KINEMATICS DERIVED FROM NORTHERN AND SOUTHERN HEMISPHERES OF HUGE ASTROMETRIC CATALOGUES

V. VITYAZEV [1], A. TSVETKOV [2],
[1] Saint-Petersburg State University
198504 Petrodvorets, Universitetsky pr., 28., S.Petersburg, Russia
vityazev@list.ru
[2] Saint-Petersburg State University
198504 Petrodvorets, Universitetsky pr., 28., S.Petersburg, Russia
A.S.Tsvetkov@inbox.ru

ABSTRACT.

It is shown that the kinematic analysis of the UCAC4, PPMXL and XPM proper motions in northern and southern Galactic hemispheres detects retardation of the Galaxy's rotational velocity and acceleration of the expansion velocity of the stellar system with increasing the distance from the principal Galactic plane. The estimates of the vertical gradient of the Galactic rotation are UCAC4: 40.1 ± 0.2; PPMXL: 36.2 ± 0.4; XPM: 37.7 ± 0.1 km $\cdot$ s^{-1} $\cdot$ kpc^{-1}, while the values of the vertical gradient of the expansion velocity turned out to be UCAC4: 11.9 ± 0.2; PPMXL: 19.0 ± 1.1; XPM: 10.9 ± 0.3 km $\cdot$ s^{-1} $\cdot$ kpc^{-1}.

1. INTRODUCTION

Modern astrometric catalogues realizing the ICRS in optical waves with full coverage of the sky provide a qualitatively new material, in particular, for investigating the kinematics of nearby stars in both Galalactic hemispheres separately. In case of the Ogorodnikov–Milne model [1] the stellar velocity field is given by expression

$$\vec{V} = \vec{V}_0 + M^+\,\vec{r} + M^-\,\vec{r}, \tag{1}$$

where: $\vec{V}_0$ — the velocity of the Sun with respect to given centroid of stars; M^+ — the diverging matrix with the dilation coefficients M^+_{11}, M^+_{22}, M^+_{33}, and M^+_{12}, M^+_{13} M^+_{23} standing for shears in the galactic planes (x, y), (x, z), (y, z); M^- — the rotation matrix with the components Ω_1, Ω_2 Ω_3. about axes x, y, z.

Unfortunately, due to high correlations of the parameters the standard LS solutions of the Ogorodnikov-Milne equations on hemispheres are hardly to be trusted. To remedy this we use an approach the first step of which is the expansion of proper motions on a system of vector spherical harmonics which are orthonormal on a hemisphere. At the second step, the kinematical parameters are derived from the coefficients of the expansion. For more detail of the method the reader is referred to [2].

2. NUMERICAL RESULTS

We applied our method to proper motions of stars listed in the catalogues UCAC4 [3], PPMXL [4] and XPM [5]. The full description of the results may be found in [2]. The present paper is devoted to the "northern" and "southern" solutions only, since all the tree catalogues gave evidence that the parameters Ω_1, $M^+_{2,3}$, Ω_2, $M^+_{1,3}$ have different signs in different hemispheres.

Now, in the galactocentric cylindrical coordinate system [6] we have $\Omega_1 - M^+_{32} = -\frac{\partial V_S}{\partial z}$, where V_S is the circular velocity of the local reference frame around the galactic center. This quantity is identified with the Galaxy's rotational velocity in the solar neighborhood. From Table 1 which gives the numerical values for the values $\Omega_1 - M^+_{32}$ that we obtained from different samples of our catalogues, we see that the vertical gradient of the Galaxy's rotational velocity $\frac{\partial V_S}{\partial z}$ has different signs in the northern and southern galactic hemispheres, with the velocity itself decreasing with increasing distance from the principal galactic plane. Again, from the Table 1 for the the vertical gradient of the expansion velocity of the stellar system $\Omega_2 + M^+_{13} = -\frac{\partial V_R}{\partial z}$ we may conclude that the expansion velocity increases with increasing distance from the principal galactic plane. The estimates of both the gradients $\left|\frac{\partial V_S}{\partial z}\right|$ and $\left|\frac{\partial V_R}{\partial z}\right|$ derived from all the catalogues under consideration are in good agreement.

The values $\Omega_1 + M^+_{32} = -\frac{1}{R}\frac{\partial V_z}{\partial \theta}$ which are associated with the local Galactic warp, and the radial gradient of the vertical velocity field $\Omega_2 - M^+_{13} = \frac{\partial V_z}{\partial R}$ turned out to be unreliable.

Table 1: Values $\Omega_1 - M_{32}^+$ and $\Omega_2 + M_{31}^+$ obtained from northern and southern galactic hemispheres of the UCAC4, PPMXL and XPM. Units: $\mathrm{km \cdot s^{-1} \cdot kpc^{-1}}$.

