THE LOCAL STELLAR SYSTEM: KINEMATICS DERIVED FROM THE PROPER MOTIONS OF THE HIPPARCOS CATALOGUE

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Abstract

The rotational parameters of the Local Stellar system are derived from the proper motions of the HIPPARCOS catalogue. The hypothesis that the one of the phenomenon of the Local Stellar system is the Gould's Belt is adopted. Rotation of stars of different spectral types is investigated. The most likely geometrical and kinematical descriptions of the Local Stellar system are made. The solutions derived on the matherial of GC reduced onto various fundamental systems and the PPM catalogue are considered.

1. INTRODUCTION

The standard kinematical model of the proper motions of stars (Fricke, 1977) takes into account the following effects:

- the residual precessional motion of the Earth axis,
- the Solar motion,
- the Galactic rotation.

It is well known, that this model does not give a full description of the observational material. Many authors noticed the existence of the systematic parts in the proper motions, which cannot be interpreted within the ranks of the standard model. One of the earliest remark was made by Dyson (1929), who found in the proper motions the terms proportional to sin 3*l* and cos 3*l*. On the other hand, the statistical methods of investigations brought the discovering of a condensation of bright stars along a large circle inclined to the Milky Way. This star formation is known as the Gould's Belt. Further investigations by Brosche and Schwan (1981) gave evidence that after subtraction of all the standard effects the residuals of proper motions do contain some systematic components. The spherical harmonics analysis of the proper motions in various fundamental systems confirmed this conclusion (Vityazev and Tsvetkov, 1989,1990).

All these facts force us to extend the standard model with new terms to get more detail description of the observational material.

One of the possible explanations of Dyson's terms and of the North-South asymmetry of the Galactic proper motions is the hypothesis of the Local Stellar System (henceforth the LSS) and its rotation. Following Ogorodnikov's method, Shatsova, 1950, derived equations to describe the influence of the LSS rotation on the proper motions and determined the LSS parameters from the proper motions of the GC. A new method to solve the non-linear equations of the LSS rotation was applied to the proper motions of the GC reduced to the systems of the N30, FK4 and FK5 (Tsvetkov 1995). Later, the PPM catalogue was used for the purpose (Tsvetkov 1996). Now, when the HIPPARCOS is available, the LSS problem enters a new stage of its development. This paper presents the first results obtained from the HIPPARCOS data together with previous solutions found in the systems of ground based astrometric catalogues.

Another hypothesis was developed by A.M.Fridman, O.V.Khoruzhii, V.V.Lyakhovich and V.S.Avedisova in Moscow. This is the Fridman's hypothesis (1994) on the possible existence of anticyclone in the solar neighbourhood. Anticyclones are located near corotation radius of the observed spiral arms.

2. THE EQUATIONS OF THE LSS ROTATION AND THEIR SOLUTION

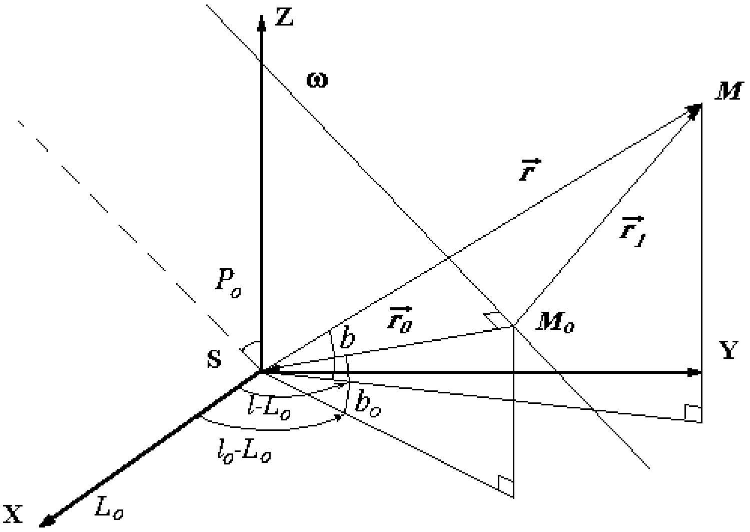

Fig. 1. ***Notations in the LSS***

Let us to consider the coordinate system with the origin at the center of the Sun and the *Z*-axis directed to the North Galactic pole (Fig. 1). We arrange the *X*-axis in such a way that the LSS rotational vector **ω** is parallel to the *XZ*-plane and the *Y*-axis is normal to both others. The longitude of the *X*-axis coincides with the longitude of the rotational pole L_0; its polar distance we denote as P_0. Draw the perpendicular from point *S* to **ω**; the point of their intersection M_0 we call the center of rotation of the LSS. Extend the vectors **r** from point *S* to point *M* (an arbitrary star) and **r** from M_0 to *M.* The longitudes of these points are $l - L_0$ and $l_0 - L_0$; the latitudes are *b* and b_0.

