.

Note that the values given here are very much sample dependent. For example, the deviations calculated for a sample of 29 OB-associations with proper motions based on at least 10 individual stars reduce to $\Delta_{\mu_l} = 0.41$, $\Delta_{\mu_b} = 0.50$ mas yr^{-1} and $\Delta_{tang} = 2.7$ km s^{-1}.

2.2 Dispersion of stellar proper motions inside OB-associations

Let us consider the dispersions of individual stellar proper motions, $\sigma_{\mu l}$ and $\sigma_{\mu b}$, in 29 OB-associations with at least 10 *Hipparcos* stars. Fig. 2 compares these dispersions computed for the old and new reductions of the *Hipparcos* data. It is obvious that closer OB-associations have larger proper motions (in absolute value) and, consequently, greater $\sigma_{\mu l}$ and $\sigma_{\mu b}$. The pluses and dots show the associations lying within 1 kpc and beyond 1 kpc from the Sun, respectively. Generally, we see a weak decrease in the dispersions of proper motions in the new reduction. The mean dispersion in the plane of the sky decreases to 1.67 mas yr^{-1} in the new reduction against 1.81 mas yr^{-1} in the old one. But the corresponding velocity dispersion remains practically at the same level, $\sigma_{tang} = 9.7$ km s^{-1}. For comparison, the mean dispersion of the line-of-sight velocities computed for 28 OB-associations containing at least 10 stars with known line-of-sight velocities amounts to $\sigma_{sight} = 12.3$ km s^{-1}.

One value of $\sigma_{\mu l}$ decreases from 4.2 mas yr^{-1} in the old reduction to 2.6 mas yr^{-1} in the new reduction (Fig. 2a). This significant change occurs in the OB-associations Ara OB1A ($r = 1.1$ kpc). The decrease is due to changes in the proper motions of the stars HD 150135 and 150136.

2.3 Trigonometric parallaxes of OB-associations

We use van Leeuwen's data to calculate the trigonometric parallaxes p_t for OB-associations as the median values of the parallaxes of individual stars. We derive them for 29 OB-associations containing at least 10 stars with known parallaxes. This allowed us to compare the distance scale for OB-associations based on photometric distances by Blaha & Humphreys (1989), r_{BH}, with that based on the *Hipparcos* data. We converted the photometric distances, r_{BH}, into photometric parallaxes, $p_{BH} = 1/r_{BH}$, and made a least-squares solution for a set of 29 linear equations, $p_t = k'p_{BH}$. The coefficient k' is equal to $k' = 1.14 \pm 0.06$ and hence coincides with the value derived for the old reduction of the *Hipparcos* data (Dambis et al. 2001). The standard deviation of the association parallaxes from the derived relationship is $\sigma = 0.44$ mas. The distance-scale factor k relating photometric r_{BH} and parallax-based distances, $r = kr_{BH}$, is $k = 0.88 \pm 0.05$. The exclusion of the nearest OB-association Sco OB2 ($r = 0.1$ kpc) changes the coefficient k' to $k' = 1.27 \pm 0.09$, which corresponds to a distance-scale factor of $k = 0.78 \pm 0.07$.
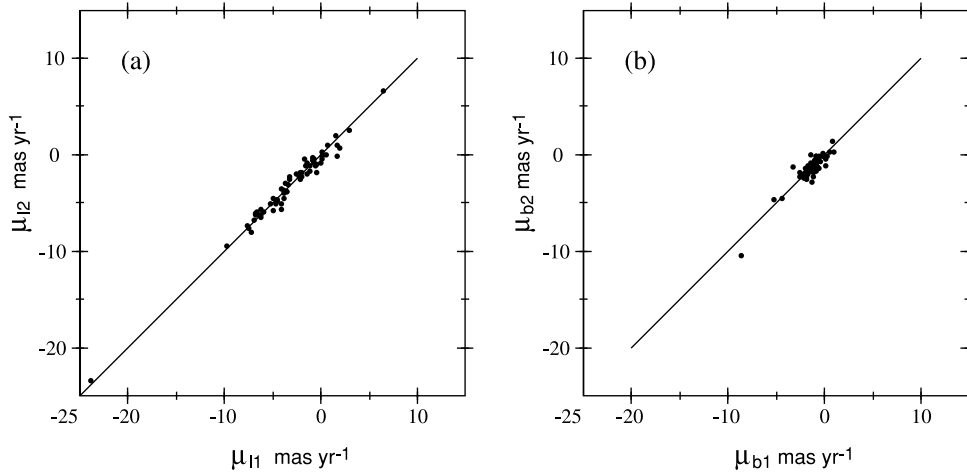
Figure 1. The proper motions of 64 OB-associations derived for the old (index 1) and new (index 2) reductions of the *Hipparcos* data: (a) proper motions along *l*-coordinate and (b) those along *b*-coordinate. The line goes at the angle of 45°.
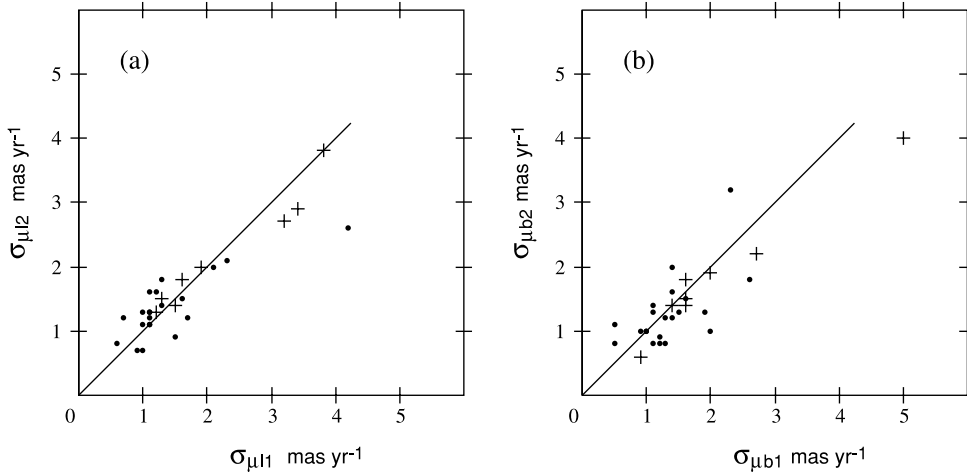
Figure 2. The dispersions of the observed proper motions for 29 OB-associations obtained for the old (index 1) and new (index 2) reductions of the *Hipparcos* data: (a) proper motions along *l*-coordinate and (b) those along *b*-coordinate. Associations located within 1 kpc are indicated by pluses, while those located at the distances $r > 1$ kpc are shown by dots. The line goes at the angle of 45°.

