SEPARATION PROPER MOTIONS FROM ORBITAL ONE OF DOUBLE OR MULTIPLE STARS BY USING HIPPARCOS AND GROUND-BASED OBSERVATIONS

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ABSTRACT. In my PhD thesis ("Improvement of accuracy of proper motions of Hipparcos Catalogue stars using optical latitude observations", Belgrade Univ., 2007) and few published papers, I used Hipparcos and ground-based long history optical observations of latitude, the Least Squares Method (LSM) with linear model, to get better proper motions in declination than the Hipparcos ones. After that, I continue this investigation, but with another model which can include the orbital motion (of double or multiple stars) into calculation and to separate the proper motion in declination from the orbital one of observed Hipparcos stars. Some parts of the sky (presented via Hipparcos stars data) are with bigger errors than averaged one of stars positions (which is about 1 mas) and of stars proper motions (close to 1 mas/yr), the shortness of the Hipparcos observations (less than four years) yields bigger proper motions errors of double or multiple stars than the single ones, about 15 years elapsed since the HIPPARCOS satellite observations because the epoch of Hipparcos Catalogue is 1991.25, etc. The data of latitude variations are used (covering the period 1899.7-1992.0) to improve the Hipparcos proper motions in declination of stars observed in line with the Earth orientation programmes; the method is presented here.

1. INTRODUCTION

The Hipparcos ESA mission (ESA, 1997) produced two catalogues in optical wavelength, both linked to the ICRF (the International Celestial Reference Frame): Hipparcos (118218 stars with coordinate accuracy close to 1 mas at the epoch 1991.25, 1 mas/yr accuracy of proper motions in $\mu_\alpha \cos\delta$ and μ_δ and very accurate parallaxes and photometry), and Tycho (1058332 stars with 25 mas accuracy of coordinates). The Hipparcos Catalogue was adopted to be the primary realization of ICRS (the International Celestial Reference System) in the domain of optical wavelengths. It contains stars brighter than $V = 12$ (mostly between $V = 7$ and $V = 9$).

It is evident that the combinations of Hipparcos and Tycho catalogues and the ground-based ones can improve the positions and proper motions of observed stars. During the last decade, a few problems concerning the Hipparcos data appeared: a better accuracy of the data for single Hipparcos stars than for double and multiple ones due to the short life of the satellite mission, different accuracy of the data on different parts of the celestial sphere, more inaccurate apparent star positions due to the errors of proper motions because their influence is linear in time (from the moment 1991.25) and by now the errors of apparent position has attained about 15 mas (one order of magnitude larger than the average position error in Hipparcos Catalogue), etc. All of this is the reason that a few star catalogues appeared after the Hipparcos one, such as ARIHIP (Wielen et al., 2001), and the Earth Orientation Catalogue (EOC-2) (Vondrák, 2004), with more accurate star positions and proper motions than those from Hipparcos.

The proper motion μ of the star (tangential part on the sphere) can be separated into two parts, μ_α (along the coordinate α) and μ_δ (along the δ): $\mu = (\mu_\alpha^2 \cos^2\delta + \mu_\delta^2)^{1/2}$. It is $\mu_\delta = (\delta_1 - \delta_2)/(t_1 - t_2)$, where δ_1 and δ_2 are two positions (in the same system) of the same star for the epoch t_1 and t_2, respectively. The error of μ_δ is $\epsilon_{\mu_\delta} = (\epsilon_1^2 + \epsilon_2^2)^{1/2}/|t_2 - t_1|$, where ϵ_1 and ϵ_2 are standard errors of δ_1 and δ_2, respectively. So, ϵ_{μ_δ} is proportional to $1/t$ (Eichhorn, 1974); with long observational interval t we can get very good accuracy ϵ_{μ_δ} (better than the Hipparcos one).

2. DATA AND METHOD

Here we use the results of latitude observations made with 10 PZT instruments (at 6 observatories: Mizusawa, Mount Stromlo, Ondřejov, Punta Indio, Richmond and Washington) and the Hipparcos Catalogue data in order to obtain proper motions in declination more accurate than the Hipparcos ones.

The reduction procedure concerning the latitude has been described in (Vondrák et al., 1998). We investigate the latitude variations φ_i with time around the corresponding mean latitudes. The elimination of systematic effects (polar motion, local and instrumental systematic variations) of interest for this investigation is described in the paper (Damljanović, 2005). Like that, we get the residuals (for corresponding observational epochs) r'_i, and assume that the values r'_i are mostly due to the catalogue systematic errors (influence of proper motions in declination) because of $\Delta\varphi + (d\varphi/dt)t \approx \Delta\delta + t\Delta\mu_\delta$, (Vondrák et al., 1998), where: $\Delta\delta$ is the correction of declination, $\Delta\mu_\delta$ is the correction of proper motion in declination, t is the time. For the case of single star, we process star by star by using the LSM and $r''_i = a + b(t_i - 1991.25)$, where a and b are the unknowns, the values r''_i are the averaged values of r'_i over subperiods of 1 year for each star, and the values t_i are the times (in years) corresponding to r''_i. The value a is the correction of $\Delta\delta$ and b is the correction of $\Delta\mu_\delta$; both are calculated for the epoch 1991.25. As an input value for the LSM, among the points r''_i we add one more point with the coordinates (1991.25, $0.''0$). All points are with suitable weights (Damljanović et al., 2006). We add our calculated corrections b to the corresponding Hipparcos proper motions in declination. In this way we obtain the values μ_δ and their errors.

In the case of double or multiple stars, we get the model (for star by star procedure) $r'''_i = b't'_i + A\sin(2\pi t'_i/P) + B\cos(2\pi t'_i/P)$, where: the residuals $r'''_i = r''_i - a$, the values $t'_i = t_i - 1991.25$ are the time (in years), b' is the unknown corrections to the Hipparcos proper motions in declination (more or less close to the suitable values b), the unknown values A and B are useful to calculate the amplitude $am = (A^2 + B^2)^{1/2}$ of periodic part. The periodic part is $am * \cos(2\pi t'_i/P - F)$ with the period P and phase F (from the moment 1991.25). At that way, we have got three unknowns to calculate: b', A and B. The value P (in years) is from the interval $(2; 4 * m')$ with step $k = 1$ year, where m' is the number of the observed years. For each star we have got $(4 * m' - 3)$ different solutions of the unknowns b', A and B, but the best one is for the value P when the calculated curve is the best fit for the set of the input points (r'''_i points plus the Hipparcos one (1991.25, $0.''0$)). The best fit is for the case $\sigma_0 = min.$, where σ_0 is the root mean square error of differences between the calculated points of the curve and suitable input ones r'''_i. Lake that, we can determine the value P, also.

Our next step is to apply this model on the data of double or multiple PZT stars, and to check the results by using the EOC-3 ones. The possible case for this model is the star H111841 (observed about 49 years at Washington and Mizusawa observatories) with the points r''_i close to the sinusoid curve.

It was evident that ground-based data are useful and can improve the reference frame (via improvement of proper motions in declination of Hipparcos stars). Because of it we continue with the investigations about the proper motions by using the ground-based data and more complex model than the linear one.

GD performed his work as a part of the Projects No 146004 "Dynamics of celestial bodies, systems and populations" supported by the Ministry of Science and Technological Development of R. Serbia.

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