AN IMPROVED STAR CATALOGUE FOR ONDŘEJOV PZT

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ABSTRACT. The observations of 305 stars made in the period from 1973 to 2002 with the PZT at Ondřejov Observatory were combined with the positions of the same stars in the catalogues AGK2, AGK3 and HIPPARCOS in order to obtain their mean positions and proper motions. The modified algorithm of Vondrák (1980) and Ron & Vondrák (1985) has been used for the adjustment. More than 77000 individual star transits in 2561 nights have been observed within the period in question with the PZT.

1. INTRODUCTION

Regular observations with the PZT at Ondřejov (Carl Zeiss Jena, $f = 3780$ mm, $D = 250$ mm) have been made since 1973 up to now. The observed stars lie in the narrow declination belt between 49°35' and 50°15'. The observations were performed in 3 different observing programmes:

- 192 stars divided into 15 unequally spaced groups were observed in the interval 1973–1978.0;
- In 1978, 113 stars were added and 8 stars excluded, which led to the observing programme consisting of 297 stars in 15 groups. The positions of the new stars were taken from AGK3 catalogue (Dieckvoss & Heckmann, 1975);
- Since 1979 224 stars divided into 16 equally spaced groups (1.5 hour) are observed. These stars were selected from the 297 stars observed in 1978.

Several star catalogues were derived from the observations done by Ondřejov PZT but only some of them were used as working catalogues for the PZT. In 1973–1978 the catalogue **PZT75** was used; the star positions were taken from the SAO catalogue and were improved from the first two years of observations (Webrová & Weber, 1976). In 1979 the catalogue **PZT75a** was used that was basically PZT75 with the positions of new 113 stars improved by using the PZT observations in 1978. In 1980–1984 the catalogue **PZT78** was used. The star positions were derived from the observations 1973–1978 in combination with the AGK2 and AGK3 positions (Vondrák, 1980). Since 1985 the catalogue **PZT83** has been used. The star positions were derived from the observations 1973–1983 in combination with AGK2 and AGK3 positions, using an analogous method as for PZT78 (Ron & Vondrák, 1985). The catalogue **PZT86**, consisting of 224 PZT stars, was derived from PZT observations in 1973–1986. This catalogue was never used for PZT adjustment, due to insufficient accuracy in proper motions (Vondrák, 1988). The catalogue **PZT89**, consisting of 305 PZT stars, was based on combination of PZT observations with AGK2/3 positions (Ron, 1992). This catalogue was used neither since we decided not to change the working catalogue, expecting the new HIPPARCOS catalogue . HIPPARCOS catalogue was used for the re-reduction of the optical astrometry observations in the HIPPARCOS reference frame (Vondrák et al. 1998). We found the inadequacy of proper motions of about 1/5 of the stars, therefore the corrections of proper motions were derived from the residuals.

2. METHOD OF SOLUTION

The present analysis uses a slightly modified method which was already used for the improvements of the catalogues PZT78, PZT83 and PZT86. The determination of positions and proper motions is divided into two steps.

In step one, only the corrections of star positions are determined in the short intervals (one or two years long). The problem is solvable on the assumption that:

- the observed quantity (i.e., latitude φ or clock correction UT0–UTC) is constant during one night;
- the error in the star's position is constant during the interval in question.

The unknowns to be found from the adjustment by the method of least squares, independently in each interval of observations, are M values of observed quantities $\bar{x}_j$ (latitude or clock correction) for each night, and N corrections of each star's catalogue position a_i (declination or right ascension). The observation equation then reads

$$v_{ij} = \bar{x}_j - a_i - x_{ij},$$

where v_{ij} and x_{ij} denote the residual after adjustment and observed value for the i-th star in the j-th night respectively. The standard least-squares method leads to the system of $M + N$ linear equations whose matrix is singular. An additional constraint has to be imposed of the form $\sum a_i = 0$ applied to a subset or all adjusted star positions. All of the observed quantities have the weight equal to one. The algorithm is applied to each of the intervals.

