COMPARISON OF THE PROPER MOTIONS IN DECINATION OF FOUR CATALOGUES VIA 807 HIPPARCOS STARS

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Input data and method of calculations

- HIPPARCOS Catalogue
- Ground-based observations, last century, lat. data of 10 PZT instr.
- Homogenize of data
- Method of calculations
- PZT Catalogue of 807 Hipparcos stars
- Comparison of p.m. in DEC (PZT, EOC-2, Hipp., new Hipp. (van Leeuwen 2007))

HIPPARCOS-HIgh Precision PARallax COllecting Satellite

- Less than 4 yr of observ., 1989.-1993.
- HIPPARCOS Catalogue (ESA 1997)
- 118218 stars, <12 mag. Epoch 1991.25
- Errors: 1 mas of pos., 1 mas/yr of p.m.
- In ICRS
- Series of homogenize EOP

Table 1: Ten PZT instruments.

observatory instr. and N	period in yr(+1900) and in MJD	$\lambda(^\circ)$, $\varphi(^\circ)$, $\lambda_W(^\circ)$
Mizusawa MZP,MZQ 137	02.I'59-21.XII'91 36570.6-48611.5 (MZP to '75.3) (MZQ from '74.2)	141.1, 39.1, 218.9
Mount Stromlo MS,184	31.X'57-27.VIII'85 36142.5-46304.7	149.0, -35.3, 211.0
Ondřejov OJP,285	05.II'73-14.XII'91 41718.9-48604.7	14.8, 49.9, 345.2
Punta Indio PIP,165	03.VIII'71-29.VI'84 41166.9-45881.1	-57.3, -35.3, 57.3
Richmond RCP,RCQ 202	05.XI'49-12.V'89 33225.2-47658.1 (RCP to '87.5) (RCQ from '81.9)	-80.4, 25.6, 80.4
Washington WA,W,WGQ 188	28.X'15-26.XII'91 20798.2-48616.0 (WA to '55.3) (W '54.3-'84.8) (WGQ from '81.7)	-77.1, 38.9, 77.1

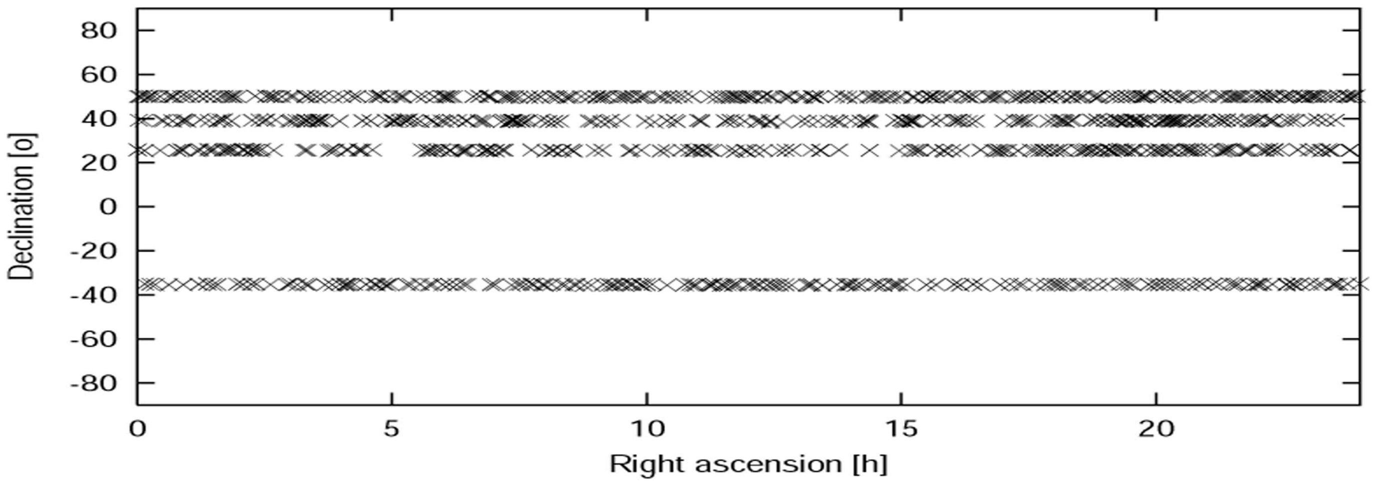

Figure 1: Distribution of 807 stars on the celestial sphere.

