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Improved proper motions in declination of some Hipparcos stars via long–term classical observations

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Abstract. In this paper we present the new possibilities of classical ground – based observations for the purpose of improving the proper motions of some HIPPARCOS stars. The coordinates of asteroids, comets and other objects are calculated mostly by using the relative method and presented in a relevant reference frame via nearby stars (at the moment of observation) which materialize that reference frame. To improve the proper motions of stars we can use the latitude/universal time variations of ground – based data. Here, the results of improved proper motions in declination of some HIPPARCOS stars are presented.

Keywords. Stellar catalogues, proper motion

1. Introduction

Two catalogues appear as products of ESA mission, the Hipparcos one and the Tycho one. The former is the primary representation of the ICRS (International Celestial Reference System) in the optical wavelengths (ESA 1997). It contains 118218 stars with precise parallaxes, positions (better than 1 mas), proper motions and photometrical data. The median precision of positions for 1058332 Tycho Catalogue stars is 25 mas. The coordinates of the other objects, (asteroids, comets, etc.) calculated by applying the relative method and using the positions of nearby stars (at the moment of observation) are presented in a catalogue which materializes the reference frame. Thus the quality of the coordinates of the observed solar system objects depends upon the accuracy of the star positions.

During the last years, problems were noted for the proper motion of some Hipparcos stars, because the mission lasted < 4 years and was too short to provide satsisfactory accuracy in proper motion. The proper motions of some Hipparcos stars have comparatively low accuracy, mostly double and multiple stars (Vondrák & Ron 2004).

On the other hand, we can see that ground–based observations with a long history have a good potential to materialize a better reference frame, more stable in time. During last few years some catalogues including ground–based data were made : TYCHO-2, ACT, FK6(I), FK6(III), GC+HIP, TYC2+HIP , ARIHIP and the most recent Earth Orientation Catalogue – EOC (Vondrák & Ron 2003).

There is a large data set of ground–based measurements of latitude/universal time variations. The Hipparcos Catalogue comprises several thousand stars which were observed from the ground for few decades and for which a large number of observations is available (Vondrák *et al.* 1998). We used some of these data to improve the proper motions in declination for some Hipparcos stars. Our results give a contribution to the investigations of possible improvement of the reference frame.

2. Data

In this paper we present our computational procedure by using the observations of several Photographic Zenith Tubes (PZT):

- PIP data, Punta Indio PZT (Argentina), observation time span 1971.6 – 1984.5,
- MS ones, Mount Stromlo PZT (Australia), 1957.8 – 1985.7,
- OJP ones, Ondřejov PZT (Czech Republic), 1973.1 – 1992.0.

We received the data from J. Vondrák, and decided to apply our procedure star by star, because the data contain star by star latitude observations (the data of each star are independent from each other). The data are referred to the Hipparcos Catalogue, corrected for instrumental constants (micrometer screw, plate scale, etc.), refraction, and errors in proper motions of some Hipparcos stars (but this correction is available for only about 20 % of the stars).

The precession–nutation model IAU 1980 and the MERIT Standards were used to compute the apparent places of the stars. The mean latitudes, corrections of conventional longitudes and tectonic plate motions (from the NUVEL–1 NNR geophysical model) were subtracted from the results in order to bring them all to a homogeneous system.

For each star we prepared a separate file with all observations made with PIP, MS or OJP. There are 165 Hipparcos stars observed with PIP instrument, 184 with MS, and 285 with OJP (157 stars are common to both PIP and MS). We used the polar motion coordinates from the file EOPOA00.dat by Vondrák.

3. Results

The latitude data we received mostly contain time variations due to polar motion changes with time, but we want to investigate the proper motion. Thus, at first it was necessary to calculate and remove the polar motion component.

We took the coordinates of the polar motion (x and y) from the file EOPOA00.dat and adapted x and y by linear interpolation to the moment of interest. Also, we repeated that calculation for each of the mentioned instruments, and removed the calculated polar motion part from the received latitude data for each star. For this purpose, we used the Kostinski's formula (Kulikov 1962) where λ (longitude of the instrument) is calculated from the zero–meridian to the west. The values of λ and φ (latitude) for mentioned stations are from (Vondrák *et al.* 1998).

