Hipparcos: Rotational vector of nearby stars

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Abstract

This investigation shows that the vector of rotation of nearby stars derived from the proper motions of the Hipparcos catalogue is not perpendicular to the Galactic plane. It can be interpreted as the effect of the presence of the Local Stellar system. We found that the rotation of stars nearer than 150 pc can be considered as the superposition of the Galactic rotation and the Local Stellar system rotation. The coordinates of the rotational pole are in the good agreement with the previous works devoted to the Local Stellar system. The kinematics of stars that are more distant than 200 pc is very close to the standard model of the Galactic rotation.

The Hipparcos catalogue gives the good opportunity to investigate the stellar kinematics of stars in different distance ranges. One of the interesting problems is the question about the direction of rotational vector $\mathbf{\Omega}$ for a group of stars. Usually, everyone adopts that the rotational vector consists of the Galactic rotation and of the precessional motion. If the system of a catalogue is ICRF (the Hipparcos catalogue is the case), there are no precessional components in the proper motions by definition. It means that the rotational vector of a group of stars should be perpendicular to the Galactic plane.

Let us consider the behavior of the rotational vector for groups of stars which are placed at different distances from us. We use the model, which takes into account only the the Sun motion and the rotation of the stellar system, to obtain the components of the rotational vector ω_x, ω_y, ω_z:

$$\mu_l \cos b = \frac{1}{kr}\left(V_x \sin l - V_y \cos l\right) + \frac{1}{k}\left(-\omega_x \sin b \cos l - \omega_y \sin b \sin l + \omega_z \cos b\right), \tag{1}$$

$$\mu_b = \frac{1}{kr}\left(V_x \sin b \cos l + V_y \sin b \sin l - V_z \cos b\right) + \frac{1}{k}\left(\omega_x \sin l - \omega_y \cos l\right). \tag{2}$$

Here l, b, r are the Galactic coordinates of stars;
$k = 47.4$ is the factor to convert the dimensions;
V_x, V_y, V_z are the components of Sun motion;
ω_x, ω_y, ω_z are the components of rotational vector.

We solved equations (1) and (2) for stars of different distances. This solution is shown in the table 1. The pictures 1-2 illustrate the dependence of $|\mathbf{\Omega}|$ and the latitude of rotational pole b_Ω on the distance. The analysis of these results shows that

- The rotational vector is determined with big errors in the Sun neighborhood from 0 to 50 pc. Here the large non-rotational motions predominate over any rotational components in the proper motions.
- The rotational vector is determined very reliably in the distance ranges from 50 till 150 pc, but its direction dramatically differs from normal to the Galactic plane. The deviation reaches 50°.
- The rotational vector approaches smoothly the normal position at the distance 150 pc, and its direction becomes normal at the distance 250 pc. The angular velocity takes usual value in this region, too.

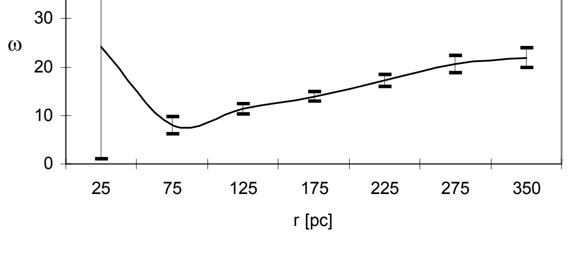


Fig. 1. *Dependence of* $|\Omega|$ ($km{\cdot}s^{-1}{\cdot}kpc^{-1}$) *on the distance to stars.*

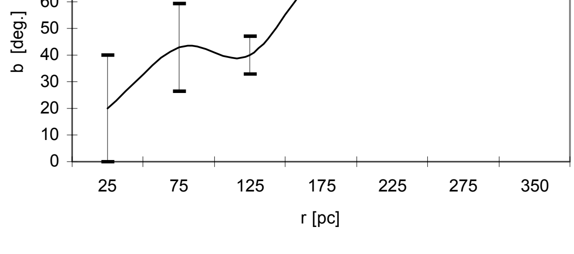


Fig. 2. *Dependence of* b_Ω *on the distance to stars.*

Table 1. Values of the Sun motion parameters and the components of rigid rotational vector for stars at different distances.

