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Foreword

You will find herewith the proceedings of the workshop Ceres 2001 organized in honour of the bicentenary of the discovery of Ceres by Piazzi and dedicated to astrometry and physics of asteroids thanks to observational networks.

We are glad to present here these proceedings : the contributions of the participants covered all the topics of the workshop. They deal with celestial mechanics and physics of the asteroids and also with theoretical and observational studies. The progress of our knowledge on asteroids needs to investigate simultaneously these topics. The efficiency of the observational networks has been put into light and the need of an improved astrometric accuracy was demonstrated as a necessary step for new discoveries. The determination of the masses of the asteroids, the interpretation of the observations of occultations, will be improved thanks to high accurate astrometric observations, together with photometric measurements. Then we will be able to reach information on what are the asteroids and what are the composition and the evolution of the solar system.

We hope that discussions have been helpful for the participants and that collaborations have started among them.

Parameters of catalogue orientations as obtained from observations of the selected minor planets at Nikolaev Astronomical Observatory

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Abstract. *Photographic positions of 19 selected minor planets (SMP) obtained with the Zonal astrograph (F=2.04 m, D=0.12 m, field is 5°×5°) at Nikolaev Astronomical Observatory during 1961-1997 were reduced to the FK5 and ICRS systems. The average accuracy of minor planet positions is ±0.19 in FK5 and. ±0.16 in ICRS systems in both coordinates. (O-C) differences between observed and calculated positions of the 12 selected minor planets were used to calculate the mutual orientation parameters the FK5 and DE200, ICRS and DE200, ICRS and DE403 systems.*

1 . Introduction

The idea to use of bright minor planet observations for determination of the fundamental catalogue zero-point corrections was advanced by F. Dyson in 1928 and it was actively discussed in 30-th years of the last century [1]. It was supposed that star-like images of minor planets and night period of observations would be allowed to improve precision of minor planet positions as compared with observations of the big inner planets and Sun. As a result the precision of the determination of the zero-point corrections would be also improved.

It was obtained enormous number of the selected minor planet observations from 1935 up to now. These observations were used to define the orientation parameters of star catalogues $\Delta\alpha_0$ and $\Delta\delta_0$ and to study zonal periodical errors of reference catalogues. But using of the minor planet observations for this aim was not successful. Precision of the zero-point corrections by minor planet observations turned out to be worse than one of determination of the corrections by Sun and the big inner planets. Besides essential scatter of the zero-point corrections (especially for correction to origin of right ascensions) remained, both by observations of the same minor planet with different instruments, and by observations of different minor planets on the same instrument.

2 . Observations and reductions

The observations of SMP were started at Nikolaev Astronomical Observatory in 1961 when the Zonal astrograph was placed here. The photographic observations at Nikolaev were finished in 1998. Now CCD-observations are carried out on this instrument.

About 2.5 thousands of photographic observations of 19 SMP were obtained at Nikolaev from 1961 to 1997. Summery of these observations are given in Table 1. The way of observations and measuring of photoplates were kept unchanged during this entire interval. But the

different reference catalogues such as Yale, AGK3, SAO, PPM and FOCAT were used during 36 years of the observations. Second, reduction algorithms and programs have been developed and modified by different authors and at different time. Therefore it was necessary all observations to reprocessed to same reference system using new reduction programs. As of 19 minor planets observed the 12 brightest SMP accounted for 95% of all observations then only the 12 SMP will be discussed below.

At the beginning all observations of the 12 SMP were reduced to the FK5/JD2000 system using reference stars from the PPM catalogue. After publicizing Hipparcos and Tycho catalogues we reduced these observations to the new International Celestial Reference System (ICRS) using dependences, obtained in previous reduction, and reference star positions from Hipparcos and Tycho catalogues (HT).

Table 1 : Observations of minor planets at Nikolaev observatory in 1961-1997

Minor planet	Observational period	Number of positions	Number of oppositions	T days	V deg
1 Ceres	1961–97	217	22	131	28
2 Pallas	1961–97	264	26	124	26
3 Juno	1961–96	245	25	119	26
4 Vesta	1961–97	241	23	122	31
5 Astraea	1983	4	1	9	3
6 Hebe	1961–97	226	23	119	31
7 Iris	1961–97	197	20	129	39
11 Parthenope	1961–97	196	20	122	32
15 Eunomia	1987–91	12	2	111	25
18 Melpomene	1962–97	212	20	115	32
25 Phocaea	1976–91	34	4	95	25
39 Laetitia	1962–93	237	24	106	23
40 Harmonia	1962–94	203	21	112	32
148 Hallia	1977	8	1	122	26
185 Eunike	1973	6	1	84	18
389 Industria	1991	4	1	34	8
433 Eros	1975	11	1	46	26
532 Herculina	1975–92	68	9	102	24
704 Interamnia	1974–90	65	7	109	20
All observation		2450	251		

Because the accuracy of the Tycho proper motions is generally too low to calculate positions at other epochs with sufficiently accuracy the proper motions were taken from ACTRC catalogue. In result we obtained two rows of the minor planet observations in FK5 and in ICRS systems. The observed positions (O) were compared with positions computed in IAA (Institute of Applied Astronomy, St.-Petersburg) by planet theories DE200 and DE403 (C) [2]. The averaged accuracy of minor planet observations at Nikolaev is ±0.19 for FK5 and. ±0.16 for ICRS systems in both coordinates [3, 4].