In step two, the corrections of the star positions, obtained in step one for the particular one or two year intervals, are combined and adjusted in order to derive the new improved positions and proper motions in the epoch J2000.0. In order to obtain proper motions with better precision, PZT observations can be combined with the AGK2/3 or HIPPARCOS catalogue positions of the stars, used as fictitious observations. The observation equation for the i-th star observed in the k-th PZT interval reads

$$v_{ik} = \Delta x_i + \Delta\mu_i(t_{ik} - 2000) - \Delta_k - a_{ik},$$

where a_{ik} is the result from the preceding step and Δ_k is an additional constant shift of the PZT results for the k-th interval. The observation equation for the i-th star in AGK2/3 catalogue or in the HIPPARCOS catalogue (experiment b and c, see below) is

$$v_{ik} = \Delta x_i + \Delta\mu_i(t_{ik} - 2000) + l_{ik},$$

where l_{ik} is the difference PZT83 – AGK2/3 or HIPPARCOS at the mean epoch of the catalogues. The shifts Δ_k were identically put equal to zero in case of fictitious observations to bring the resulting positions and proper motions to the system of the reference catalogue. The input values a_{ik} are taken with the weights derived from the standard deviations of particular stars which lead to weights ranging from 1 to 50. These values roughly correspond to the number

k	Interval	N	m_α [s]	m_δ [″]	M	n
1	1973/74	197	±0.0127	±0.142	156	4432
2	1975/76	192	±0.0128	±0.144	167	4130
3	1977	197	±0.0130	±0.131	104	2333
4	1978	296	±0.0127	±0.133	107	3869
5	1979	224	±0.0128	±0.132	108	3057
6	1980	224	±0.0136	±0.135	97	2638
7	1981	224	±0.0128	±0.126	114	2870
8	1982	224	±0.0140	±0.132	138	3956
9	1983	224	±0.0130	±0.133	144	4189
10	1984	224	±0.0129	±0.135	149	4024
11	1985	224	±0.0134	±0.149	122	3452
12	1986	224	±0.0134	±0.157	133	3830
13	1987	224	±0.0135	±0.149	123	3610
14	1988	224	±0.0135	±0.140	112	3433
15	1989	224	±0.0134	±0.133	130	4004
16	1990	224	±0.0144	±0.148	135	4367
17	1991	224	±0.0144	±0.152	111	4168
18	1992	224	±0.0146	±0.147	70	2654
19	1993	224	±0.0168	±0.175	49	1736
20	1994	224	±0.0182	±0.178	49	1755
21	1995/96	224	±0.0175	±0.179	50	1883
22	1997/98	224	±0.0180	±0.179	77	2792
23	1999/00	224	±0.0208	±0.214	46	1524
24	2001/02	224	±0.0220	±0.217	69	2390
1-24	1973/2002	305	±0.0144	±0.150	2560	77096

Table 1: The survey of PZT observations obtained from the adjustment in step one. N – the number of different stars observed in the interval, m_α, m_δ – standard errors of a single observation in right ascension and declination, M is the number of observing nights in the interval and n – number of star transits observed in the interval.

of observations of the i-th star in the k-th interval. The weights of the fictitious observations l_{ik} taken from AGK2/3 were set to 1 and 2, respectively (see, Vondrák, 1980). The weight of fictitious observation taken from HIPPARCOS catalog was set to the value of the average number of observation of one star (250) and moreover, this value leads to the smallest average standard errors. The observational equations lead to the system of $2N+K$ linear equations. For more information on the solution of normal equations see Vondrák (1980) and Ron & Vondrák (1985).

3. THE OBSERVED DATA USED IN THE ADJUSTMENT AND THE RESULTS

From the reduction of PZT observation we can get the values φ and UT0–UTC, separately for each star transit. We have re-reduced all PZT observations obtained in 1973-2002, using the single catalogue, PZT83. The detection of the outliers has been done before the adjustment – the observation was excluded in case its difference from the 'floating' median (the L1 norm applied to the interval of 15 days before and after the moment of observation in question) was greater

catalogue	m_α [s]	m_{μ_α} [s/cy]	m_δ [$''$]	m_{μ_δ} [$''$/cy]	t_0
PZT83	±0.0019	±0.0240	±0.020	±0.260	1978.8
PZT86	±0.0015	±0.0510	±0.017	±0.570	1981.6
PZT01a	±0.0015	±0.0089	±0.016	±0.095	1984.8
PZT01b	±0.0015	±0.0081	±0.016	±0.085	1984.0
PZT01c	±0.0013	±0.0089	±0.013	±0.088	1986.2

Table 2: The average standard errors of the catalogues PZT83, PZT86 and PZT01a,b,c in position m_α, m_δ and proper motion m_{μ_α}, m_{μ_δ}.

than 0.8$''$ and 0.08s for φ and UT0–UTC, respectively. If applied, the fictitious observations were taken from the AGK2/3 catalogue (Dieckvoss & Heckmann, 1975) and HIPPARCOS catalogue (ESA, 1997) (in the experiments b and c, see below).