In order to increase the sample size, we turned to the second part of the high-luminosity-star catalogue of Blaha & Humphreys (1989), which includes field stars. The distances to these stars were determined using the same photometric calibration as was used for stars of OB-associations. For 1006 field stars, we found trigonometric parallaxes p_t determined with the errors of less than 1 mas. Note that 534 of them are located within 1 kpc. The coefficient in the relation between trigonometric and photometric parallaxes is $k' = 1.20 \pm 0.02$. The rms deviation of the stellar parallaxes from the relation derived is $\sigma = 1.5$ mas. The distance-scale coefficient is $k = 0.83 \pm 0.02$ and practically coincides with the value calculated for the old reduction, $k = 0.84 \pm 0.02$ (Dambis et al. 2001). Thus, the old and new reductions of the *Hipparcos* data yield very similar results indicating that the distance scale for OB-associations by Blaha & Humphreys (1989) should be shrunk by 10–20 per cent.

2.4 Rotation curve

An analysis of the line-of-sight velocities and proper motions of OB-associations derived for the old reduction of the *Hipparcos* data suggests that Galactic rotation curve is practically flat and

that it is characterized by a large angular rotation velocity at the solar distance, $\Omega_0 = 31 \pm 1$ km s^{-1} kpc^{-1} (Dambis, Mel'nik & Rastorguev 2001; Mel'nik, Dambis & Rastorguev 2001). The large value of Ω_0 was also derived from an analysis of the kinematics of blue supergiants, $\Omega_0 = 29.6 \pm 1.6$ km s^{-1} kpc^{-1} (Zabolotskikh, Rastorguev & Dambis 2002), and from the kinematics of star-forming regions with the proper motions and parallaxes based on the VLBI measurements, $\Omega_0 = 30 \pm 1$ (Reid et al. 2009). In this paper, we determine the parameters of the rotation curve from an analysis of the kinematics of OB-associations based on the new reduction of the *Hipparcos* data.

