BETTER PROPER MOTIONS ACCURACY FOR STARS WITH HIPPARCOS SATELLITE AND GROUND-BASED OBSERVATIONS

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ABSTRACT. About 15 years elapsed since the HIPPARCOS ESA satellite mission observations (the epoch of Hipparcos Catalogue is 1991.25). The errors of the Hipparcos stars proper motions were close to 1 mas/year, and nowadays the error of apparent places of these stars is more than 15 mas. It exceeds the error of Hipparcos stars positions (about 1 mas) by one order of magnitude. Some parts of the sky (presented via Hipparcos stars data) are with bigger errors than mentioned ones, the shortness of the Hipparcos observations yields bigger proper motions errors of double or multiple stars than the single ones, etc. There are numerous astrometric ground – based observations of some stars referred to Hipparcos Catalogue. Here, the data of latitude variations of 26 instruments are used to improve the Hipparcos proper motions in declination μ_δ of observed stars. The method and results are presented here.

1. INTRODUCTION

After less than four years of the Hipparcos satellite observations and a few years of analysis, at the end of 1997, the optical counterpart of the ICRF appeared. It was the HIPPARCOS Catalogue (ESA, 1997) with astrometric data for 118218 stars: the magnitudes of stars are until 12 (mostly between 7 and 9), the standard error of positions is about 1 mas (at the epoch of the catalogue 1991.25), the standard error of the proper motions $\mu_\alpha \cos\delta$ and μ_δ is near 1 mas/yr, etc. Some time after that, a few new catalogues were finished with better accuracy of proper motions: ACT, FK6, GC+HIP, TYC2+HIP, TYCHO-2, ARIHIP, EOC-2 (Vondrák, 2004), EOC-3, etc. The period of Hipparcos satellite observations is not enough to get a good accuracy of proper motions for some stars as double or multiple ones. Some regions of Hipparcos Catalogue are with bigger errors of proper motions than other ones. Also, the calculated apparent positions of Hipparcos stars are about 15 mas now (15 years after 1991.25) with the errors of proper motions of about 1 mas/yr; 15 mas is near the ground – based error of observed positions and one order bigger than the error of Hipparcos positions. The astro-geodesy observations need better accuracy of calculated apparent positions of Hipparcos stars, and during last decade some investigations started to improve proper motions of these stars by using their ground-based observations.

Here, the latitude variations of 10 PZT (photographic zenith tube), 14 ZT (visual zenith – telescope), 1 FZT (floating zenith – telescope) and 1 VZT (visual zenith tube), made in accordance with the Earth rotation programmes and covering the interval 1899.7 – 1992.0, with the OA00 (Vondrák, 2002) solution of the EOP were used to improve the accuracy of Hipparcos μ_δ. The method of this investigation is different than the one used for EOC-2. The determined corrections of Hipparcos μ_δ are with accuracy similar to one of ARIHIP, EOC-2 and EOC-3 proper motions data.

2. DATA AND CALCULATIONS

The data of seven ZT ILS stations (Carloforte, Cincinnati, Gaithersburg, Kitab, Mizusawa, Tschardjui and Ukiah) covering the interval 1899.7 – 1979.0, 10 PZT instruments (3 at Washington, 2 at Mizusawa and Richmond, 1 at Ondřejov, Punta Indio and Mount Stromlo), and the other 8 stations (Belgrade ZT, Blagoveschtschensk ZT, Irkutsk ZT, Poltava ZT, Pulkovo 2 ZT, Varsovie ZT, Mizusawa FZT, Tuorla-Turku VZT) were used. It is $\mu_\delta = (\delta_1 - \delta_2)/(t_1 - t_2)$ with the error $\epsilon_{\mu_\delta} = (\epsilon_1^2 + \epsilon_2^2)^{1/2}/|t_2 - t_1|$, where δ_1 and δ_2 are two positions of the star for the epochs t_1 and t_2, respectively. Both positions are in the same system. The standard errors of δ_1 and δ_2 are ϵ_1 and ϵ_2, respectively. It is evident that ϵ_{μ_δ} is proportional to $1/t$. Then, it is possible to get better accuracy ϵ_{μ_δ} than the Hipparcos one if there is long observational interval t and lot of observations of any observed star (or star pair) per year, even

Hipparcos accuracy of star positions is much better than ground – based one. Each ZT or FZT star pair was observed from a few until few hundred times per year, and the accuracy of one ZT star pair observation is near $0.2''$ (it is similar situation in the case of PZT and VZT star observations). Also, the time intervals of some stars (or star pairs) observations are few decades long. During calculations, both data (ground – based and Hipparcos ones) were used for any star; the latitude data with Hipparcos ones give better results than only latitude ones. In the case of the ILS stations (with nearly the same latitude $+39.^{o}1$), during calculations of any star pair, the data (latitude variations φ_i) of all 7 ILS ZT stations were used. Similar situation is for stars observations of PZT stations Punta Indio – Mount Stromlo and Washington – Mizusawa. Each mentioned code (CA, etc.) is in line with the monograph (Vondrák et al., 1998). Some effects were removed from received data (Vondrák et al., 1998).

The main effect presented into the star pair latitude changes φ_p is the polar motion part. That effect was calculated (by using the Kostinski formula $\Delta\varphi_i = x_i \cos\lambda_W + y_i \sin\lambda_W$) and removed from φ_p values. The polar motion coordinates x and y are from mentioned EOP solution OA00. The longitude λ_W is west of the zero meridian. The systematic variations (local, instrumental, etc.) for each instrument were calculated and removed from φ_p values, also. For each star pair, the average values of φ_p values (without the polar motion and systematic variations) give the points r'_n (about one point per year, n ones for observed interval). Without the polar motion and systematic variations, the values φ_p are mostly with catalogue errors. It is $\Delta\varphi_p + (d\varphi_p/dt)t \approx (\Delta\delta_S + \Delta\delta_N)/2 + t(\Delta\mu_{\delta_S} + \Delta\mu_{\delta_N})/2$ (Vondrák et al. 1998), where: $\Delta\delta_S$ and $\Delta\delta_N$ are corrections of declinations (for S and N star, respectively), $\Delta\mu_{\delta_S}$ and $\Delta\mu_{\delta_N}$ are corrections of μ_δ (for S and N star, respectively), t is the time. To calculate the corrections of star pairs (of common ZT/Hipparcos stars) μ_δ, the Least Squares Method and the linear model were used (Damljanović, 2005) $r'_n = a + b(t_n - 1991.25)$, where r'_n is the star pair residue, t_n (in years) is the epoch instant of r'_n, a is in line with $(\Delta\delta_S + \Delta\delta_N)/2$, b is in line with $(\Delta\mu_{\delta_S} + \Delta\mu_{\delta_N})/2$. The values a and b, for each ZT star pair, are in line with the epoch of Hipparcos Catalogue (1991.25). The points r'_n and the Hipparcos one are with suitable weights (Damljanović et al., 2006). The ZT and FZT data give the corrections (of Hipparcos μ_δ values) but to star pairs because the ZT and FZT observations were made for star pairs in line with Horrebow – Talcott method. The author found the original way to solve this problem and to separate them (Damljanović and Pejović, 2006). In the case of PZT and VZT observations, we are using the similar procedure (Damljanović, 2005; Damljanović and Vondrák, 2005), but instead of latitude of observed star pair (of ZT) it is the latitude of single star observation (of PZT). The calculated value of a is in line with $\Delta\delta$, and the value of b is in line with $\Delta\mu_\delta$. The main results are in mentioned papers (Damljanović and Pejović, 2006; Damljanović et al., 2006).

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