KINEMATIC CONTROL OF THE INERTIALITY OF ICRS CATALOGS

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Abstract—We perform a kinematic analysis of the Hipparcos and TRC proper motions of stars by using a linear Ogorodnikov–Milne model. All of the distant \((r > 0.2 \text{ kpc})\) stars of the Hipparcos catalog have been found to rotate around the Galactic \(y\) axis with an angular velocity of \(M_{13} = -0.36 \pm 0.09 \text{ mas yr}^{-1}\). One of the causes of this rotation may be an uncertainty in the lunisolar precession constant adopted when constructing the ICRS. In this case, the correction to the IAU (1976) lunisolar precession constant in longitude is shown to be \(\Delta p_1 = -3.26 \pm 0.10 \text{ mas yr}^{-1}\). Based on the TRC catalog, we have determined the mean Oort constants: \(A = 14.9 \pm 1.0\) and \(B = -10.8 \pm 0.3 \text{ km s}^{-1} \text{kpc}^{-1}\). The component of the model that describes the rotation of all TRC stars around the Galactic \(y\) axis is nonzero for all magnitudes, \(M_{13} = -0.86 \pm 0.11 \text{ mas yr}^{-1}\).

INTRODUCTION

Based on the Ogorodnikov–Milne model and using the proper motions of stars, Clube (1972, 1973), du Mont (1977, 1978), and Miyamoto and Sôma (1993) modeled the Galactic rotation. This modeling showed that, apart from the Galactic rotation parameters, it is possible to control the inertiality of the catalogs being analyzed and to refine the adopted precession constant. Here, instead of the currently popular method for solving the Ogorodnikov–Milne model equations using parallaxes, we use a method for determining the kinematic parameters of the Galactic rotation that is completely free from parallax errors to analyze Hipparcos data (ESA 1997). In this method, the parallactic factor is assumed to be equal to unity. First, this assumption makes it possible to analyze stars even with negative parallaxes (the Hipparcos catalog). Second, since the proper motions of TRC stars (Høg et al. 1998) can be analyzed in full only by this method, this approach yields comparable data for both ICRS catalogs (International Celestial Reference System). The kinematic method for controlling the inertiality of the catalogs of stellar proper motions is based on the analysis of the two components of the rigid-rotation tensor that describe the rotation about the Galactic \(y\) and \(x\) axes in the Galactic coordinate system.

BASIC EQUATIONS

In this paper, we use a rectangular Galactic coordinate system with the axes directed away from the observer toward the Galactic center \((l = 0^\circ, b = 0^\circ,\) the \(x\) axis), along the Galactic rotation \((l = 90^\circ, b = 0^\circ,\) the \(y\) axis), and toward the North Galactic Pole \((b = 90^\circ,\) the \(z\) axis). In the Ogorodnikov–Milne model, we use the notation introduced by Clube (1972, 1973) and employed by du Mont (1977, 1978). When using only the stellar proper motions, one of the diagonal terms of the deformation matrix is known (Ogorodnikov 1965) to remain indeterminate. It is possible to determine the differences between the diagonal
elements of the deformation matrix, for example, in the form \((M_{11}^+ - M_{22}^+)\) and \((M_{33}^+ - M_{22}^+)\). In this approach, the basic equations can be written as

\[
\mu_l \cos b = (1/r)(X_\odot \sin l - Y_\odot \cos l) - M_{32}^+ \cos l \sin b - M_{13}^+ \sin l \sin b + M_{21}^- \cos b + 220 \, \text{km s}^{-1} \quad (1)
\]

\[
\mu_b = (1/r)(X_\odot \cos l \sin b + Y_\odot \sin l \sin b - Z_\odot \cos b) + M_{33}^+ \sin l - M_{13}^- \cos l - 0.5(M_{11}^+ - M_{22}^+) \cos^2 l \sin 2b + 0.5(M_{33}^+ - M_{22}^+) \sin 2b \quad (2)
\]