Let us suppose that the motion of young objects of the disc obeys a circular rotation law. We can then write the equations for the line-of-sight velocities and proper motions in the following form:

$$V_r = R_0(\Omega - \Omega_0)\sin l \cos b$$
$$- (u_0 \cos l \cos b + v_0 \sin l \cos b + w_0 \sin b), \tag{1}$$

$$4.74\mu_l r = R_0(\Omega - \Omega_0)\cos l - \Omega r \cos b$$
$$- (-u_0 \sin l + v_0 \cos l). \tag{2}$$

These are the so-called Bottlinger equations, where Ω and Ω_0 are the angular rotation velocities calculated at the Galactocentric distance R and at the distance of the Sun R_0, respectively. The velocities u_0 and v_0 characterize the solar motion with respect to the centroid of objects considered in the direction towards the Galactic Centre and in the direction of Galactic rotation, correspondingly. The velocity w_0 is directed along the z-coordinate, and we set it equal to $w_0 = 7.5$ km s^{-1} (see Section 2.5). The factor 4.74 converts the left-hand part of equation (2) (where proper motion is in mas yr^{-1} and the distance is in kpc) into the units of km s^{-1}.

We expanded the angular rotation velocity Ω at Galactocentric distance R into a power series in $(R - R_0)$

$$\Omega = \Omega_0 + \Omega_0'(R - R_0) + 0.5\Omega_0''(R - R_0)^2, \tag{3}$$

where Ω_0' and Ω_0'' are its first and second derivatives taken at the solar Galactocentric distance.

We solve the equations for the line-of-sight velocities and proper motions jointly and use weight factors p_{vr} and p_{vl} to allow for observational errors and 'cosmic' velocity dispersion:

$$p_{vr} = \left(\sigma_0^2 + \varepsilon_{vr}^2\right)^{-1/2}, \tag{4}$$

$$p_{vl} = \left[\sigma_0^2 + (4.74\varepsilon_{\mu l}r)^2\right]^{-1/2}, \tag{5}$$

We adopt $\sigma_0 = 7.0$ km s^{-1}, which is approximately equal to the rms deviation of the velocities from the rotation curve (for more details see Dambis, Mel'nik & Rastorguev 1995, 2001).

The errors of the median velocities ε_{vr} and ε_{vl} depend on the velocity dispersion and the number of stars with known kinematics in the association:

$$\varepsilon_{vr} = \frac{\sigma_{vr}}{\sqrt{n_{vr}}} \tag{6}$$

$$\varepsilon_{vl} = \frac{4.74r\sigma_{\mu l}}{\sqrt{n_\mu}}. \tag{7}$$

Our approach includes two scaling parameters: the solar Galactocentric distance R_0 and the distance-scale coefficient k, $r = kr_{BH}$. There is currently no consensus of opinion on the exact value of R_0: different authors report values in the range $R_0 = 7.0–9.0$ (see e.g. a review by Nikiforov 2004). For this reason, we calculated the parameters of the rotation curve and the distance-scale coefficient for five values: $R_0 = 7.1, 7.5, 8.0, 8.5$ and 9.0 kpc. In our previous works, we adopted $R_0 = 7.1$ (Dambis et al. 2001; Mel'nik et al. 2001), which we derived from an analysis of Cepheid line-of-sight velocities (Dambis et al. 1995) and from the spatial distribution of globular clusters (Rastorguev et al. 1994).

To determine the rotation curve, we selected 70 line-of-sight velocities and 62 proper motions of OB-associations based on at least two stars. We discarded the proper motions for two distant OB-associations R 103 ($r = 3.2$ kpc) and Ara OB1B ($r = 2.8$ kpc) having inexplicably large residual velocities along the z-coordinate, $V_z = -31$ and -24 km s^{-1}. Note that the old reduction of the *Hipparcos* catalogue also yields large V_z velocity components for these associations, $V_z \approx -22$ km s^{-1}.

We use standard least-squares method (Press et al. 1987) to solve the system of 132 equations, which are linear in the parameters Ω_0, Ω_0', Ω_0'', u_0 and v_0, for each value of non-linear parameter k. We then determine the value of k that minimizes the sum of squared normalized residual velocities χ^2 – which has a unique minimum in the interval (0.4, 1.2) – and estimate its standard error using the technique proposed by Hawley et al. (1986).

