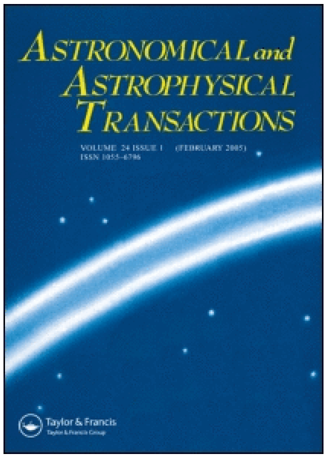

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Local kinematics of the Galaxy

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We found the parameters of the velocity ellipsoid in the solar neighbourhood, the Galactocentric solar velocity, and the circular velocity at the solar radius. In order to take into account biasing and irregularities of the velocity field, we extrapolated to zero heliocentric distance. For the Galactocentric solar velocity, we also extrapolated to zero angular momentum. As for the circular velocity, extrapolation to zero eccentricity was used.

Keywords: Milky Way; Structure; Kinematics

Investigations of the stellar kinematics in the solar neighbourhood are of interest from different points of view. Firstly, the solar neighbourhood is a typical region of the Galactic disc. Therefore, the kinematic properties of nearby stars shed light on the whole Galactic disc kinematics. Secondly, an analysis of these data allows us to estimate a few fundamental Galactic parameters, e.g. the circular velocity at the solar circle. Thirdly, kinematic data contain information concerning the distribution of gravitating matter in the Milky Way, because the velocity distribution of stars is mostly defined by a smoothed Galactic field, where the stars move.

In order to estimate the kinematic parameters (e.g. the parameters of the velocity ellipsoid), different techniques can be utilized. The simplest method is to take any sample of the stars and to calculate the mean characteristics of interest (e.g. the residual velocity dispersions or the mixed moments of the dispersion tensor). However, such an approach is incorrect, because biasing due to the omission of low-luminosity stars when the distance from the Sun is increasing is not taken into account.

In order to correct the results for such biasing, we suggest that the values under consideration are extrapolated to zero heliocentric distance. Sometimes, similar approaches were used for estimations of the stellar number density in the solar neighbourhood (see, for example, [1]).

The basic idea of this approach is very simple. The solar neighbourhood of a definite radius is covered by a system of concentric spheres which have centres in the Sun. Using the samples

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of stars inside each sphere, we calculate the mean values of the parameters under consideration (e.g. velocity dispersions). Then, using the least-mean-squares method, we fit the dependences of these parameters on the sphere radii. Usually we used linear or quadratic fittings, although, in principle, more complicated functions (e.g. parts of the Taylor series) can be used. Then a free term gives the unbiased value of interest [2]. Thus, the parameters of the residual velocity ellipsoid parameters can be estimated.

When we estimate the Galactocentric solar velocity, we use also an additional extrapolation to zero angular momentum ($L_z \to 0$). For the circular velocity, an additional extrapolation to zero eccentricity can be used [3].

As we mentioned above, two kinds of fitting were used. The first is linear fitting according to

$$X = Ar + B, \tag{1}$$

and the second is quadratic fitting according to

$$X = Ar^2 + B. \tag{2}$$

Both fittings were used for the estimations of the parameters of the velocity ellipsoid. For the Galactocentric and circular velocities, we used only linear fitting.

As for the initial sample of stars, we used the list compiled by Goncharov [4].

The results of both fittings for the velocity ellipsoid are shown in table 1. The results of the two fittings are generally in agreement. The mixed moments are usually not very far from zero.