where \(X_\odot, Y_\odot,\) and \(Z_\odot\) are the velocity components of the peculiar solar motion, and \(M_{21}^-, M_{13}^-,\) and \(M_{32}^+\) are the vector components of the rigid rotation of an infinitesimal solar neighborhood around the corresponding axes. In accordance with the adopted rectangular coordinate system, the following rotations are positive: from axis 1 to axis 2, from axis 2 to axis 3, and from axis 3 to axis 1. The quantity \(M_{11}^+\) is an analogue of the Oort constant \(B\). Each of the quantities \(M_{12}^+, M_{13}^+,\) and \(M_{23}^+\) describes the deformation in the corresponding plane. The quantity \(M_{12}^+\) is an analogue of the Oort constant \(A\). The diagonal components of the deformation tensor \(M_{11}^+, M_{22}^+,\) and \(M_{33}^+\) describe the overall contraction or expansion of the entire stellar system. Equations (1)–(2) contain eleven unknowns that can be determined by the least-squares method. The quantity \(1/r\) is the parallactic factor, which is assumed to be equal to unity. In this case, the stars are referred to a unit sphere. In this approach, all of the parameters being determined are proportional to the heliocentric distance of the stellar centroid under consideration and are expressed in the same units as the stellar proper motion components, i.e., in mas yr\(^{-1}\). Before the appearance of the Hipparcos catalog, researchers were forced to use this method of analysis because of the lack of highly accurate stellar parallaxes. When the distances to stars are known, the parallactic factor is \(1/r = \pi/4.74\), where \(\pi\) is the parallax, and the factor 4.74 is equal to the ratio of the number of kilometers in an astronomical unit to the number of seconds in a tropical year. To express the solar velocity components (mas yr\(^{-1}\)) in km s\(^{-1}\), they must be multiplied by 4.74/\(\pi\); to express any of the derived (in mas yr\(^{-1}\)) components of the deformation and rotation tensors in km s\(^{-1}\) kpc\(^{-1}\), they must be multiplied only by the proportionality factor 4.74.

**THE SYSTEM OF THE HIPPARCOS CATALOG**

We divided the Hipparcos stars into seven groups, depending on the heliocentric distance (kpc): 0.05–0.1, 0.1–0.2, 0.2–0.3, 0.3–0.45, 0.45–0.66, > 0.66, and the group of stars with negative parallaxes. We imposed a constraint on the stellar space velocity that allows us to discard only those stars whose space velocities exceed the hyperbolic velocity, for example, stars with enormous peculiar velocities acquired through explosions and encounters, \(V = 220 + 62 = 282\) km s\(^{-1}\). Here, 220 km s\(^{-1}\) is the circular velocity of Galactic rotation at the solar Galactocentric distance (recommended by IAU 1986) and 62 km s\(^{-1}\) is the mean stellar space velocity dispersion in the solar neighborhood (estimated by Oort). The Hipparcos stars whose space velocities exceed the hyperbolic velocity were found, for example, by Moffat et al. (1998). In this case, when using only the stellar proper motions, we estimated the stellar space velocities on the basis of the Kleiber theorem (Agekyan et al. 1962):

\[
|V_t| \cdot 4.74 \cdot r < \frac{3.14}{4} \cdot |V|.
\]
Table 1: Kinematic parameters inferred from the proper motions of Hipparcos stars.