Table 2 lists the parameters Ω_0, Ω_0', Ω_0'', u_0, v_0 and k calculated for different values of R_0. It also gives the rms residual σ, the value of χ^2 and the standard errors of the parameters. It clearly shows that Ω_0, u_0, v_0 and k are practically independent of the choice of R_0. The parameters Ω_0' and Ω_0'' vary conspicuously with R_0, whereas the Oort constant $A = -0.5R_0\Omega'$ remains practically unchanged, $A = 17.3–17.9$ km s^{-1} kpc^{-1}. Generally, we can observe a weak tendency for decreasing χ^2 with increasing R_0. Note, however, that the circular rotation law is too simplified to describe the motion of OB-associations (see Section 2.6). The kinematical parameters derived for the old and new reductions of the *Hipparcos* catalogue agree within the errors [compare table 4 in Dambis et al. (2001) with Table 2 in this paper]. We found the velocity field of OB-associations to be very robust, so that the exclusion of objects with velocity components derived from two to four stars has no significant effect on the results.
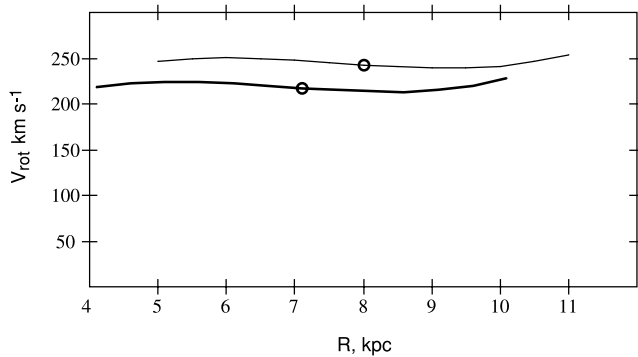
Fig. 3 shows the Galactic rotation curves within the 3 kpc of the Sun computed for $R_0 = 7.1$ and 8.0 kpc. It is immediately apparent that the rotation curve is practically flat in both cases. The linear velocity at the solar distance is equal to $\Theta_0 = 218$ and 243 km s^{-1}, respectively, and remains constant within 3 kpc from the Sun with the accuracy of ±3 per cent.

2.5 Motions along the z-coordinate

Let us consider motions along the z-coordinate. The velocities of OB-associations, V_z, calculated from proper motions μ_b and the line-of-sight velocities V_r,

$$V_z = 4.74r\mu_b \cos b + V_r \sin b, \tag{8}$$

determine the solar velocity w_0. Its value derived for 59 OB-associations is $w_0 = 7.6 \pm 0.7$ ($\sigma_{vz} = 5.2$ km s^{-1}) and $w_0 = 7.5 \pm 0.6$ ($\sigma_{vz} = 5.0$ km s^{-1}) for the old and new reductions, respectively.

Table 2. Parameters of the rotation curve.

R_0 (kpc)	Ω_0 (km s^{-1} kpc^{-1})	Ω_0' (km s^{-1} kpc^{-2})	Ω_0'' (km s^{-1} kpc^{-3})	u_0 (km s^{-1})	v_0 (km s^{-1})	k	A (km s^{-1} kpc^{-1})	σ (km s^{-1})	χ^2
7.1	30.7	−5.1	1.6	7.6	11.4	0.77	17.9	7.1990	134.3
7.5	30.6	−4.7	1.4	7.7	11.6	0.78	17.7	7.1693	133.2
8.0	30.4	−4.4	1.3	7.9	11.8	0.79	17.6	7.1407	132.2
8.5	30.4	−4.1	1.1	7.9	12.0	0.79	17.5	7.1194	131.4
9.0	30.3	−3.8	1.0	8.1	12.2	0.80	17.3	7.1045	130.8
Error	±0.9	±0.2	±0.2	±1.0	±1.3	±0.1	±0.8		

Figure 3. The Galactic rotation curve derived from an analysis of the line-of-sight velocities and proper motions of OB-associations for the adopted solar Galactocentric distances of $R_0 = 7.1$ and 8.0 kpc. The position of the Sun is shown by a circle.