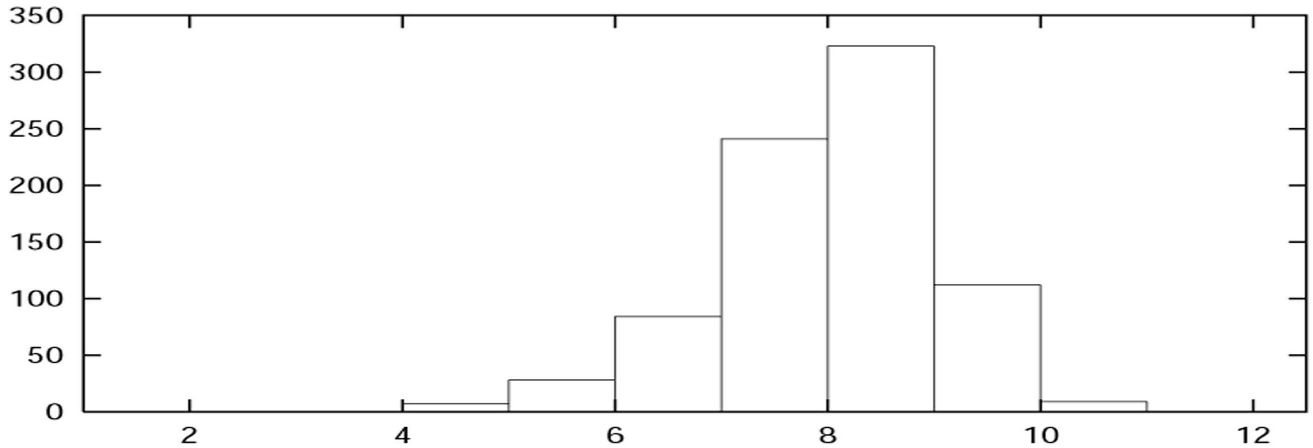

Figure 2: Distribution of magnitudes of 807 stars.

$\alpha(t)$, $\delta(t)$

Together, μ, the distance to the star, and its radial velocity determine the space velocity of a star.

The proper motion of a star μ has got two parts: along the α coordinate (μ_α) and along the δ coordinate (μ_δ). It is

$\mu = \sqrt{\mu_\alpha^2 \cos^2 \delta + \mu_\delta^2}$.

$\mu_\delta = \frac{\delta_1 - \delta_2}{t_1 - t_2}$,

and to calculate the value μ_δ it is necessary to have at least two positions of a star (δ_1, δ_2) in the same system (Eichhorn 1974) and their epochs (t_1, t_2), respectively. The standard errors of positions are ε_1 and ε_2, respectively; the error of μ_δ is

$\varepsilon_{\mu_\delta} = \frac{\sqrt{\varepsilon_1^2 + \varepsilon_2^2}}{t_2 - t_1}$ (Eichhorn 1974).

The value of ε_{μ_δ} is inversely proportional to the observed interval

$t = t_2 - t_1$

of the PZT star. If t is long enough, it is possible to get a similar or better accuracy of μ_δ than the Hipparcos one.

There are more than 0.9 million observations made at 6 observatories during the interval 1915.8 – 1992.0, and several hundreds of observations per year (on the average) for each PZT star. The standard error of a single PZT observation ranges from 100 mas to 200 mas, and of the Hipparcos star position is near 1 mas.

Three subgroups: A (313 stars with $\geq$ 20 years of PZT observations), B (685 stars with $\geq$ 10 years), C (all 807 stars).

We removed the polar motion effect $\Delta\varphi_i$ from latitude variations φ_i to get the residuals r_i, and the systematic ones (local, instrumental, etc.) se_i from r_i values to calculate the residuals r_i' (Damljanović & Pejović 2005 (Proc.IAU Coll.197), Damljanović 2005 (Serb.Astron.J. 170), Damljanović *et al.* 2006 (Serb.Astron.J. 172), Damljanović & Pejović 2006 (Serb.Astron.J. 173), Damljanović & Pejović 2008 (Serb.Astron.J. 177), Damljanović 2008 (Planetary and Space Science 56), Damljanović & Pejović 2010 (Astron.Nachr. 331)). For every PZT star

$$r_i = -(\varphi_i - \Delta\varphi_i), \tag{1}$$

$$r_i' = r_i - se_i. \tag{2}$$

To determine $\Delta\varphi_i$: Kostinski's formula $\Delta\varphi_i = x_i \cos\lambda_W + y_i \sin\lambda_W$ (Kulikov 1962). The values (x_i, y_i) are from file EOPOA00.dat (Vondrák *et al.* 1998). The latitude φ_s of any observed PZT star: by using McCarthy's (1970) formula

$$\varphi_s = \delta_{app} + F. \tag{3}$$

For a PZT star, the set of values r_i' (with the constant and linear part) is close to $\Delta\varphi_s + (d\varphi_s/dt)t$, and according to Vondrák *et al.* (1998)

$$\Delta\varphi_s + (d\varphi_s/dt)t \approx \Delta\delta + t\Delta\mu_\delta. \tag{4}$$