After removing the polar motion part, for each star we are left with residuals (polar motion value minus mean value of n latitudes of some Hipparcos star observed during the subperiod, approximately one year long). Thus for each star we have got nearly one data point (residual) per year. Each data point contains: MJD, residual, standard error, and number of latitudes n (used in the mean value calculation of the mean value). A few examples are presented in the figures: in Fig. 1 we show the residuals as a function of time (MJD) of the common PIP and MS Hipparcos star H68419 (MS is the longer curve); Fig. 2 shows the same for OJP H80585. The curves are almost straight lines; thus the residuals are well prepared. The calculation of the free term a, of the linear one b and of its standard errors was made for each star by using the Lest-Squares Method (LSM) and linear model

$$Y(i) = a + b * (X(i) - 1991.25),$$

where: $X(i)$ is time in years, $Y(i)$ – mentioned residuals, i is the number of residuals (points). The linear term b is our correction of μ_δ (proper motion in declination).

For the cases presented in the figures, the results are (LSM, linear model, no weights):
- PIP, H68419 , $a = -0.''071 \pm 0.''043$, $b = -0.''0021/year \pm 0.''0032/year$,
- MS, H68419 , $a = -0.''103 \pm 0.''028$, $b = -0.''0042/year \pm 0.''0013/year$,
- OJP, H80585 , $a = -0.''411 \pm 0.''013$, $b = -0.''0103/year \pm 0.''0013/year$.

The results for the star H68419, as obtained from the PIP and from the MS data set, are in good agreement (thus our procedure is correct), but the values for the star H80585 (OJP data) are too high and questionable (the same occurs for the other OJP stars).

To explain the results for the star H80585 it was necessary to identify the trends of all PIP, MS and OJP data. We determined the values of a and b (LSM, the same model, no weights), but for the points of all PIP stars (similar for MS and OJP):
- PIP, $a = -0.''069 \pm 0.''005$, $b = -0.''0018/year \pm 0.''0004/year$,
- MS, $a = -0.''019 \pm 0.''003$, $b = -0.''0008/year \pm 0.''0002/year$,
- OJP, $a = -0.''426 \pm 0.''002$, $b = -0.''0118/year \pm 0.''0002/year$.

Evidently, the results concerning PIP and MS are still in a good agreement (the values of b are small for both instruments), but the results for OJP show the reason why the values for a and b are so large in case of Hipparcos star H80585. Similar results are obtained for most of the other PIP, MS and OJP stars. This means that these data still contain some systematic errors which we need to determine and remove before our final calculations, but the procedure of calculation is correct, which was our purpose to show here. Also, after finishing the calculations for the other instruments (here, we present only three of them) we are going to send the results to Dr. Vondrák, and expect new Vondrák's solutions of the Earth Orientation Parameters (EOP) and full comparison of our results, in line with the long–term Earth rotation studies (Vondrák & Ron 2004). At present, we can conclude that our calculated correction is justified if our procedure for the same star observed at different sites (see Fig. 1) gives us similar results. It means that the procedure can extract the effect of proper motion affecting latitude changes with time.