2.6 Residual velocities

Residual velocities characterize non-circular motions in the Galactic disc. They are determined as differences between the observed velocities and model velocities computed in terms of the circular rotation law with adopted components of the solar motion. We calculated the distribution of the residual velocities of OB-associations in the Galactic plane for the different values of R_0. For this aim, we selected 59 OB-associations containing at least two stars with known line-of-sight velocities and proper motions using the new reduction of the *Hipparcos* data. We set the distance-scale coefficient equal to $k = 0.80$ in all cases and adopt the values of the other parameters from the corresponding lines of Table 2. The fields of residual velocities are nearly the same for different R_0, and we therefore show only the field computed for $R_0 = 7.5$ kpc (Fig. 4).
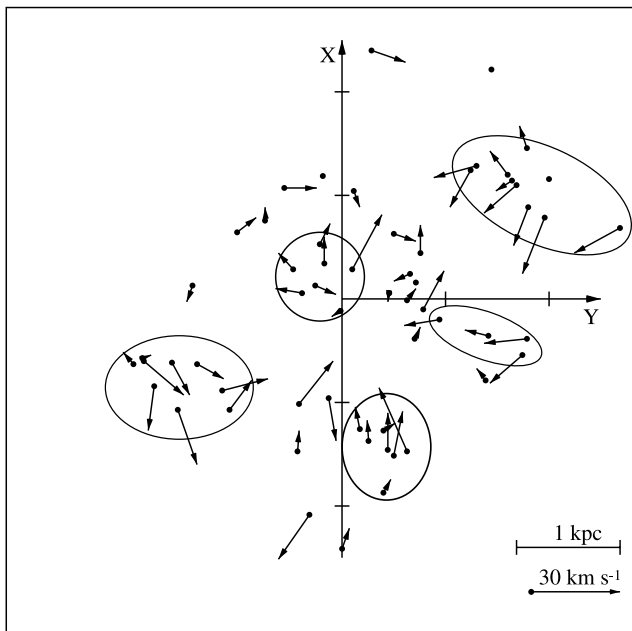
Figure 4. The residual velocities of OB-associations derived for the new reduction of the *Hipparcos* data and $R_0 = 7.5$ kpc. The ellipses indicate the positions of the stellar-gas complexes. The X- and Y- axes are directed away from the Galactic centre and towards the Galactic rotation, respectively. The Sun is at the origin.

Note that the residual velocities calculated for $R_0 = 7.1$ and 9.0 kpc differ, on average, by 1.1 km s^{-1}.

The distributions of the residual velocities of OB-associations derived for the old and new reductions of the *Hipparcos* data resemble each other (compare fig. 2 in Mel'nik et al. 2001 and Fig. 4 of the present paper). The velocities differ, on average, by 3.5 km s^{-1}.

Fig. 4 also shows the grouping of OB-associations into regions of intense star formation, which practically coincide with the stellar-gas complexes identified by Efremov & Sitnik (1988). For each complex, we calculated the mean residual velocities of OB-associations, which are listed in Table 3. Positive radial residual velocities V_R are directed away from the Galactic Centre, and the positive azimuthal residual velocities V_θ are in the sense of Galactic rotation. Table 3 also contains the rms errors of the mean velocities, the average Galactocentric distances R, the intervals of galactic longitudes l, the intervals of heliocentric distances r and names of OB-associations the region includes.

Fig. 4 and Table 3 clearly show that young stars in some regions have conspicuous residual velocities. The mean radial residual velocities in the Perseus, Cygnus and Carina regions are directed towards the Galactic Centre and are equal to $V_R = -7, -5$ and -6 km s^{-1}, respectively, whereas those in the Sagittarius region and in the Local System are directed away from the centre and are equal to $V_R = +10$ and $+5$ km s^{-1}, respectively. As for the mean azimuthal residual velocities, they are close to zero in the Sagittarius region and in the Local System. In the Perseus and Cygnus regions the direction of azimuthal motions is opposite to that of Galactic rotation, and the corresponding velocity components are $V_\theta = -6$ and -10 km s^{-1}, respectively, whereas in the Carina region the azimuthal residual velocity, which is equal to $V_\theta = +5$ km s^{-1}, is directed in the sense of Galactic rotation.

Similar kinematical features are observed in the old reduction of the *Hipparcos* catalogue. The mean residual velocities in the stellar-gas complexes derived for the old and new reductions differ, on average, by 1.0 km s^{-1}. The maximal difference (2.1 km s^{-1}) is observed in the Cygnus region [compare table 1 in Melnik & Rautiainen (2009) with Table 3 of the present paper]. Thus, the mean residual velocities in the stellar-gas complexes depend only slightly on the choice of the data-reduction way.

3 CONCLUSIONS

Proper motions of OB-associations derived for the old and new reductions differ, on average, by $\Delta_{\mu_l} = 0.58$ and $\Delta_{\mu_b} = 0.62$ mas yr^{-1}. This translates into a mean velocity difference of $\Delta_{\text{tang}} = 4.6$ km s^{-1}, which does not exceed the standard deviation of the velocities of OB-associations from the rotation curve, $\sigma = 7.2$ km s^{-1}. Generally, the new reduction brings a weak decrease in the dispersions of stellar proper motions inside OB-associations.