We use the linear fit

$$r_i'' = a + b(t_i - 1991.25), \tag{5}$$

and our correction to $\mu_{\delta_{HIP}}$ is the value of b (calculated together with the value of a by using the LSM). Both, a and b are in accordance with the epoch 1991.25.

The random and systematic errors: by using the formula according to Ivanov & Yatsenko (2003) and LSM

$$k_1 + k_2(m - m_0) + k_3(B - V) = \Delta, \tag{6}$$

where: k_1, k_2 and k_3 are the unknowns (which describe the systematic part of differences Δ), m are the magnitudes of stars, and $B - V$ their color indices. s_0 (the error of unit weight of the solution of the system given by formula (6)) presents the random part of Δ; s_0 is the sum of random errors of both of the two treated catalogues.

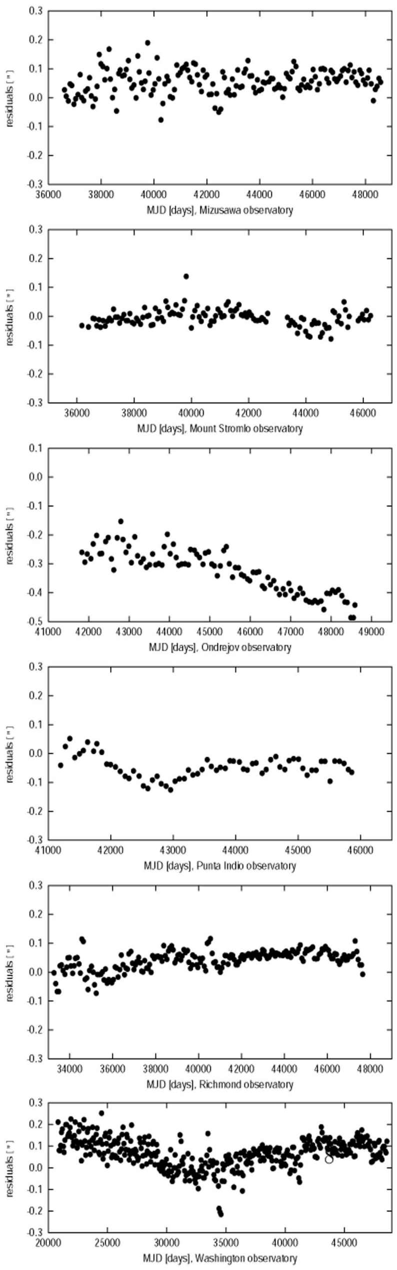

Figure 3: Mean residuals r_i in bins of 0.2 years vs. time (MJD).

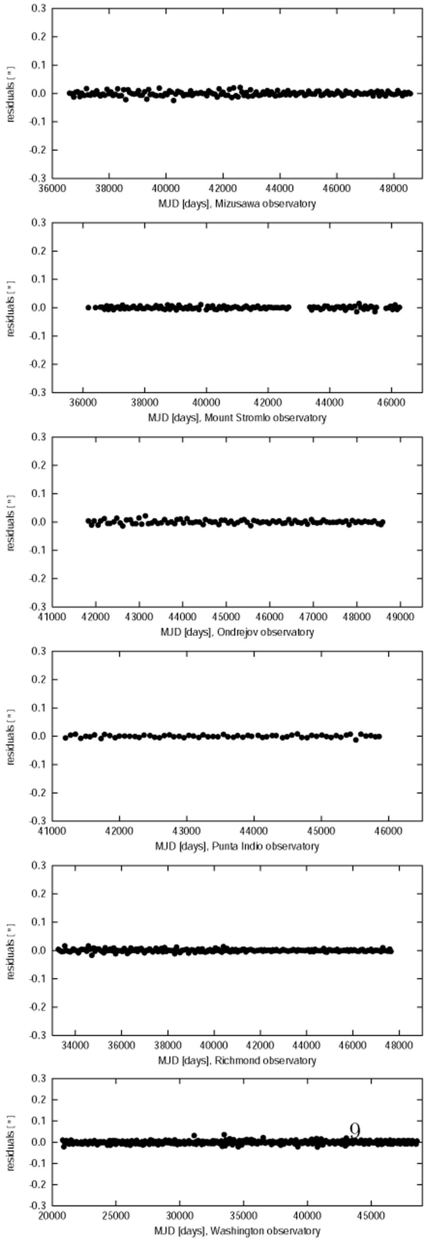

Figure 4: Mean residuals r_i' in bins of 0.2 years vs. time (MJD).

