New approach to the construction of stellar velocity field in the Sun neighborhood

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August 22, 2000

Introduction

The catalogue Hipparcos, which is used in our work, contains three spatial coordinates α, δ, π. It means we have a possibility to investigate the distribution of the nearest stars in space. We have to mention that only the Hipparcos stars with distances less than 100 pc have the accuracy of parallax determination, which is better than 10% (for stars at 400 pc the accuracy is about 50%). However, the construction of 3D velocity field requires not only the positions of stars but also the knowledge of three components of spatial velocity.

The Hipparcos catalogue contains the individual proper motions of stars, which are determined with accuracy as high as 1 mas/yr. Unfortunately, the determination of radial velocities was not implemented on the spacecraft. Under this circumstances, we cannot determine all three components of spatial velocity directly for each star.

This paper proposes a new approach to construct the full stellar velocity field in spite of the absence of radial velocities in the Hipparcos data.

The Method

Let us consider the Airy-Kowalsky equations, which describe the influence of the solar motion on the proper motions:

$$\begin{aligned} \mu_l \cos b &= \frac{1}{kr}\left(V_X \sin l - V_Y \cos l\right), \\ \mu_b &= \frac{1}{kr}\left(V_X \sin b \cos l + V_Y \sin b \sin l - V_Z \cos b\right). \end{aligned} \qquad (1)$$

The solution of these equations yields the components of the Solar motion V_x, V_y, V_z relative to the centroid of used stars. The equations (1) were used by many authors for different catalogues. Usually, not all stars were applied for the solution but the samples of stars common to general characteristic, e. g. spectral type, magnitude, etc. The main result was the values of the parameters for each group of stars were different.

In all previous investigations the samples of stars had one and the same center – the Sun. The individual parallaxes of the Hipparcos stars allow to arrange the non-concentric samples. If the equations (1) is solved for an arbitrary sample, then one obtains the vector of the solar motion **V** relative to the used group of stars. In what follows we will call such solution the central solution $\mathbf{V}_0$ if the center of the used group is the Sun. It is obvious that the difference between an arbitrary solution and the central solution

$$\Delta\mathbf{V} = \mathbf{V} - \mathbf{V}_0 \qquad (2)$$

is velocity of an arbitrary centroid relative to the “central centroid”.

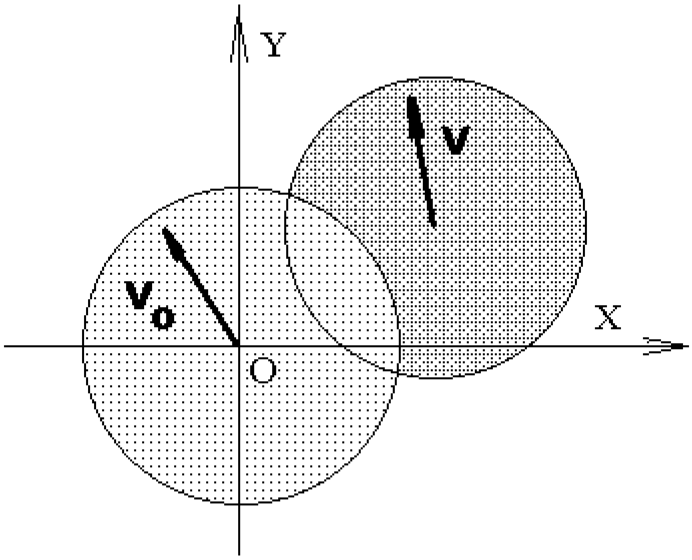


Fig. 1. *Method of non-concentric selection*

Taking into consideration a set of spherical samples with the coordinates of their centers X_i, Y_i, Z_i we are able to determine the vectors of the centoid motions with respect to the central centroid. Thus obtained velocity field can be represented graphically and investigated by the vector analysis techniques.

Thus, we managed the three-dimensional velocity field of stars using only the proper motions of stars and spatial coordinates without knowledge of radial velocity.