Units: V_x, V_y, V_z – components of the Sun motion – km·s^{-1};

ω_x, ω_y, ω_z – components of the rotational vector – km·s^{-1}·kpc^{-1};

|V| – modulus of the Sun velocity – km·s^{-1};

$L_\odot$, $B_\odot$ – coordinates of the Sun apex – degree;

$|\Omega|$ – modulus of the angular velocity – km·s^{-1}·kpc^{-1};

L_Ω, B_Ω – coordinates of the rotational pole – degree.

	0-50 pc	50-100	100-150	150-200	200-250	250-300	300-400
V_x	3.1 ± 0.3	4.4 ± 0.2	7.3 ± 0.2	8.4 ± 0.2	9.6 ± 0.3	9.8 ± 0.4	11.5 ± 0.6
V_y	7.1 ± 0.3	8.0 ± 0.2	12.0 ± 0.2	13.5 ± 0.2	14.9 ± 0.3	15.4 ± 0.6	17.2 ± 1.1
V_z	4.3 ± 0.3	4.7 ± 0.2	6.0 ± 0.2	6.8 ± 0.2	6.5 ± 0.3	7.0 ± 0.5	7.9 ± 0.7
ω_x	– 16.2 ± 8.7	– 0.87 ± 2.3	2.12 ± 1.4	1.56 ± 1.2	–1.41 ± 1.3	0.93 ± 1.6	–0.75 ± 1.7
ω_y	16.1 ± 8.3	– 5.79 ± 2.3	– 8.46 ± 1.4	– 4.00 ± 1.3	– 1.61 ± 1.5	2.89 ± 2.3	– 1.15 ± 3.5
ω_z	– 8.2 ± 8.4	–5.5 ± 2.3	– 7.3 ± 1.4	–13.2 ± 1.2	–17.1 ± 1.3	–20.0 ± 1.6	–21.9 ± 2.0
|V|	8.9 ± 0.3	10.3 ± 0.2	15.3 ± 1.2	17.3 ± 0.2	18.9 ± 0.3	19.6 ± 0.6	22.1 ± 0.9
$L_\odot$	67 ± 2	61 ± 1	59 ± 1	58 ± 1	57 ± 1	58 ± 2	56 ± 2
$B_\odot$	29 ± 2	27 ± 1	23 ± 1	23 ± 1	20 ± 1	21 ± 1	21 ± 2
$\|\Omega\|$	24. ± 23.	8.0 ± 1.8	11.3 ± 1.1	13.9 ± 1.0	17.3 ± 1.2	20.7 ± 1.8	21.9 ± 2.0
L_Ω	135 ±21	261 ± 23	284 ± 9	291 ± 17	229 ± 38	72 ± 32	237 ± 100
B_Ω	– 20 ± 20	– 43 ± 16	– 40 ± 7	– 72 ± 5	– 83 ± 5	– 82 ± 6	– 86 ± 8

We can consider the full rotational vector as superposition of the Galactic rotation **S** and the rotation of the Local Stellar system и **Q** :

$$\mathbf{\Omega} = \mathbf{S} + \mathbf{Q}. \tag{3}$$

We know that the rotational vector became to be perpendicular to the Galactic plane if we use distant stars. It means that the components ω_x and ω_y are insignificant, and component ω_z takes the value about 20 km·s^{-1}·kpc^{-1}. We can interpret this result as diluting of the "normal" Galactic kinematics by the stars of the Local stellar system in the distances till 150 pc. On the other hand, the "normal" Galactic kinematics predominates over other phenomena since 250 pc. This circumstance allows us to suppose that the "true" Galactic rotation is one derived from stars that are more distant than 250 pc. For distant stars, we assume $\mathbf{Q} \equiv 0$ and $\mathbf{\Omega} \equiv \mathbf{S}$. For example, for the stars of the spectral type F at the distances 300-400 pc, we obtain