Since we do not know the function $\omega = \omega(\mathbf{r}_1)$ we may adopt it as truncated Taylor series in powers of *r*. The existence of the third harmonics in the representations of observational proper motions indicates that the rotational center is very close to us and we cannot ignore the second terms:

$$\omega(\mathbf{r}) = \omega_0 + \left(\frac{d\omega}{dr}\right)_0 r + \frac{1}{2}\left(\frac{d^2\omega}{dr^2}\right)_0 r^2 \ .$$

The explicit equations of the LSS rotation are given in Shatsova, 1950, and Tsvetkov, 1995. They may be represented in the form

$$y = f(\mathbf{x},\mathbf{t}),$$

where y is either $\mu_l \cos b$, μ_l and v_r ,
x is the vector of unknown variables;
t is the vector of coordinates of the northern trapezium center;
f is a non-linear function of **x** and **t**.

The coordinates of the LSS rotational pole can be obtained from the equation but, to reduce the correlations between the parameters , we adopt them to be those of the Gould's Belt:

$$L_0 = 343° \ , P_0 = 17° \ .$$

When the distances to the stars are not known we are forced to solve our equations for the parameters

$$n_0 = \frac{r_0}{\langle r\rangle}, \quad \omega'_0\langle r\rangle, \quad \omega''_0\langle r^2\rangle$$

instead of $r_0, \omega'_0, \omega''_0$. It is likely, that now, when the parallaxes for more than 100 000 stars had been measured on board of the HIPPARCOS satellite, we have got a possibility to obtain directly the values of $r_0, \omega'_0, \omega''_0$. Still, even the HIPPARCOS catalogue does not list all the stars suitable for our task. That is why the technique to derive the averaged parameters is worthy of consideration, and the data from the HIPPARCOS catalogue may be used to test it. Besides, the question remains: “which part of stars belongs to the LSS?” This problem is needed to be investigated in the future.

There are other kinematic phenomena, which interfere with the LSS rotation. Since the Galactic rotation and the solar motion are symmetric with respect to the Galactic equator we can exclude them by considering

$$\delta\mu_l \cos b = (\Delta\mu_l \cos b)_{\mathrm{N}} - (\Delta\mu_l \cos b)_{\mathrm{S}}\,, \quad \delta\mu_b = (\Delta\mu_b)_{\mathrm{N}} + (\Delta\mu_b)_{\mathrm{S}}\,,$$

$$\delta v_r = (\Delta v_r)_{\mathrm{N}} - (\Delta v_r)_{\mathrm{S}}\,,$$

where values in the parentheses are taken at the symmetric points with respect to the galactic plane.

Thus we have the equations which describe the influence of the rotation of the LSS on the $\mu_l \cos\delta$, μ_b and v_r as non-linear functions of unknown parameters $l_0, b_0, n_0, \omega_0, \omega_0'\langle r\rangle, \omega_0''\langle r^2\rangle$ and coordinate l, b, r.

To apply conventional LSM technique for solving these equations, the latters are to be linearized and the initial rough approximation of the parameters under consideration are to be known. In the previous papers this method was tested on artificial data and showed stability to random component.

RESULTS FROM THE GC PROPER MOTIONS REDUCED ONTO THE SYSTEMS OF N30, FK4 AND FK5.

The proper motions of stars listed in the GC and reduced onto fundamental systems FK3, N30, FK4, FK5, have been used to obtain the parameters of the LSS (Tsvetkov, 1991). A weak dependence of the parameters on the choice of the fundamental system was found (Table 1). On the contrary, the selection of stars by spectral types influenced the solution very much.

Table 1 LSS parameters in different fundamental systems

Units: l_0, b_0 *– degrees;* n_0 *– dimensionless;* ω_0, $\omega_0' r$, $\omega_0'' r^2$ *– arcsec / cy .*

	FK5	FK4	N30	GC
l_0	280. ± 5.	282. ± 6.	279. ± 6.	284. ± 8.
b_0	-4. ± 2.	-5. ± 2.	-9. ± 3.	-7. ± 3.
n_0	1.29 ± 0.16	1.33 ± 0.17	1.20 ± 0.21	0.95 ± 0.20
ω_0	0.69 ± 0.25	0.66 ± 0.27	0.20 ± 0.27	0.66 ± 0.26
$\omega_0' r$	-1.26 ± 0.30	-1.26 ± 0.30	-1.75 ± 1.29	-1.03 ± 0.31
$\omega_0'' r^2$	3.46 ± 0.80	3.46 ± 0.80	5.93 ± 3.80	2.35 ± 0.84

RESULTS OBTAINED FROM THE PPM

Table 2. The l-solutions derived from the stars of PPM of spectral types F, G and for al l spectra.