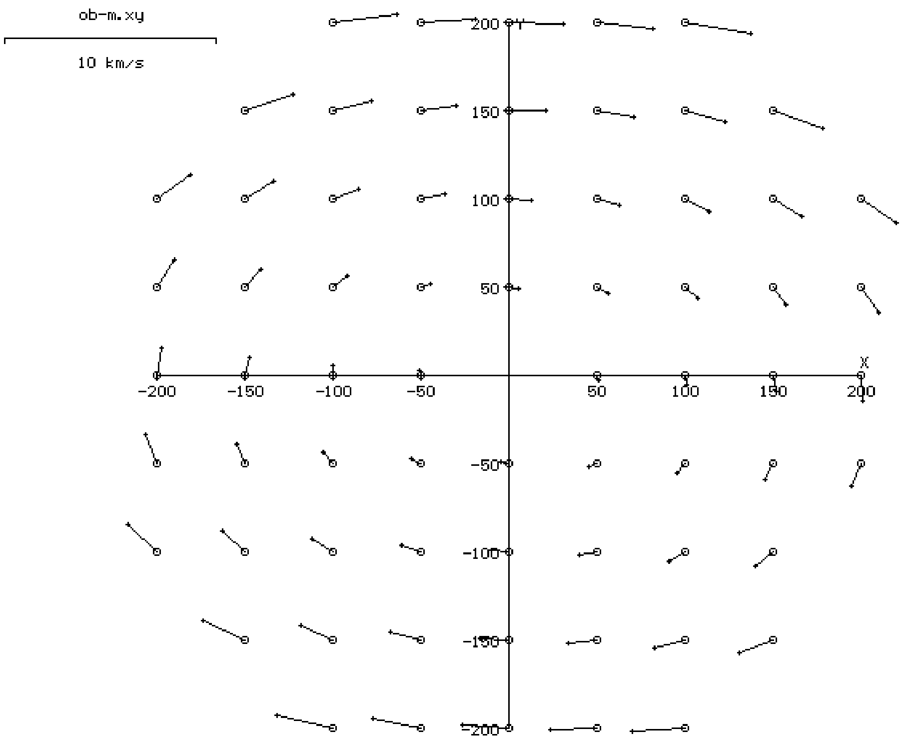


Fig. 2. *Model velocity field of OB-stars in XY-plane*

Testing the method

We performed the test of our method to ascertain its reliability. The artificial catalogue was constructed with proper motions, which are conformable with the Galactic rotation model by Oort-Linblad. The coordinates of stars were taken directly from the Hipparcos catalogue. The modeled velocity field for OB-stars is shown in Fig. 2. The Oort-Lindblad model predicts the zero-field in the XZ- and YZ-plane. It was confirmed by our test, too.

The Fig. 2 is widely known. It was obtained in theory years ago. We can conclude that our method is reliable and produces undistorted results.