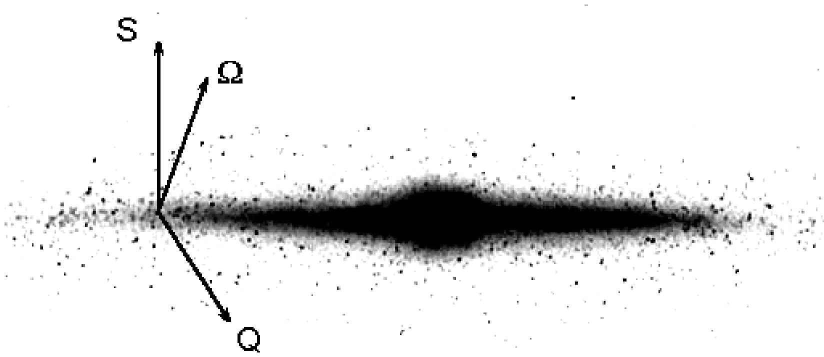
$$\omega_x = -\,0.75 \pm 1.75 \ \ \text{km·s}^{-1}\text{·kpc}^{-1},$$
$$\omega_y = -\,1.15 \pm 3.48 \ \ \text{km·s}^{-1}\text{·kpc}^{-1},$$
$$\omega_z = -\,21.88 \pm 2.03 \ \ \text{km·s}^{-1}\text{·kpc}^{-1}.$$

This yields

$$S = 21.9 \pm 2.0 \ \text{km·s}^{-1}\text{·kpc}^{-1},$$
$$B_s = -\,86° \pm 8°.$$

Now, we calculate the vector **Ω** and then the vector **Q** for stars with the same spectrum but placed from 100 to 200 pc:

$$\omega_x = +\,5.53 \pm 1.45 \ \text{km·s}^{-1}\text{·kpc}^{-1},$$
$$\omega_y = -\,7.84 \pm 1.44 \ \ \text{km·s}^{-1}\text{·kpc}^{-1},$$
$$\omega_z = -\,6.20 \pm 1.49 \ \ \text{km·s}^{-1}\text{·kpc}^{-1}.$$



Pic. 3. *The rotational vectors* **S**, **Q** *and* **Ω.**

Using the simple equation

$$\mathbf{Q} = \mathbf{\Omega} - \mathbf{S}, \tag{4}$$

we obtain

$$q_x = +\,6.27 \pm 1.45 \ \text{km}\cdot\text{s}^{-1}\cdot\text{kpc}^{-1},$$
$$q_y = -\,6.69 \pm 1.44 \ \text{km}\cdot\text{s}^{-1}\cdot\text{kpc}^{-1},$$
$$q_z = +\,15.68 \pm 1.49 \ \text{km}\cdot\text{s}^{-1}\cdot\text{kpc}^{-1}.$$

It gives the next parameters of the rotational vector of the Local stellar system:

$$Q = 18.2 \pm 1.5 \ \text{km}\cdot\text{s}^{-1}\cdot\text{kpc}^{-1},$$
$$L_q = 313° \pm 9°,$$
$$B_q = +\,60° \pm 7°.$$

We can conclude:

1. The positive value of q_z tells that the rotation of the Local stellar system is reverse to the rotation of the Galaxy ($q_z \cdot \omega_z < 0$);
2. The value: Q = 20 km·s^{-1}·kpc^{-1}= 0.5 "/cy is very close to the one derived from other works devoted to the Local stellar system (about 1 "/cy);
3. The coordinates of the rotational pole are close to the ones adopted for the Gould's belt.

This small investigation allows us to use the new approach to the determination of the parameters of Local stellar system. By means of the method used in our previous investigations [3, 5, 6], we found the next parameters of the Local stellar system for the F-stars of the Hipparcos catalogue from the main sequence on HR diagram:

the coordinates of the rotational pole –

$$L_0 = 313° \pm 9°,$$
$$B_0 = +\,60° \pm 7°;$$

the coordinates of the rotational center (see fig. 4) –

$$l_0 = 253° \pm 9°,$$
$$b_0 = -\,13° \pm 8°;$$
$$r_0 = 180 \pm 70 \ \text{pc};$$

the angular velocity and its derivatives in the Sun neighbourhood –

$$q_0 = +0.92 \pm 0.19 \ {}^{''}/_{\text{cy}},$$
$$q_0' r = -\,0.95 \pm 0.27 \ {}^{''}/_{\text{cy}},$$
$$q_0'' r^2 = +2.12 \pm 0.83 \ {}^{''}/_{\text{cy}};$$

What is the dynamics of the Local stellar system? Now, it is considered as "anticyclones" between the spiral arms of our Galaxy[1]. The existence of the Local stellar system is confirmed also by radio observation on 21 cm[2].