|        | 1      | 2       | 3       | 4       | 5       | 6       | 7       | 8       |
|--------|--------|---------|---------|---------|---------|---------|---------|---------|
| $\tau$, kpc | 0.074  | 0.142   | 0.243   | 0.361   | 0.570   | 1.2     | $\sim 2$| $r > 0.2$|
| $N_*$  | 13453  | 29378   | 2032    | 16040   | 11441   | 10015   | 3833    | 58675   |
| $X_\odot$ | 25.32  | 14.27   | 8.10    | 6.05    | 4.53    | 3.56    | 2.23    | 5.89    |
|        | $\pm 0.70$ | $\pm 0.25$ | $\pm 0.17$ | $\pm 0.14$ | $\pm 0.13$ | $\pm 0.11$ | $\pm 0.19$ | $\pm 0.08$ |
| $Y_\odot$ | 47.97  | 23.24   | 13.37   | 10.24   | 8.06    | 6.75    | 5.81    | 10.22   |
|        | $\pm 0.69$ | $\pm 0.13$ | $\pm 0.18$ | $\pm 0.15$ | $\pm 0.14$ | $\pm 0.13$ | $\pm 0.18$ | $\pm 0.08$ |
| $Z_\odot$ | 18.59  | 10.04   | 5.66    | 4.27    | 3.23    | 2.49    | 2.03    | 4.10    |
|        | $\pm 0.68$ | $\pm 0.24$ | $\pm 0.16$ | $\pm 0.13$ | $\pm 0.12$ | $\pm 0.10$ | $\pm 0.16$ | $\pm 0.07$ |
| $V_\odot$ | 20.1   | 19.6    | 19.1    | 21.6    | 26.4    | 45.7    | $\sim 62.0$ | 22.0    |
|        | $\pm 0.2$ | $\pm 0.2$ | $\pm 0.2$ | $\pm 0.2$ | $\pm 0.4$ | $\pm 0.7$ | $\pm 1.7$ | $\pm 0.1$ |
| $L_\odot$ | 62.2   | 58.6    | 58.8    | 59.4    | 60.6    | 62.2    | 69.0    | 60.0    |
|        | $\pm 0.7$ | $\pm 0.5$ | $\pm 0.6$ | $\pm 0.7$ | $\pm 0.8$ | $\pm 0.9$ | $\pm 1.7$ | $\pm 0.4$ |
| $B_\odot$ | 18.9   | 20.2    | 19.9    | 19.8    | 19.3    | 18.0    | 18.1    | 19.2    |
|        | $\pm 0.7$ | $\pm 0.5$ | $\pm 0.6$ | $\pm 0.6$ | $\pm 0.7$ | $\pm 0.9$ | $\pm 1.4$ | $\pm 0.3$ |
| $M_{12}^+$ | 2.40   | 2.20    | 2.96    | 2.85    | 2.77    | 2.91    | 2.48    | 2.90    |
|        | $\pm 0.86$ | $\pm 0.30$ | $\pm 0.21$ | $\pm 0.17$ | $\pm 0.16$ | $\pm 0.14$ | $\pm 0.21$ | $\pm 0.09$ |
| $M_{32}^+$ | $-0.18$ | 0.06    | $-0.15$ | $-0.10$ | 0.07    | $-0.11$ | $-0.53$ | $-0.16$ |
|        | $\pm 0.70$ | $\pm 0.25$ | $\pm 0.18$ | $\pm 0.15$ | $\pm 0.14$ | $\pm 0.13$ | $\pm 0.21$ | $\pm 0.08$ |
| $M_{13}^+$ | $-2.44$ | $-1.06$ | $-0.62$ | $-0.15$ | $-0.24$ | $-0.18$ | $-0.68$ | $-0.36$ |
|        | $\pm 0.69$ | $\pm 0.25$ | $\pm 0.18$ | $\pm 0.15$ | $\pm 0.15$ | $\pm 0.13$ | $\pm 0.21$ | $\pm 0.09$ |
| $M_{21}^+$ | $-2.40$ | $-2.47$ | $-3.01$ | $-3.03$ | $-3.00$ | $-2.85$ | $-2.76$ | $-2.93$ |
|        | $\pm 0.68$ | $\pm 0.24$ | $\pm 0.16$ | $\pm 0.13$ | $\pm 0.12$ | $\pm 0.10$ | $\pm 0.16$ | $\pm 0.07$ |
| $M_{11}^+ - M_{22}^+$ | 0.08 | $-2.13$ | $-2.00$ | $-1.40$ | $-1.16$ | $-1.50$ | $-0.62$ | $-1.35$ |
|        | $\pm 1.76$ | $\pm 0.62$ | $\pm 0.42$ | $\pm 0.34$ | $\pm 0.32$ | $\pm 0.27$ | $\pm 0.41$ | $\pm 0.19$ |
| $M_{13}^+$ | $-4.01$ | $-0.56$ | $-0.10$ | $-0.12$ | $-0.14$ | $-0.07$ | $-0.75$ | $-0.11$ |
|        | $\pm 0.92$ | $\pm 0.33$ | $\pm 0.23$ | $\pm 0.20$ | $\pm 0.19$ | $\pm 0.17$ | $\pm 0.25$ | $\pm 0.11$ |
| $M_{23}^+$ | $-1.38$ | $-0.58$ | 0.41    | $-0.03$ | $-0.20$ | 0.14    | 0.49    | 0.13    |
|        | $\pm 0.92$ | $\pm 0.33$ | $\pm 0.23$ | $\pm 0.19$ | $\pm 0.18$ | $\pm 0.16$ | $\pm 0.25$ | $\pm 0.10$ |
| $M_{11}^+ - M_{22}^+$ | $-1.65$ | $-1.33$ | $-0.61$ | 0.17    | $-0.07$ | $-0.24$ | $-0.39$ | $-0.14$ |
|        | $\pm 1.73$ | $\pm 0.63$ | $\pm 0.44$ | $\pm 0.37$ | $\pm 0.36$ | $\pm 0.33$ | $\pm 0.52$ | $\pm 0.21$ |
| $l_{xy}$ | $-1 \pm 1$ | $11 \pm 4$ | $9 \pm 2$ | $7 \pm 2$ | $6 \pm 2$ | $7 \pm 1$ | $4 \pm 2$ | $7 \pm 1$ |