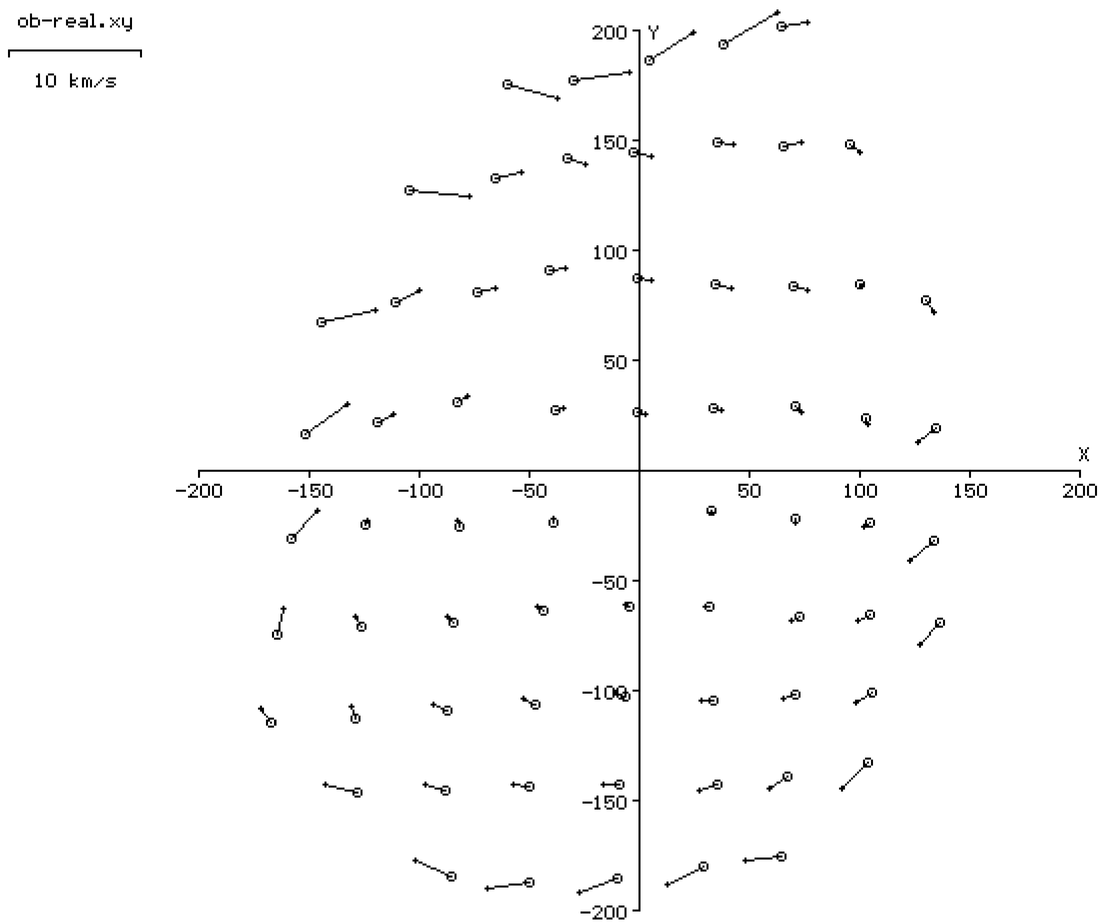


Fig 3. *Stellar velocity field of OB-stars in XY-plane*

Application of the method

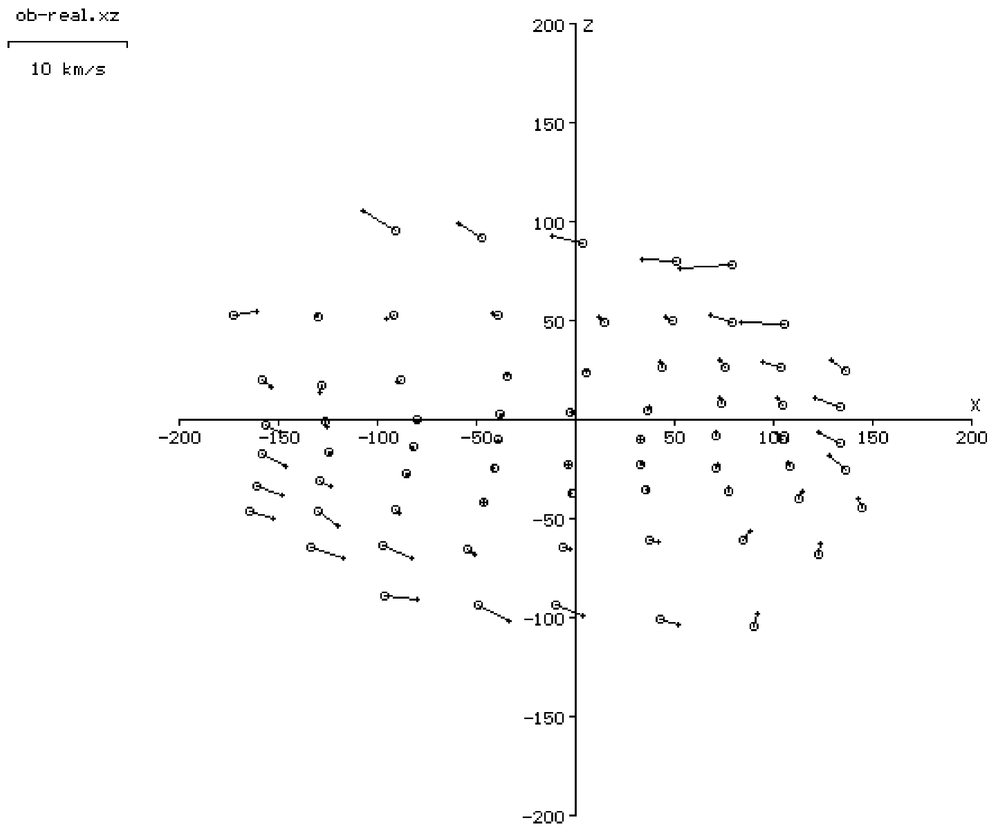
The method was applied for the Hipparcos stars. The stars were divided into three groups: OB, AF-stars from main sequence and KF-giants. In this small paper we consider only OB-stars. The distorted Galactic rotation can be observed in XY-plane but one easily notes the asymmetry of the velocity field. The behavior of stars in XZ- and YZ-plane dramatically differs from the theoretical results. The XZ-plane shows the distinct rotation. We can explain this by non-perpendicularity of the rotational vector to the Galactic plane. Moreover, the large irregularities of the velocity field are tracked in both these planes. It is an evidence of the local stellar system effects in the solar neighborhood.