An analysis of the line-of-sight velocities and proper motions of OB-associations shows that the Galactic rotation curve is practically flat within 3 kpc of the Sun and corresponds to a high angular rotation velocity at the solar distance, $\Omega_0 = 31 \pm 1$ km s^{-1} kpc^{-1}. This result does not depend on the way of the data reduction.

The values of the distance-scale coefficient k, $r = k r_{\text{BH}}$, derived from the kinematics of OB-associations, $k = 0.79 \pm 0.1$, and trigonometric parallaxes, $k = 0.78$–0.88, suggest that the distance scale of Blaha & Humphreys (1989) should be shortened by 10–20 per cent.

We calculated the parameters of the rotation curve, the components of the solar motion and the distance-scale coefficient for

Table 3. Mean residual velocities of OB-associations in the stellar-gas complexes.

Region	R (kpc)	V_R (km s^{-1})	V_θ (km s^{-1})	$l\,(°)$	r (kpc)	Associations
Sagittarius	5.6	$+9.9 \pm 2.4$	-1.0 ± 1.9	8–23	1.3–1.9	Sgr OB1, OB7, OB4, Ser OB1, OB2, Sct OB2, OB3
Carina	6.5	-5.8 ± 3.3	$+4.7 \pm 2.2$	286–315	1.5–2.1	Car OB1, OB2, Cru OB1, Cen OB1, Coll 228, Tr 16, Hogg 16, NGC 3766, 5606
Cygnus	6.9	-5.0 ± 2.6	-10.4 ± 1.4	73–78	1.0–1.8	Cyg OB1, OB3, OB8, OB9
Local System	7.4	$+5.3 \pm 2.8$	$+0.6 \pm 2.5$	0–360	0.1–0.6	Per OB2, Mon OB1, Ori OB1, Vela OB2, Coll 121, 140, Sco OB2
Perseus	8.4	-6.7 ± 3.0	-5.9 ± 1.5	104–135	1.8–2.8	Per OB1, NGC 457, Cas OB8, OB7, OB6, OB5, OB4, OB2, OB1, Cep OB1

different values of R_0. The values of Ω_0, u_0, v_0 and k are practically independent of the choice of R_0. The parameters Ω'_0 and Ω''_0 vary conspicuously with R_0, but the Oort constant $A = -0.5R_0\Omega'$ remains practically unchanged, $A = 17.3–17.9$ km s^{-1} kpc^{-1}.

The residual velocities of OB-associations derived for the old and new reductions of the *Hipparcos* data differ, on average, by 3.5 km s^{-1}. The differences in residual velocities decrease down to 1.0 km s^{-1} if OB-associations are grouped into the stellar-gas complexes. The mean residual velocities of OB-associations in the stellar-gas complexes depend only slightly on the choice of the data-reduction procedure.

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APPENDIX A

The 6 per cent estimate of the accuracy of relative distances is determined by two independent factors. First, because of non-zero sizes of associations even exact distances of their individual members may differ from the mean distance of the association by up to half of its line-of-sight size D_r. We can estimate D_r as $D_r \sim 2 \times \delta r$, where δr is an association 'radius' in the sky plane (we assume that associations have, on the average, the same sizes in the direction of the line of sight and in the sky plane), and hence even exact relative distances of association members may scatter by up to $\varepsilon_1 \leq \delta r/r$. Secondly, distance estimates for individual members are not exact, but are themselves determined with errors. The distance moduli of all member stars are determined with more or less the same standard error σ_{DM} and the contribution of these errors to the standard error of the distance modulus of the association is $\sigma = \sigma_{DM}/\sqrt{n_t}$. We assume that $\sigma_{DM} = 0.3$ mag (Mel'nik & Efremov 1995). Given that DM $= 5 \times \log_{10} r + 10$, where r is distance in kpc, the relative error of the association distance is $\varepsilon_2 = 10^{\sigma/5} - 1$. The combined relative error which includes both the scatter due to the non-zero size and that due to random errors is $\varepsilon^2 = \varepsilon_1^2 + \varepsilon_2^2$, and its mean value for OB-associations from the list of Blaha & Humphreys (1989) is 6 per cent.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article.

Table 1. Line-of-sight velocities and proper motions of OB-associations.

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