VECTORIAL HARMONICS: FROM LINK OF FRAMES TO STELLAR KINEMATICS

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1. OUTLINE OF THE METHOD

In astrometry, the vectorial spherical functions were used for the first time for determination of the orientation and spin between the FK5 and HIPPARCOS reference frames [1]. The present paper is devoted to elaboration of this approach to the kinematical analysis of the proper motions.

Let the proper motions in galactic coordinate system be $\mu_l(l,b)\cos b$ and $\mu_b(l,b)$. We are looking for decomposition of the proper motions in such a way that

$$\mu_l(l,b)\cos b\,\vec{e}_l + \mu_b(l,b)\,\vec{e}_b = \sum_{j=1}^{\infty}\left[t_j\vec{T}_j(l,b) + s_j\vec{S}_j(l,b)\right], \tag{1}$$

where $\vec{e}_l$ and $\vec{e}_b$ are the unit vectors in the directions of longitude and latitude, and $\vec{T}_j(l,b)$ and $\vec{S}_j(l,b)$ are given in [1].

In case of the Ogorodnikov–Milne model [2] the stellar velocity field is given by expression

$$\vec{V} = \vec{V}_0 + M^+\,\vec{r} + M^-\,\vec{r}, \tag{2}$$

where the following notations are used:

$\vec{V}_0$ — the velocity of the Sun with respect to given centroid of stars. This velocity is defined by components U, V, W in the directions of the principal galactic axes x, y, z;

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). Since proper motions reflect tangential motions only, we set $M^+_{22} =\ 0$. In this case the unknowns M^+_{11} and M^+_{33} are replaced with $M^*_{11} = M^+_{11} - M^+_{22}$ and $M^*_{33} = M^+_{33} - M^+_{22}$ respectively;

M^- — the rotation matrix with the components ω_1, ω_2 è ω_3 about axes x, y, z;

The crucial point of our method is that the elements of M^+ and M^- are connected to the low-order coefficients of the decomposition (1) by the following equations (with R_j standing for the normalization factor of corresponding vectorial harmonic $\vec{T}_j$ or $\vec{S}_j$):

$$t_1 = \frac{\omega_3}{R_1}, \qquad t_2 = \frac{\omega_2}{R_2}, \qquad t_3 = \frac{\omega_1}{R_3}, \tag{3}$$

$$s_4 = \frac{M^*_{33} - \frac{1}{2}M^*_{11}}{2R_4}, \tag{4}$$

$$s_5 = \frac{M^+_{23}}{R_5}\,, \qquad s_6 = \frac{M^+_{13}}{R_6}\,, \tag{5}$$

$$s_7 = \frac{M^+_{12}}{2R_7}\,, \qquad s_8 = \frac{M^*_{11}}{4R_8}\,, \tag{6}$$

whereas the rest of harmonics does not belong to the Ogorodnikov–Milne model and may be used to study the effects that are beyond the model.

2. "EXTRA-MODEL" COMPONENTS OF THE PROPER MOTIONS

When applied to stellar kinematics of HIPPARCOS catalogue, the main advantage of the vectorial harmonics over traditional approach is a chance to detect the motions which are not included in the Ogorodnikov–Milne model. Indeed, in the global solution the method of vectorial functions detected the terms $(-12.9 \pm 4.6) \times \vec{S}_{10}$, $(12.2 \pm 4.4) \times \vec{S}_{14}$, $(-12.7 \pm 4.6) \times \vec{S}_{20}$, $(11.1 \pm 4.3) \times \vec{S}_{34}$ (all in km s^{-1} kps^{-1}). Besides the global solution we applied our method to several samples of stars with different distances and spectral classes. The "extra-model" terms specified by the functions $\vec{T}_4$, $\vec{T}_6$, $\vec{S}_{10}$ and $\vec{S}_{14}$ were found to be common to all examined samples including the global solution.

In conclusion, we state that contribution of the "extra-model" components to the proper motions is comparable with the contribution of the "classical" terms (see Figure 1). The next paper will be devoted to the physical properties of the "extra-model" terms detected here.

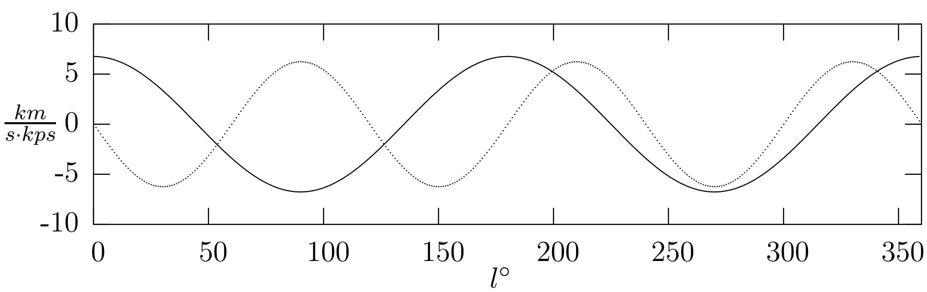

Figure 1: Contribution to the proper motions in longitude from the model harmonic $\vec{S}_7$ (Oort's coefficient $A = M^+_{12}$, solid line) in comparison to the significant "extra-model" harmonic $\vec{S}_{14}$ (dashed line).

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