3 . The orientation of the catalogue and dynamical reference systems from the observations of the minor planets

The 2328 positions of the 12 selected minor planets reduced to the FK5 and ICRS systems were used to determine the mutual orientation parameters the FK5 and DE200, ICRS and DE200, ICRS and DE403 systems. We used well-known equations of two coordinate system tie where ε_x, ε_y, ε_z are the angles of rotation of the catalogue frame axes around the x, y, z–ones of the dynamical frame of reference:

$$\Delta\alpha = \varepsilon_x \, tg\delta\cos\alpha + \varepsilon_y \, tg\delta\sin\alpha - \varepsilon_z$$
$$\Delta\delta = -\varepsilon_x \sin\alpha + \varepsilon_y \cos\alpha - \Delta\delta_0$$

As the interval of the Nikolaev observations of minor planets is sufficiently long we included in equations (1) the terms depending on time ω_x, ω_y, ω_z:

$$\Delta\alpha = tg\delta\cos\alpha\,(\varepsilon_x + \omega_x(t - t_0)) + tg\delta\sin\alpha\,(\varepsilon_y + \omega_y(t - t_0)) - (\varepsilon_z + \omega_z(t - t_0)),$$
$$\Delta\delta = -\sin\alpha\,(\varepsilon_x + \omega_x(t - t_0)) + \cos\alpha\,(\varepsilon_y + \omega_y(t - t_0)) - \Delta\delta_0$$

in which $\Delta\alpha$ and $\Delta\delta$ are (O-C) differences between observed and calculated minor planet positions; ε_x, ε_y, ε_z are the initial values of rotation angles and ω_x , ω_y, ω_z, are the initial values of spin or angular velocities of rotation at the initial epoch t_0 = 1991 07 20.0 TDB (JD 2448439.5). $\Delta\delta_0$ is the constant systematic error of the catalogue declination frame and not connected to the rotation angles. The calculations have been done in each minor planet separately and on all observations together. The results are given in Tables 2, 3. The unit weight errors, σ_0 , are given in the last column of the tables. So far as the orientation parameters for ICRS and DE200, ICRS and DE403 are very similar the ones for ICRS and DE403 are presented here only.

Table 2 : Orientation parameters of FK5 and DE200/LE200 systems by observations 12 SMP at the epoch JD=2448439.5 (in mas).

Mainor planet	ε_x		ε_y		ε_z		ω_x		ω_y		ω_z		$\Delta\delta_0$		σ_0
1 Ceres	12	±21	–32	±17	–35	±13	5.6	±1.9	–2.9	±1.5	1.0	±1.2	–53	±12	±161
2 Pallas	– 3	20	–18	18	–20	14	0.2	1.6	–0.8	1.5	–0.7	1.2	–35	12	171
3 Juno	19	20	33	21	–27	14	–0.3	1.8	1.7	1.8	0.2	1.3	–65	13	183
4 Vesta	– 2	19	8	18	–48	13	3.1	1.6	0.8	1.6	3.5	1.3	–109	12	179
6 Hebe	– 2	21	–13	22	–42	15	0	2.0	–1.8	1.9	3.0	1.3	–65	13	178
7 Iris	8	27	5	23	–46	18	8.0	2.2	–3.0	2.5	1.0	1.6	–53	15	198
11 Parthenope	16	28	– 9	25	–54	19	–0.6	3.1	0	1.7	2.3	1.5	–54	15	197
18 Melpomene	11	24	– 5	24	2	17	4.2	2.0	–1.3	2.1	0.4	1.4	–39	15	191
39 Laetitia	46	23	57	24	–46	16	4.0	1.9	–4.8	1.9	2.4	1.4	–65	14	202
40 Harmonia	20	30	16	28	–74	22	–0.4	2.4	1.6	2.1	2.3	1.7	–56	16	223

Table 2 : Orientation parameters of FK5 and DE200/LE200 systems by observations 12 SMP at the epoch JD=2448439.5 (in mas).