Note: $\tau$ is the mean distance, $N_*$ is the number of stars, the coordinates of the solar apex $L_\odot$ and $B_\odot$ and the vertex $l_{xy}$ are in degrees, $V_\odot$ is the solar velocity in km s$^{-1}$; all of the remaining quantities are in mas yr$^{-1}$. 
Here, \( V_t = \sqrt{\mu^2_{\cos b} + \mu^2_b} \) is the tangential velocity of the star in mas yr\(^{-1}\), and \( V \) is the total space velocity of the star in km s\(^{-1}\). Table 1 presents the results of the simultaneous solution of Eqs. (1) and (2). Columns 1–7 give the parameters obtained from the proper motions of the stars located in seven “thin” spherical shells. All of the stars with negative parallaxes were assumed to be located at a heliocentric distance of 2 kpc. The last column gives the kinematic parameters determined from the proper motions of 58675 distant stars located farther than 0.2 kpc from the Sun (the mean heliocentric distance of this group of stars is 0.371 kpc). We emphasize that these are special solutions; they were obtained by setting the parallactic factor equal to \( 1/r = 1 \). We needed the parallaxes to divide the stars into distance-limited groups. This method made it possible, first, to use the most distant Hipparcos stars with negative parallaxes, second, to completely eliminate all of the effects of random parallax errors when solving Eqs. (1) and (2), and, third, to ensure that the results obtained by this method are in close agreement with those obtained from the proper motions of TRC stars. Since we used this approach to control the inertiality of the Hipparcos catalog, the solution from the last column of Table 1 that is of greatest interest in this respect may be called inertial. Let us consider the derived kinematic parameters of the inertial solution (in mas yr\(^{-1}\)):

\[
M_{12}^+ = +2.90 \pm 0.09, \\
M_{21}^- = -2.93 \pm 0.07, \\
M_{13}^- = -0.11 \pm 0.11, \\
M_{13}^+ = -0.36 \pm 0.09, \\
M_{23}^+ = +0.13 \pm 0.10, \\
M_{32}^- = -0.16 \pm 0.08, \\
M_{11}^+ - M_{22}^+ = -1.35 \pm 0.19, \\
M_{33}^+ - M_{22}^+ = -0.14 \pm 0.21.
\]

As we can see, the following quantities are statistically significant: \( M_{12}^+ \), \( M_{21}^- \), and \( (M_{11}^+ - M_{22}^+) \). Based on these quantities, we find that \( A = 13.7 \pm 0.4 \) km s\(^{-1}\) kpc\(^{-1}\), \( B = -13.9 \pm 0.3 \) km s\(^{-1}\) kpc\(^{-1}\), \( C = -3.2 \pm 0.5 \) km s\(^{-1}\) kpc\(^{-1}\) and the vertex deviation \( l_{xy} = 7 \pm 1^\circ \). To this end, we used the standard relations \( A = M_{12}^+ \cdot 4.74, B = M_{21}^- \cdot 4.74, C = 4.74 \cdot (M_{11}^+ - M_{22}^+)/2 \) and \( \tan 2l_{xy} = -C/A \).