	Sp All	**F**	**G**
l_0	237. ± 5.	264. ± 14.	245. ± 9.
b_0	-5.4 ± 1.0	-20.2 ± 17.5	-4.3 ± 1.6
n_0	0.09 ± 0.06	0.30 ± 0.14	0.20 ± 0.15
ω_0	0.20 ± 0.15	0.73 ± 0.22	-0.22 ± 0.22
$\omega_0' r$	0.00 ± 0.04	-0.23 ± 0.17	0.03 ± 0.08
$\omega_0'' r^2$	5.92 ± 0.99	1.16 ± 0.78	6.48 ± 1.83

The new mass catalogue of position and proper motions (PPM) became available in 1993. It contains more than 300 000 stars of various magnitudes (up to 14-15$^{\mathrm{m}}$) and spectral types.

The structure of PPM is heterogeneous. It contains both the nearby and distant stars, the latters may not belong to the LSS. That is why we came across the difficulties with the solution. The PPM does not include the individual parallaxes and we could not select the nearby stars, which in principle, are expected to form the LSS. The solutions found for bright stars ($m<9^m$) are shown in Table 2..

RESULTS FROM THE PROPER MOTIONS OF THE HIPPARCOS CATALOGUE

Before the HIPPAROCS era, all the previous solution were obtained in the assumption that the stars distributed in spherical layer in a small distance range. Although the HIPPARCOS catalogue contains individual parallaxes for each star, we use old technique for the purpose to prove its validity in previous cases. Now, we can really construct the subset of the stars in prescribed distance range and solve the equations on this data. Also, the selection of stars has been made by spectral type.

The HIPPARCOS proper motions have been averaged over spherical trapezia to get the differences "North – South" of $\mu_l \cos\delta$ and the sums of μ_b "North + South".

We carried out solutions of the $\delta\mu_l \cos\delta$ LSS equation. The parameters were determined for each spectral type and for several distance groups. We failed to obtain the solution for spectral types O-B and K-M as well as for the stars that have distances more than 300 ps (Table 3).

The solution of the $\delta\mu_b$ equation is now under construction.

Table 3. The dependence of the LSS parameters on the distance

	0-150 ps	50-150 ps	100-200 ps	150-250 ps	200-300 ps
l_0	284.8 ± 15.9	283.8 ± 15.3	283.1 ± 14.1	293.3 ± 13.2	248.0 ± 13.3
b_0	-8.9 ± 9.9	-7.8 ± 8.8	-12.0 ± 10.6	-14.3 ± 15.3	-2.7 ± 1.7
n_0	1.0 ± 0.5	1.0 ± 0.6	0.8 ± 0.3	0.8 ± 0.3	0.6 ± 0.4
ω_0	0.9 ± 0.2	0.9 ± 0.3	1.2 ± 0.2	0.3 ± 0.2	-0.2 ± 0.2
$\omega'_0 r$	-0.9 ± 0.5	-0.9 ± 0.5	-0.7 ± 0.4	-0.5 ± 0.4	-0.1 ± 0.3
$\omega''_0 r^2$	1.5 ± 1.6	1.6 ± 1.8	1.3 ± 1.3	1.5 ± 1.6	6.8 ± 2.9

Table 4. The dependence of the LSS parameters on the spectral type

	A	F	G
l_0	297.7 ± 19.0	280.9 ± 10.4	289.4 ± 16.5
b_0	-13.1 ± 13.8	-3.2 ± 3.3	-1.8 ± 7.1
n_0	0.7 ± 0.4	1.4 ± 0.9	5.9 ± 18.8
ω_0	1.0 ± 0.3	0.6 ± 0.3	0.1 ± 0.4
$\omega'_0 r$	-1.0 ± 0.6	-0.9 ± 0.4	-0.8 ± 0.6
$\omega''_0 r^2$	1.3 ± 2.1	4.6 ± 2.5	3.4 ± 3.3

COMPARISON OF THE SOLUTIONS AND CONCLUSIONS

Results of our investigation can be summarized as follows:

- The proper motions of nearby stars with distances less than 300 ps do not contradict the assumption that the LSS rotates.
- The LSS consists basically of the A-F stars, not of the O-B and K-M stars.
- For the first time the localization of the LSS in the 3D space was traced.

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