532 Herculina	13	40	−3	44	−65	28	−9.3	7.7	−6.0	9.0	6.1	5.7	−42	31	220
704 Interamnia	11	53	−37	48	−65	26	−2.1	8.0	−2.1	5.5	−6.7	4.2	− 8	40	190
All SMP	19	7	1	6	−39	5	2.3	0.6	0.2	0.5	1.5	0.4	−53	4	190

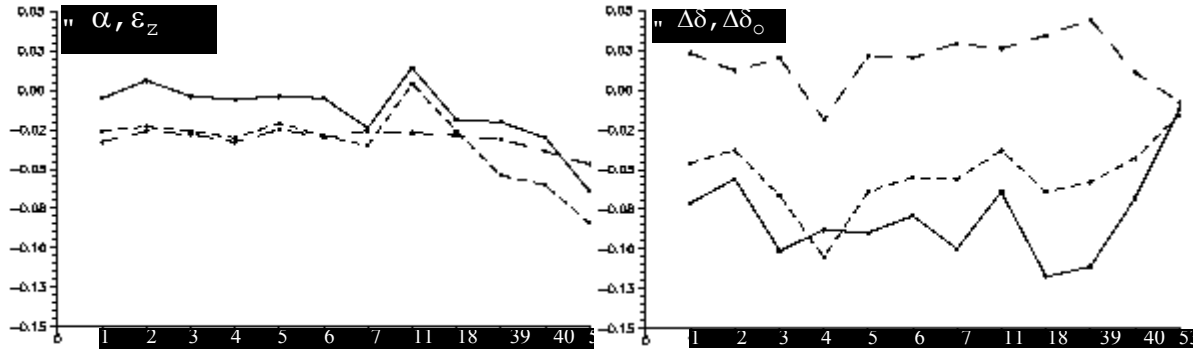
Table 3 : Orientation parameters of ICRS DE403/LE403 systems by observations 12 SMP at the epoch JD=2448439.5 (in mas)

Minor planet	ε_x		ε_y		ε_z		ω_x		ω_y		ω_z		$\Delta\delta_0$		σ_0
1 Ceres	21	±16	−14	±13	−36	±10	5.3	±1.5	−1.8	±1.2	0.2	±1.0	22	±9	±125
2 Pallas	−11	16	− 10	15	− 44	11	−1.8	1.3	−0.4	1.2	1.6	0.9	25	10	135
3 Juno	− 6	16	− 10	17	− 45	11	−1.6	1.5	−0.6	1.5	2.9	1.1	20	10	148
4 Vesta	− 4	14	− 12	13	− 44	10	1.5	1.4	0.5	1.2	2.5	1.0	− 24	9	133
6 Hebe	10	18	− 19	19	− 45	13	1.4	1.7	−1.8	1.6	2.7	1.2	16	11	155
7 Iris	8	23	6	20	− 49	15	2.6	1.9	−1.0	2.1	2.9	1.3	19	13	169
11 Parthenope	13	25	− 23	22	− 38	17	2.3	2.8	−1.3	1.6	1.4	1.3	40	14	175
18 Melpomene	15	21	− 2	21	− 38	15	3.1	1.7	−2.6	1.8	1.3	1.2	26	13	164
39 Laetitia	20	20	19	21	− 51	14	3.3	1.7	3.1	1.7	2.9	1.2	28	12	177
40 Harmonia	16	26	7	24	− 48	19	1.2	2.3	0.4	1.8	1.6	1.5	46	14	194
532 Herculina	5	27	− 11	30	− 42	19	−5.4	5.3	0.4	6.2	3.9	4.0	8	22	152
704 Interamnia	34	37	− 21	34	− 49	19	4.2	5.7	−3.2	3.9	1.6	3.0	34	28	136
All SMP	9	6	− 7	5	− 43	4	1.3	0.5	−0.6	0.5	2.1	0.4	22	3	158

As one can see from tables the values of orientation parameters ε_x, ε_y. ε_z are in a good agreement for ICRS–DE403 system and ones have large scatter for FK5–DE200 by the observations of the different minor planets.

4 . Influence of systematic errors of the reference catalogue on determination of the orientation parameters

To define reason of the large scatter of parameters ε_z, $\Delta\delta_o$ for FK5–DE200 we investigated star position differences between the PPM and HT catalogues for all reference stars (8060) used when the reduction of the 12 minor planet observations were made. Since systematic errors in HC and TC are believed to be negligible any difference between HT and PPM positions can be consider as errors in the PPM star positions. The mean differences (PPM–HT) (solid line) in right ascension (left) and in declination (right) averaged in the observation zone for the each minor planets and parameters ε_z and $\Delta\delta_0$, which can be considered as the corrections to zero–points of the FK5 (dotted line) and ICRS (dashed line) systems are shown on Figure 1.



Number of minor planet Number of minor planet

Figure 1 : Influence of the PPM catalogue systematic errors $\Delta\alpha$, $\Delta\delta$ (1) on determination of orientation parameters ε_Z (left) and $\Delta\delta_o$ (right) between catalogue and dynamical systems. FK5–DE200 (dotted line), ICRS–DE403 (dashed line).

As one can see on Fig.1 the scatter of the points for dashed line is insignificant. It testify about rather good taking into consideration of the systematic errors in the Nikolaev photographic observations of the selected minor planets. The solid line and the dotted line is in a good agreement on Fig.1. This fact can be considered as evidence of the influence systematic errors of the PPM catalogue on the determination of the orientation parameters between system of the PPM catalogue and dynamical system of reference given by the DE200 ephemeris. The anomalous value $\Delta\delta_o$ for Vesta possibly are caused by either irregular figure of Vesta or no taking into account of magnitude equation.

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