The Oort constants \( A \) and \( B \) obtained by this method are in good agreement with the values recommended by the IAU (1986) and with the values from the paper by Bobylev (2004): \( A = 13.7 \pm 0.6 \) km s\(^{-1}\) kpc\(^{-1}\), \( B = -12.9 \pm 0.4 \) km s\(^{-1}\) kpc\(^{-1}\) in which they were calculated by analyzing their recent determinations by various authors. The vertex deviation also agrees with its published determinations based on various observational data, for example, with those by Dehnen and Binney (1998). Note, nevertheless, that \( M_{13}^- \) is also statistically significant. Figure 1 shows a plot of \( M_{13}^- \) against heliocentric distance constructed from the data of Table 1. As we can see from Table 1 and Fig. 1, \( M_{13}^- \) is nonzero for the most distant Hipparcos stars. It should also be emphasized that, as can be seen from Fig. 1, the constraint \( r > 0.2 \) kpc used to obtain the inertial solution and to determine \( M_{13}^- \) has such an effect that we obtain a lower limit on \( M_{13}^- \).
THE SYSTEM OF THE TRC CATALOG

The results of our solution of Eqs. (1) and (2) based on TRC stars of mixed spectral composition are plotted against magnitude in Fig. 2. The random errors of all of the sought unknowns are small in all of the magnitude intervals, each of which contains \( \approx 100000 \) stars, and are equal to 0.1–0.2 mas yr\(^{-1}\) for faint stars. As we can see from Fig. 2, the parameters that describe the deformation in the \( yz \) plane and the rotation around the \( x \) axis, i.e., \( M^+_{23} \) and \( M^-_{32} \), are virtually equal to zero. The parameters that describe the deformations in the \( xy \) and \( yz \) planes and the rotation around the \( z \) and \( y \) axes differ significantly from zero. The values of \( M^-_{13} \) are nonzero for the faintest TRC stars. We calculated the mean, \( M^-_{13} = -0.86 \pm 0.11 \) mas yr\(^{-1}\), by using the results obtained in nine intervals of magnitudes fainter than 9\( m \).5. This result must be compared with the results of our analysis of the proper motions for Hipparcos stars. The deviation of the vertex \( l_{xy} \) is virtually equal to zero in each magnitude interval, which does not confirm the conclusions drawn from our analysis of the Hipparcos stellar proper motions. This result probably stems from the fact that to compile the reference catalog that the TRC was intended to be (Kuzmin et al. 1999), the stars were selected kinematically; no high proper-motion stars were used. We calculated the mean values of \( M^+_{21} = 3.15 \pm 0.20 \) mas yr\(^{-1}\) and \( M^-_{12} = -2.27 \pm 0.06 \) mas yr\(^{-1}\) by the mean of the nine values obtained in the intervals of magnitudes fainter than 9\( m \).5 (the mean being \( m = 11\)\( m \).2). This yields the following Oort constants: \( A = 14.93 \pm 0.97 \) km s\(^{-1}\) kpc\(^{-1}\) and \( B = -10.77 \pm 0.31 \) km s\(^{-1}\) kpc\(^{-1}\), which are in good agreement with those calculated by Olling and Dehnen (1999) from the Tycho/ACT proper motions of red giants: \( A = 14.2 \pm 1 \) km s\(^{-1}\) kpc\(^{-1}\) and \( B = -12.7 \pm 1 \) km s\(^{-1}\) kpc\(^{-1}\). The model component that describes the rotation about the Galactic \( y \) axis inferred here from a kinematic analysis of the proper motions of TRC stars is \( M_y = -0.86 \pm 0.11 \) mas yr\(^{-1}\) and confirms the rotation that we found from the Hipparcos
Figure 2: Kinematic parameters inferred from the proper motions of TRC stars versus magnitude (Tycho B mag.).
Table 2: Precession corrections $\Delta p_1$ and $\Delta E$, mas yr$^{-1}$.