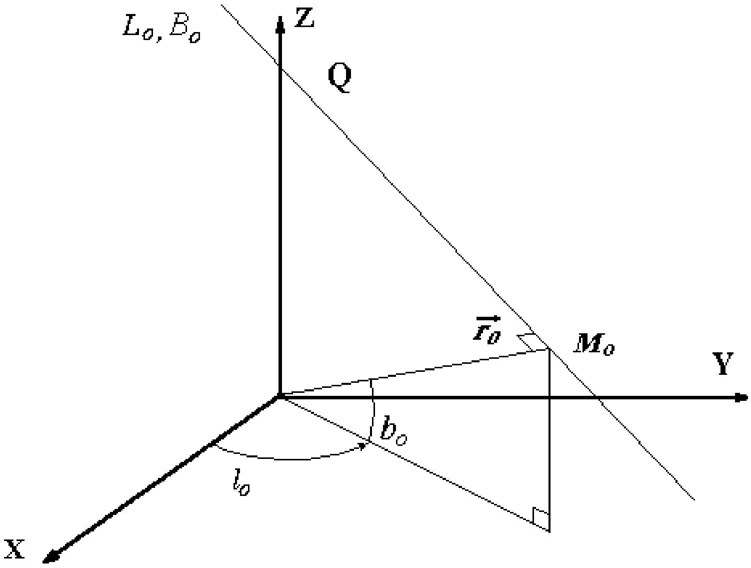


Fig. 4. *The parameters of the Local stellar system.*

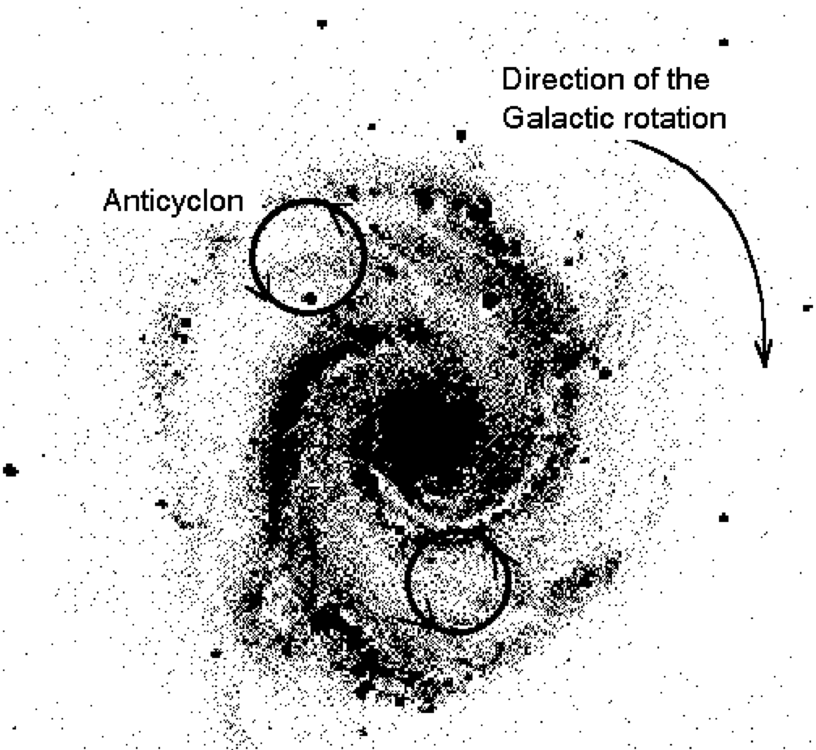


Fig. 5. *The "anticyclones" in the Galaxy.*

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