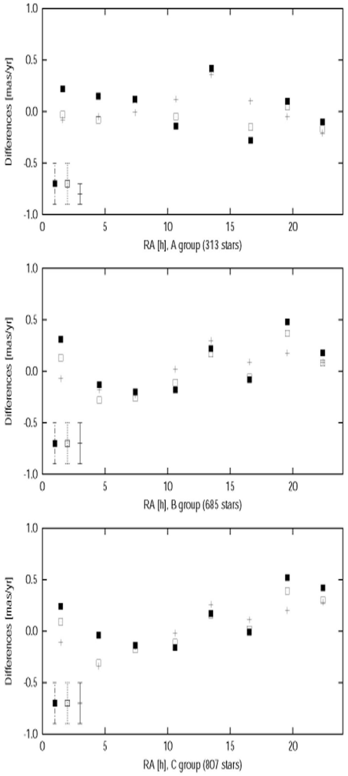

Figure 5: Mean proper motion differences (with a typical mean error bars), as a function of α, between our results and: the re-reduced Hipparcos (solid rectangle), Hipparcos (open rectangle) and EOC-2 ones (the sign +).

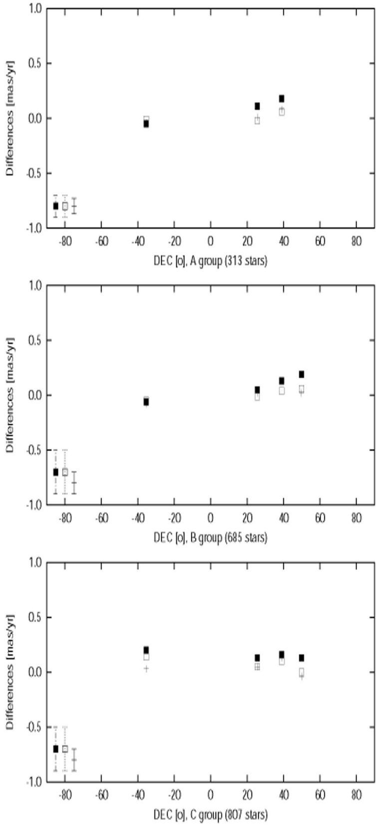

Figure 6: Mean proper motion differences (with a typical mean error bars), as a function of δ, between our results and: the re-reduced Hipparcos (solid rectangle), Hipparcos (open rectangle) and EOC-2 ones (+).

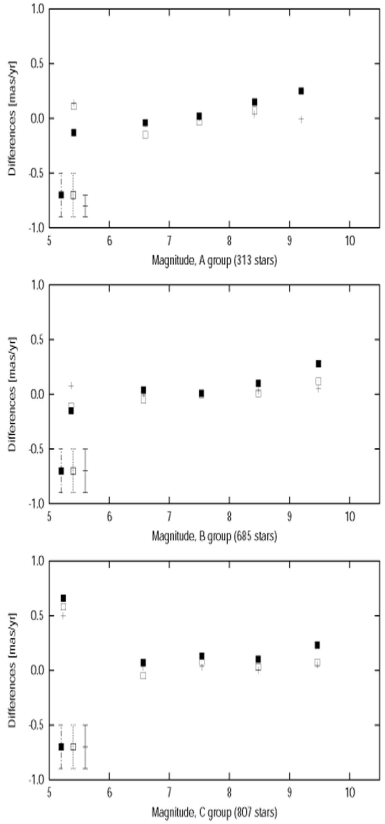

Figure 7: Mean proper motion differences (with a typical mean error bars), as a function of magnitude, between our results and: the re-reduced Hipparcos (solid rectangle), Hipparcos (open rectangle) and EOC-2 ones (+).