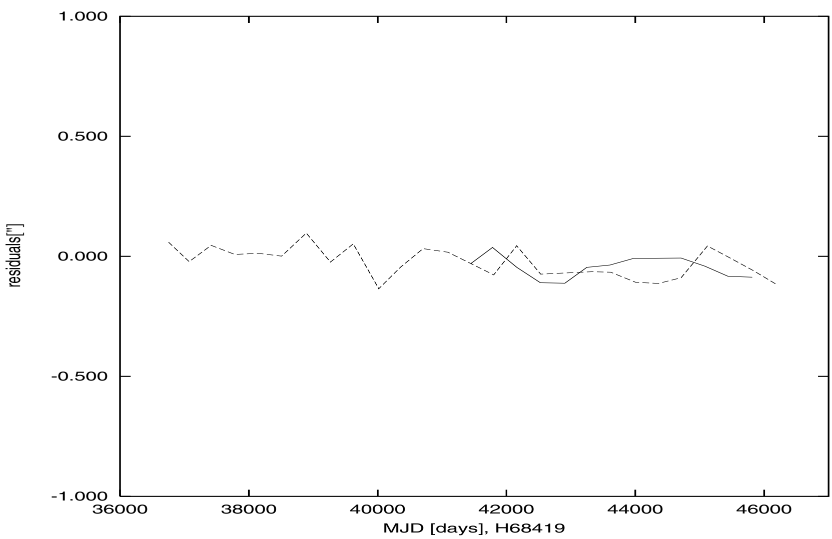

Figure 1. The residuals as a function of time (MJD) of the common PIP (shorter curve) and MS (longer one) Hipparcos star H68419.

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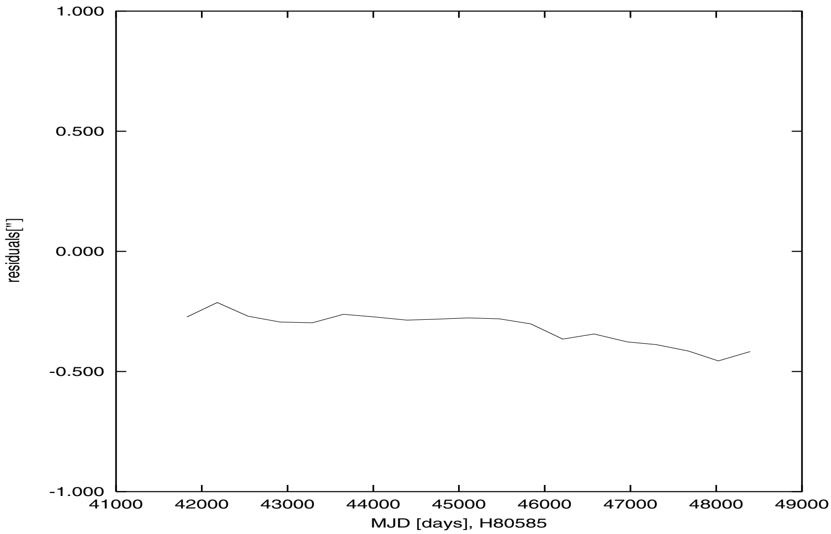

Figure 2. The residuals with MJD of OJP Hipparcos star H80585.

It is necessary to be careful with PZT latitude data because of their level of formal errors (much larger than the Hipparcos ones) and of different kinds of systematic ones, but these data with a long history still can give us useful informations. One possibility is to improve proper motion for some Hipparcos stars as shown here.

4. Conclusions

We used the latitude data of PIP, MS, and OJP PZTs to improve the proper motions in declination for some Hipparcos stars. The main features of the data and our calculation procedure are explained. A few examples (see the Fig. 1 and Fig. 2) are given. This kind of investigation is the way, step by step, to obtain more accurate data than the Hipparcos ones, in a long–term sense, and the combination of ground – based optical observations with space ones can give us a better reference frame.

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References

ESA 1997, *The Hipparcos and Tycho Catalogues* ESA SP-1200

Kulikov A.K. 1962, *Izmenyaemost' sirot i dolgot*, Moskva

Vondrák, J., Pešek, I., Ron, C. & Čepek, A. 1998, *Astron. Inst. Acad. Sci. Czech R., Publ. No.*, 87

Vondrák, J. & Ron, C. 2003 in: N. Capitaine (ed.), Observatoire de Paris, *Journées 2002 Systèmes de Référence Spatio – Temporels*, p. 49

Vondrák, J. & Ron, C. 2004 in: R.Gaume, D.McCarthy and J.Souchay (eds.), *in Proc. IAU XXV Joint Discussion 16: The ICRS Maintenance and Future Realizations*, in press