As for estimations of the solar Galactocentric velocity $V_{\rm gal}$ in the direction of galactic rotation, two variants of extrapolation order were used: firstly,

$$r \longrightarrow 0, \quad L_z \longrightarrow 0; \tag{3}$$

secondly,

$$L_z \longrightarrow 0, \quad r \longrightarrow 0. \tag{4}$$

It should be noted that, in this case, it is necessary to use some values of the solar Galactocentric distance and velocity (the parameter of interest) when we calculate the angular momenta for individual stars. Our calculations have shown that the results depend only slightly on the adopted solar Galactocentric distance R_0 (it was varied within the interval from 7.5 to 8.0 kpc). As for the velocity, if its value was predicted correctly, then it should be in agreement with the result of the double fitting. It was indeed. Both choices of fitting order led to similar results, although the uncertainties are rather different. The final result is $V_{\rm gal} = 235 \pm 4\,{\rm km\,s^{-1}}$ (for $R_0 = 7.8$ kpc).

Table 1. The results for the velocity ellipsoid.

Parameter	Linear fitting	Quadratic fitting
$\bar{U}$ (km s^{-1})	-8.6 ± 0.1	-8.8 ± 0.1
$\bar{V}$ (km s^{-1})	-18.9 ± 0.1	-19.8 ± 0.2
$\bar{W}$ (km s^{-1})	-7.0 ± 0.1	-7.6 ± 0.1
S_{uu} (km^2 s^{-2})	1189 ± 21	1202 ± 10
S_{uv} (km^2 s^{-2})	28 ± 12	1 ± 9
S_{uw} (km^2 s^{-2})	-73 ± 3	-72 ± 4
S_{vv} (km^2 s^{-2})	694 ± 12	739 ± 8
S_{vw} (km^2 s^{-2})	11 ± 7	43 ± 4
S_{ww} (km^2 s^{-2})	299 ± 8	316 ± 3

When we estimated the circular velocity V_{circ}, we used a double extrapolation to zero eccentricity $e \to 0$ and then to zero heliocentric distance. To determine the eccentricity, we used the epicyclic approximation. The eccentricities of star orbits

$$e = \frac{R_{\mathrm{a}} - R_{\mathrm{p}}}{R_{\mathrm{a}} + R_{\mathrm{p}}} \tag{5}$$

(here R_{a} and R_{p} are the apocentric and pericentric distances, respectively, from the Galactic axis) were calculated from the following formula:

$$e^2 = \left(1 - \frac{R}{R_0}\right)^2 + \frac{1}{4}(1 + \lambda)\left(\frac{V_R}{V_{\mathrm{circ}}}\right)^2, \tag{6}$$

where $\lambda = A/(-B)$, A and B are the Oort dynamic constants, V_R is the Galactocentric velocity component in the R direction, R is the distance from the Galactic axis, and V_{circ} and R_0 are the parameters. Our calculations have shown that the estimated circular velocity almost does not depend on the adopted values of these parameters (the differences are less than $1\,\mathrm{km\,s^{-1}}$). Its value is $V_{\mathrm{circ}} = 215 \pm 5\,\mathrm{km\,s^{-1}}$, which is about $20\,\mathrm{km\,s^{-1}}$ less than the Galactocentric solar velocity.

Thus, using extrapolation allows us to estimate important local kinematic parameters corrected for observational selection. We have estimated those using the sample of stars within 200 pc from the Sun; these stars have the most reliable spatial positions and velocities at the moment.

In future work, we shall use the same methods to find the velocity ellipsoids for stars of different types and different ages. Also, we shall estimate the uncertainties in our extrapolations using Monte Carlo simulations.

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References

[1] T.A. Agekian and V.V. Orlov, Pis'ma Astron. Zh. **23** 936 (1997).

[2] A. Mülläri, C. Flynn and L.P. Ossipkov, in *Stellar Dynamics: from Classic to Modern*, edited by I.I. Nikiforov and L.P. Ossipkov (St Petersburg University Press, St Petersburg, 2001), p. 51.

[3] L. Ossipkov, A. Mylläri and C. Flynn, Astron. Soc. Pacif. Conf. Ser. **316** 215 (2004).

[4] G.A. Goncharov, www.geocities.com/orionspiral/ (2005).