| Reference              | Data     | $\Delta p_1$  | $\Delta E$  |
|------------------------|----------|---------------|--------------|
| Miyamoto, Sôma (1994)  | ACRS     | $-2.7_{(0.3)}$|              |
| Walter, Ma (1994)      | VLBI     | $-3.6_{(1.1)}$|              |
| Charlot et al. (1995)  | VLBI+LLR | $-3.0_{(0.2)}$| $-1.3_{(0.2)}$|
| Rybka (1995)           | PPM      | $-3.1_{(0.2)}$|              |
| Bobylev (1997)         | PUL2–PPM | $-2.8_{(0.8)}$|              |
| Ma et al. (1998)       | VLBI     | $-2.84_{(0.04)}$|              |
| Vityazev (1999)        | CGC–HIP  | $-3.4_{(1.0)}$| $-3.3_{(1.0)}$|

catalog (solution (3)). In this case, we have an upper limit, since the data for the faintest stars include the effect of the real rotation of nearby stars that to the Local stellar system (Fig. 1).

CORRECTION TO THE IAU (1976) PRECESSION CONSTANT

The proper motions of the Hipparcos stars are free from the effect of precession of the Earth’s axis. However, the Hipparcos catalog is an extension to the optical range of the ICRF system (Ma et al. 1998), which is based on ground-based VLBI observations of radio sources. To determine the precession parameters from the analysis of $M_y$, we use two equations that, given the numerical values for epoch J2000.0 (Perryman et al. 1997), can be written as

$$M_x = \Omega_x - 0.0965\Delta p_1 + 0.4838\Delta E,$$

$$M_y = \Omega_y + 0.8623\Delta p_1 - 0.7470\Delta E.$$  \hspace{1cm} (5)

Here, $\Omega_x$ and $\Omega_y$ are the vector components of the real rigid rotation of the stellar system, and this rotation actually exists at heliocentric distances up to $r \approx 0.2$ kpc. Assuming that at large distances, $M_x - \Omega_x = 0$ and $M_y - \Omega_y = -0.36 \pm 0.09$ mas yr$^{-1}$ includes only the precession quantities, we obtain from the solution of Eqs. (5) and (6)

$$\Delta p_1 = -0.50 \pm 0.13 \text{ mas yr}^{-1},$$

$$\Delta E = -0.10 \pm 0.02 \text{ mas yr}^{-1}.$$  \hspace{1cm} (7)

Setting $\Delta E = 0$, we obtain the following estimate from Eq. (6):

$$\Delta p_1 = -0.42 \pm 0.10 \text{ mas yr}^{-1}.$$  \hspace{1cm} (8)

Table 2 gives the results of the determinations of two precession parameters by various authors: the correction to the IAU (1976) constant of lunisolar precession in longitude, $\Delta p_1$, and $\Delta E$, which is the sum of the corrections to the rate of planetary precession and the motion of the zero point of right ascensions. Miyamoto and Sôma (1994) determined the precession correction based on a kinematic analysis of the proper motions of ACRS stars using the Ogorodnikov–Milne kinematic model. Walter and Ma (1994) determined the precession correction based on VLBI observations of extragalactic radio sources from an annual catalog. Charlot et al. (1995) determined the precession correction by analyzing a 24-yr-long series of lunar laser radar observations and a 16-yr-long series of radiointerferometric
Figure 3: Linear velocity vectors $M_{13} \cdot r = W$ versus heliocentric distance $r$. The Galactic plane coincides with the $xz$ plane, the $x$ axis coincides with the $r$ direction, and the $z$ axis is directed upward.