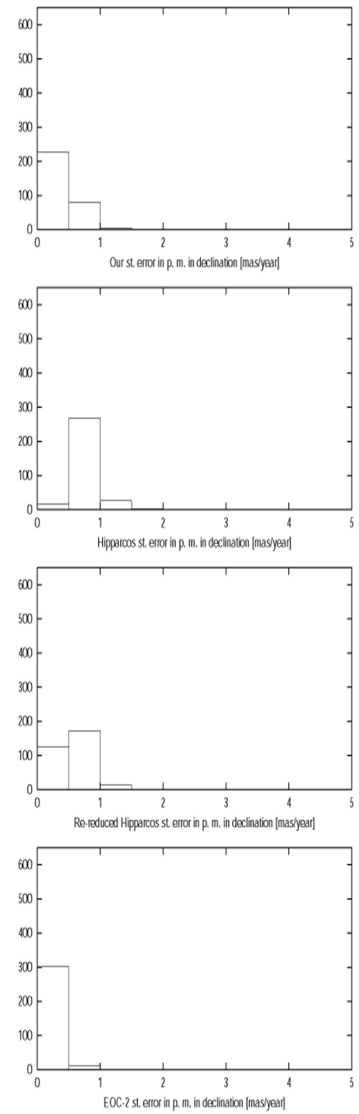

Figure 8: Distribution of standard errors in proper motions in declination for group A.

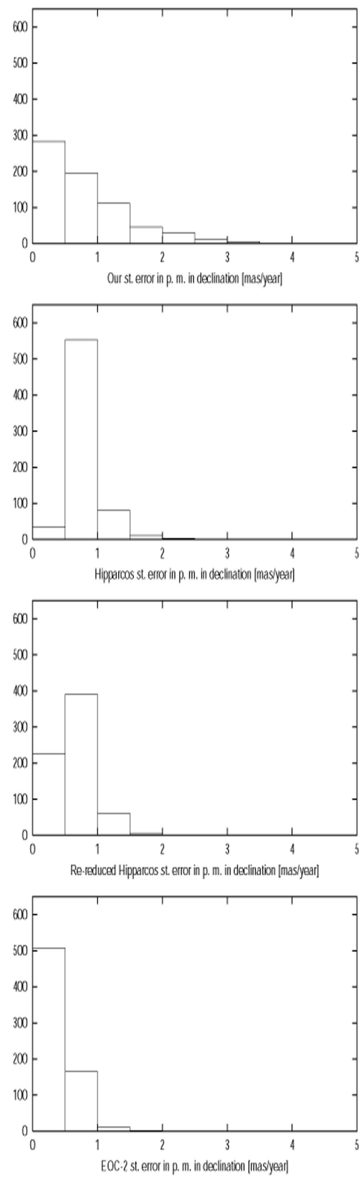

Figure 9: Distribution of standard errors in proper motions in declination for group B.

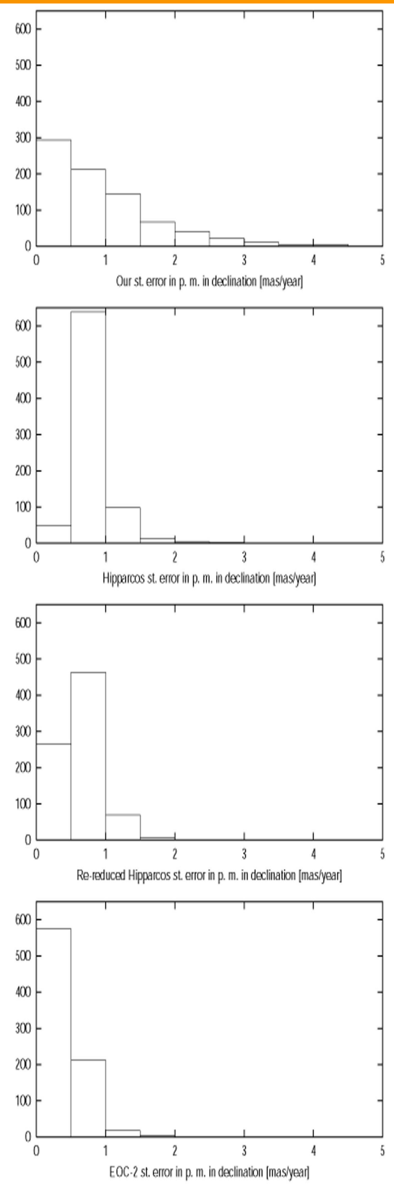

Figure 10: Distribution of standard errors in proper motions in declination for group C.