	11^m	12^m	13^m	14^m	15^m	16^m
Catalogue UCAC4						
$(\Omega_1 - M_{32}^+)_N$	$42,4 \pm 0,8$	$39,6 \pm 0,7$	$36,9 \pm 0,5$	$35,7 \pm 0,4$	$35,2 \pm 0,3$	$36,0 \pm 0,3$
$(\Omega_1 - M_{32}^+)_S$	$-41,5 \pm 0,9$	$-42,1 \pm 1,1$	$-44,6 \pm 0,8$	$-43,2 \pm 0,7$	$-42,3 \pm 0,4$	$-41,9 \pm 0,3$
$\lvert\frac{\partial V_S}{\partial z}\rvert$	42.0 ± 0.6	$40,8 \pm 0,7$	$40,8 \pm 0,5$	$39,4 \pm 0,4$	$38,7 \pm 0,3$	$39,0 \pm 0.2$
$(\Omega_2 + M_{31}^+)_N$	$-15,6 \pm 0,8$	$-19,7 \pm 0,7$	$-16,3 \pm 0,5$	$-10,9 \pm 0,4$	$-7,8 \pm 0,3$	$-6,6 \pm 0,3$
$(\Omega_2 + M_{31}^+)_S$	$11,3 \pm 0,9$	$13,6 \pm 1,1$	$11,8 \pm 0,8$	$12,6 \pm 0,7$	$9,5 \pm 0,4$	$7,3 \pm 0,3$
$\lvert\frac{\partial V_R}{\partial z}\rvert$	$13,5 \pm 0,6$	$16,7 \pm 0,7$	$14,0 \pm 0,5$	$11,7 \pm 0,4$	$8,6 \pm 0,3$	$6,8 \pm 0,2$
Catalogue PPMXL						
$(\Omega_1 - M_{32}^+)_N$	51.3 ± 1.8	40.2 ± 1.6	45.1 ± 1.7	47.8 ± 1.0	$47.3 \pm 0,7$	$43.9 \pm 0,6$
$(\Omega_1 - M_{32}^+)_S$	-45.6 ± 2.8	$-47,0 \pm 1,7$	$-40,5 \pm 1.7$	-35.4 ± 1.2	$-33,2 \pm 0,8$	$-29,4 \pm 0,7$
$\lvert\frac{\partial V_S}{\partial z}\rvert$	48.4 ± 1.7	43.6 ± 1.2	42.8 ± 1.2	41.6 ± 0.8	40.3 ± 0.5	36.7 ± 0.5
$(\Omega_2 + M_{31}^+)_N$	$-20,8 \pm 1,8$	$-17,3 \pm 1,7$	$-21,1 \pm 1,7$	$-18,1 \pm 1,0$	$-16,5 \pm 0,7$	$-11,9 \pm 0,6$
$(\Omega_2 + M_{31}^+)_S$	$16,2 \pm 2,8$	$21,6 \pm 1,7$	$23,4 \pm 1,7$	$25,3 \pm 1,2$	$18,9 \pm 0,8$	$17,9 \pm 0,7$
$\lvert\frac{\partial V_R}{\partial z}\rvert$	$18,5 \pm 1,6$	$19,4 \pm 1,2$	$22,2 \pm 1,2$	$21,7 \pm 0,8$	$17,7 \pm 0,5$	$14,9 \pm 0,4$
Catalogue XPM						
$(\Omega_1 - M_{32}^+)_N$	34.4 ± 1.4	33.3 ± 0.8	34.6 ± 0.5	37.7 ± 0.4	38.1 ± 0.3	36.4 ± 0.2
$(\Omega_1 - M_{32}^+)_S$	-63.0 ± 1.4	-62.3 ± 0.9	-56.6 ± 0.6	-49.1 ± 0.4	-42.1 ± 0.4	-39.8 ± 0.3
$\lvert\frac{\partial V_S}{\partial z}\rvert$	48.7 ± 1.0	47.8 ± 0.6	45.6 ± 0.4	43.4 ± 0.3	40.1 ± 0.2	38.1 ± 0.2
$(\Omega_2 + M_{31}^+)_N$	$-6,8 \pm 1,4$	$-9,7 \pm 0,8$	$-8,6 \pm 0,5$	$-6,0 \pm 0,3$	$-4,7 \pm 0,3$	$-3,9 \pm 0,2$
$(\Omega_2 + M_{31}^+)_S$	$19,9 \pm 1,4$	$19,6 \pm 1,0$	$17,0 \pm 0,7$	$14,3 \pm 0,4$	$11,5 \pm 0,4$	$8,6 \pm 0,3$
$\lvert\frac{\partial V_R}{\partial z}\rvert$	$13,3 \pm 1,0$	$14,6 \pm 0,6$	$12,8 \pm 0,4$	$10,2 \pm 0,3$	$8,1 \pm 0,2$	$6,3 \pm 0,2$

3. CONCLUSIONS

The success of this paper is based on the vector spherical harmonics solutions of the Ogorodnikov-Milne equations on hemispheres which permitted to obtain the uncorrelated values of the kinematical parameters and to show that some of them have different signs in both hemispheres. The transition to the Galactocentrical cylinder coordinate system immediately made it clear that the change of signs is connected with the retardation of the Galaxy's rotational velocity and acceleration of the expansion velocity of the stellar system with increasing the distance from the principal Galactic plane.

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