Further improvement of the method

To our opinion, the method in its present status has at least two drawbacks.

1. The solutions in neighboring points are correlated since all samples of stars contain the Sun to escape ill conditional systems of equations the least square technique is based upon;
2. The solutions, which are close to the center, have larger weight because the number of stars diminishes with the distance due to the observational selection.

We hope to overcome these problems in the nearest future.



Pic. 4. *Stellar velocity field of OB-stars in XZ-plane*

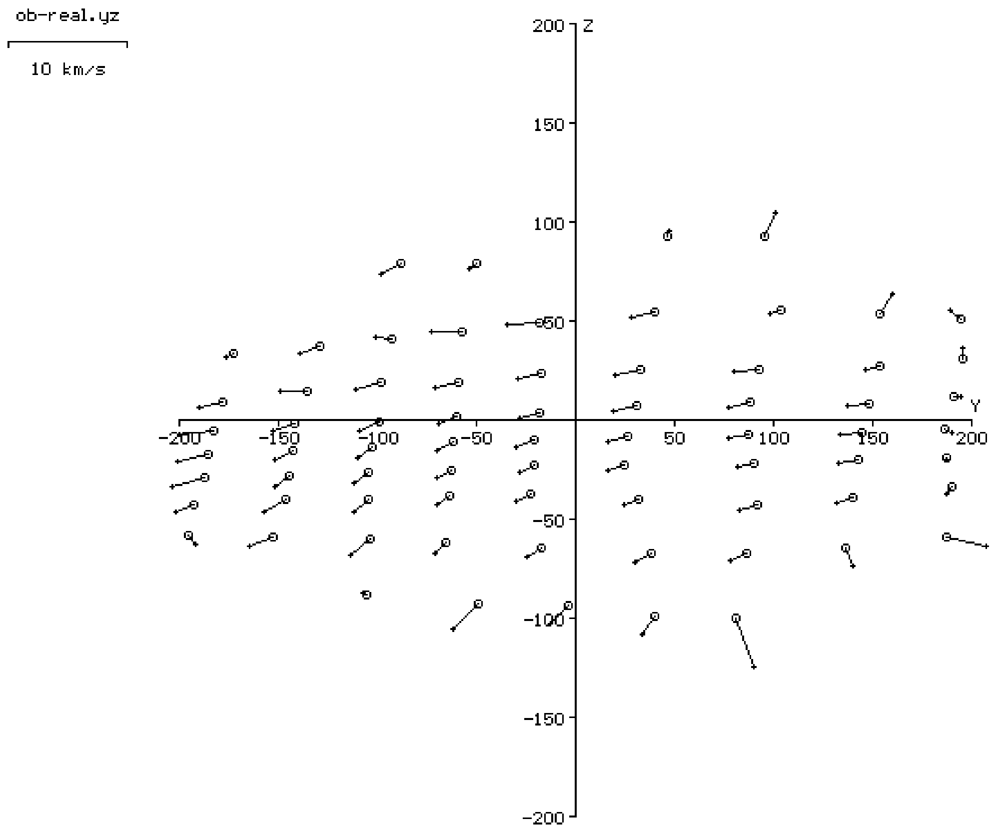


Fig. 5. *Stellar velocity field of OB-stars in YZ-plane*