Table 2: Comparison of μ_δ (of subgroups A, B, C), from our results (PZT), EOC-2, Hipparcos (HIP) and new Hipparcos (NHIP), to get formal and systematic errors (in 0.″00001/yr).

catalogue	s_0	k_1	k_2	k_3
PZT-EOC2, A	49	-2 ± 4	0 ± 3	6 ± 6
PZT-EOC2, B	131	6 ± 8	-3 ± 5	-5 ± 11
PZT-EOC2, C	168	1 ± 9	-7 ± 6	6 ± 13
PZT-HIP, A	111	-2 ± 10	7 ± 7	6 ± 14
PZT-HIP, B	180	6 ± 11	2 ± 7	-7 ± 15
PZT-HIP, C	209	5 ± 12	-5 ± 7	3 ± 16
PZT-NHIP, A	122	6 ± 11	10 ± 7	2 ± 15
PZT-NHIP, B	189	8 ± 12	6 ± 7	0 ± 16
PZT-NHIP, C	215	11 ± 12	-3 ± 7	7 ± 17
EOC2-HIP, A	88	0 ± 8	6 ± 5	0 ± 11
EOC2-HIP, B	107	0 ± 7	5 ± 4	-2 ± 9
EOC2-HIP, C	110	4 ± 6	1 ± 4	-3 ± 8
EOC2-NHIP, A	102	7 ± 9	9 ± 6	-4 ± 13
EOC2-NHIP, B	119	3 ± 7	10 ± 4	5 ± 10
EOC2-NHIP, C	132	10 ± 7	4 ± 4	1 ± 10
NHIP-HIP, A	78	-8 ± 7	-3 ± 5	4 ± 10
NHIP-HIP, B	76	-3 ± 5	-5 ± 3	-8 ± 6
NHIP-HIP, C	81	-6 ± 5	-2 ± 3	-4 ± 6

Table 3: Comparison of Hipparcos, ACT, CMC11, FONAC, NPM1 and PPM with the use of stars with large proper motions, in Ivanov & Yatsenko (2003), to get formal and systematic errors (in 0.″00001/yr).

catalogue	stars	s_0	k_1	k_2	k_3
HIP-ACT	1792	364	−16	−14	—
HIP-CMC	960	512	13	—	−11
HIP-CMC	10188	476	−8	−10	3
HIP-FON	960	505	—	40	−16
HIP-FON	12686	455	7	—	−7
HIP-NPM	960	799	167	−90	−21
HIP-NPM	2430	718	93	−165	—
HIP-PPM	14612	627	−11	−23	—
CMC-FON	960	475	—	41	—
CMC-NPM	960	796	154	−83	−217
FON-NPM	960	776	163	−14	176

4. CONCLUSIONS

It is possible to check the proper motions in declination of the observed PZT/Hipparcos stars. During the last century, PZT data were used to monitor the Earth orientation, but now they can also be used to check the Hipparcos satellite data (Ron & Vondrák 2001).

The PZT catalogue of μ_δ for 807 stars was constructed: after calculating and removing the polar motion and some systematic (local, instrumental, etc.) effects from the observed latitudes, using the linear fit to calculate the corrections of the Hipparcos proper motions in declination, the LSM to calculate the unknowns, including the Hipparcos point (1991.25, 0.″0) and assigning weights to all input points in the calculations, etc.

The values of μ_δ from the PZT catalogue were compared with the EOC-2, Hipparcos and re-reduced Hipparcos data, and the consistency is good. In any case, with about 20 years of PZT observations, the proper motions in declination obtained by our method are formally on the level of the Hipparcos ones.

- Following the procedure of determining random and systematic errors of four catalogues by pairs (Hipparcos, new Hipparcos, EOC-2 and PZT), according to Ivanov & Yatsenko (2003), we did not find a significant relationship between the differences of μ_δ and magnitudes and color indices of the common 807 stars.

- We can conclude that all catalogues have high accuracy of μ_δ, since after using our sample of 807 common stars, their random and systematic errors of μ_δ are small and close to each other.

Our formal error (for all subgroups A, B and C) is too small, i.e. underestimated by a factor near 1.7 (for EOC-2, it is 2.0) if the new Hipparcos (or Hipparcos) is the reference catalogue. Our results provide an independent checking of μ_δ from the catalogues Hipparcos, new Hipparcos and EOC-2.

The PZT catalogue, URL: http://saj.matf.bg.ac.rs/177/pdf/Table2.dat. Also, the data will be provided on request to those who are interested.