Results (7)–(9) have yet another important implication: they show that $M_y = -0.36 \pm 0.09$ mas yr$^{-1}$ may have a nature unrelated to the real stellar motions. The HI layer in the Galaxy is known to have an extended warp (Kulikovskii 1985; Carroll and Ostly 1996). Smart et al. (1997) and Drimmel et al. (2000) considered the hypothesis that the extended Galactic HI layer affects the kinematics of OB stars. Drimmel et al. (2000) used simulations to estimate the angular velocity of the precession of OB stars in the $zx$ plane, $-25$ km s$^{-1}$ kpc$^{-1}$. The effect of our $M_{13} = -0.36$ mas yr$^{-1}$ (solution (3)) on the kinematic parameters of stars is easy to calculate. Since $M_{13} = 4.74 = -1.7$ km s$^{-1}$ kpc$^{-1}$, it is equal to $-1.7$ and $-3.4$ km s$^{-1}$ at $r = 1$ and 2 kpc, respectively. The presence of such a fictitious wave could completely explain the precession velocity of $-25$ km s$^{-1}$ kpc$^{-1}$ found by Drimmel et al. (2000) for distant OB stars. In Fig. 3, the linear rotation velocity vectors $M_{13} r$ are plotted.
against heliocentric distance \( r \). This rotation is attributable to the \( M_{13} = -0.36 \) mas yr\(^{-1} \) that we inferred from the Hipparcos catalog. The directions of the vectors are indicated in accordance with the fact that the rotation takes place in the \( zx \) plane and that, according to the chosen coordinate system, the rotation from the \( z \) axis to the \( x \)-axis is positive. In Fig. 4, the \( W \) components of space velocity (the linear velocity along the \( z \)-coordinate) are plotted against heliocentric distance \( R \). The points are plotted by using the data obtained by Drimmel et al. (2000) for a sample of 4250 Hipparcos OB stars in the magnitude interval 0–13\(^{m} \). A comparison of Fig. 3 (the Sun is assumed to be at a Galactocentric distance of about \( R_{\odot} = 8.0 \) kpc) and Fig. 4 leads us to conclude that the value of \( M_{13} = -0.36 \) mas yr\(^{-1} \) that we inferred from Hipparcos data almost completely explains the slope of the plot in Fig. 4. Eliminating the dependence that we found should significantly reduce the precession of \(-25 \) km s\(^{-1} \) kpc\(^{-1} \) for distant OB stars derived by Drimmel et al. (2000). In this case, the fact that distant OB stars belong to the hydrogen layer implies that there is only a linear displacement of all distant OB stars along the \( z \) coordinate.

**CONCLUSIONS**

Based on a linear Ogorodnikov-Milne model, we have performed a kinematic analysis of the Hipparcos and TRC stellar proper motions. We found the rotation of all distant (\( r > 0.2 \) kpc) Hipparcos stars with a mean angular velocity of \( M_{13} = -0.36 \pm 0.09 \) mas yr\(^{-1} \) about the Galactic \( y \) axis. One of the causes of this rotation may be an inaccuracy of the lunisolar precession constant adopted when creating the ICRF (Ma et al. 1998). We showed that, in this case, the correction to the IAU (1976) constant of lunisolar precession in longitude is \( \Delta p_1 = -3.26 \pm 0.10 \) mas yr\(^{-1} \). We have shown that eliminating the rotation \( M_{13} = -0.36 \pm 0.09 \) mas yr\(^{-1} \) from the proper motions of distant OB stars should lead to a significant reduction in the \(-25 \) km s\(^{-1} \) kpc\(^{-1} \) precession of distant OB stars inferred by Drimmel et al. (2000). In this case, the fact that distant OB stars belong to the hydrogen layer reduces only to a linear displacement of all distant OB stars along the \( z \) coordinate. We have determined the mean Oort constants \( A = 14.9 \pm 1.0 \) km s\(^{-1} \) kpc\(^{-1} \) and \( B = -10.8 \pm 0.3 \) km s\(^{-1} \) kpc\(^{-1} \) from TRC data. The model component that describes the rotation of all
TRC stars about the Galactic $y$ axis was found to be nonzero for all magnitudes, $M_\text{13}^{-1} = -0.86 \pm 0.11$ mas yr$^{-1}$.

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