In step one we divided the period of the PZT observations into 24 intervals, one or two years long. The constraint $\sum a_i = 0$ was applied to all observed stars ($i = 1, .., 305$).

The global statistics of the observations in different intervals is displayed in Tab. 1. It should be noted that the progressive decrease of the accuracy after 1992 is caused by the considerable limitation of observations.

In step two the combination of the corrections for each of 24 intervals was performed. We have done 3 experiments:

- Only the PZT observations were used (PZT01a), processed similarly as in Vondrák (1988);
- PZT observations were combined with AGK2 and AGK3 positions (PZT01b), processed similarly as in Ron & Vondrák (1985);
- PZT observations were combined with the HIPPARCOS positions (PZT01c). Only 282 stars from the HIPPARCOS catalogue were observed in Ondřejov PZT. Further 17 stars which were detected as suspicious in Vondrák et al. (1998) were rejected which led to 265 stars that were constrained by $\sum a_{ij} = 0$, leading to the catalogue linked to the HIPPARCOS reference frame.

The resulting standard errors of the three experiments and the comparison with the previous catalogues PZT83 and PZT86 are shown in Tab. 2. The accuracy of these catalogues at any epoch t can be described by a standard error m_t calculated from the formula

$$m_t^2 = m_0^2 + m_\mu^2 (t - t_0)^2,$$

where standard errors m_0 and m_μ and the mean epoch of the catalogue t_0 are given in Tab. 2 (m_0 means m_α or m_δ and analogously for m_μ). These errors are graphically compared in Fig. 1. It is evident that the precision of all the catalogues PZT01a,b,c is superior to that of PZT83 and PZT86 in longer time span.

4. CONCLUSIONS

The new PZT01 catalogue using more than 77000 transits in the period 1973–2002 gives the positions and proper motions of 305 stars with significantly better precision than each of the previous PZT catalogues. The standard errors of proper motions are comparable to those of the Hipparcos Catalogue. For the stars that were observed during the whole period the mean errors

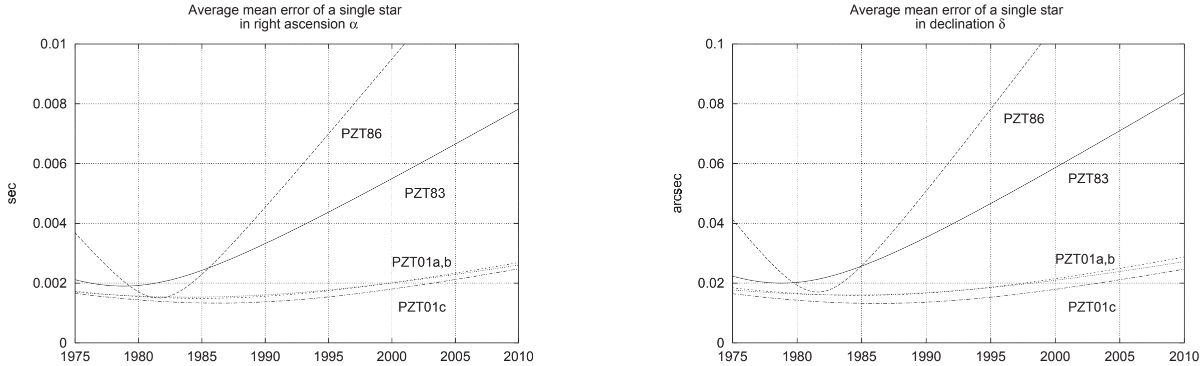

Figure 1: Comparison of the average mean errors in right ascension m_α and declination m_δ of a single star in the cataogues PZT83, PZT86 and PZT01a,b,c in the interval 1975–2010.

do not exceed ±0.003s and $\pm 0.03''$ in right ascension and declination, respectively, in the interval 35 years long. Adding the fictitious observations from AGK2/3 catalogues to the adjustment does not bring any longer an obvious improvement as it does in our previous solutions (PZT83, PZT89). The next processing of the PZT observations will be used to improve the new Earth Orientation Catalogue (Vondrák & Ron, 2003).

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