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Photographic observations of solar system bodies at the Engelhardt astronomical observatory⋆ *(Research Note)*

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ABSTRACT

We describe a large database of photographic observations of Solar System bodies obtained at the Engelhadt Astronomical Observatory (EnAO). We give a brief description of the methods of observations and the accuracy of their reduction with the PPM and Tycho-2 catalogues. The photographic positions of the major planets, except Jupiter, are in the system of the Tycho-2 catalogue and their comparison with DE200 ephemeris coordinates are given.

Key words. Astrometry – planets ans satellites: general – catalogs

1. Introduction

Modern technologies have replaced classical methods of observations in astronomy and in astrometry. However many photographic plates have been gathered at astronomical observatories. This point was reflected in the B3 XXIV IAU resolution (Andersen & Kraft 2001) by the IAU General Assembly.

The EnAO has a large database of photographic observations of various celestial bodies including solar system objects.

The results of reduction of observations of solar system bodies were published mainly in the Proceeding of the EnAO and Transactions of Kazan City Astronomical Observatory, thus are not available in English.

2. Photographic observations of Solar System bodies at EnAO and Zelenchuk station

The high altitude Zelenchuk station was built near the six-meter telescope in 1975 ($\lambda = 2^{\rm h}45^{\rm m}46.43^{\rm s}, \varphi = 43°39'10'', H = 2024$ m) (Rizvanov et al. 2001) equipped with a Zeiss astrograph 400/2000 and Schmidt camera.

We obtained about three thousand observations at EnAO and Zelenchuk station with the Zeiss telescope ($D = 400$ mm, $f = 2000$ mm), AFR-18 (photovisual, $D = 200$, $f = 2000$), 16'' refractor ($D = 400$ mm, $f = 3450$ mm), Meniscus camera ($D = 340$ mm, $f = 1200$ mm) and Schmidt camera ($D = 350$ mm, $f = 2000$ mm). The major planets with the exception of Pluto and Neptune were observed with a special cassette chamber equipped with a rotating disk which had an open sector to reduce the brightness of the planets. The dimension of the sector was chosen based on the brightness of the planet. The disk was placed in the centre of the astrograph field. The stars' true brightness were preserved.

3. Reduction of the observations

A brief description of the astrographic plate reduction method of the Solar System bodies is given below.

10 to 35 reference stars were chosen from each plate. The measurements were carried out with the machine "Ascorecord". We removed radial cubic distortion from the measured coordinates of reference stars and planets. The Zeiss Astrograph has a coefficient of distortion $v = -5 \times 10^{-8}$ mm/mm^3. We also took into account differential refraction and the error in the tilt. The first was calculated with the formulae given by Rizvanov & Dautov (1998) and the second was determined using the following atrometric plate solution:

$$ax + by + c + kx^2 + lxy = \xi, \quad dx + ey + f + qxy + ry^2 = \eta. \quad (1)$$

Standard coordinates of the reference stars ξ, η were calculated from their catalogue α and δ values for the epoch and equinox of the date of the observation using the standard formulae. Thus, we obtained the standard coordinates of the planets also for the epoch and equinox of the date of the observation. The planets' right ascension and declination were calculated with these standard formulae. The apparent topocentric coordinates were transformed into geocentric $\alpha_{\rm geoc}, \delta_{\rm geoc}$. To compare these coordinates with the ephemeredes of the planets the differences of $({\rm O–C})_\alpha$ and $({\rm O–C})_\delta$ were obtained.

⋆ Tables 3 to 7 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/444/625

Table 1. The accuracy of the reduction of planet observations in the systems of the PPM and Tycho-2 catalogues.

Planets	$(O–C)^S_\alpha$ PPM	$(O–C)^S_\alpha$ Tycho-2	rms^S_α PPM	rms^S_α Tycho-2	$(O–C)''_\delta$ PPM	$(O–C)''_\delta$ Tycho-2	rms''_δ PPM	rms''_δ Tycho-2
Venus	–0.010	–0.008	±0.028	±0.015	0.09	0.05	±0.30	±0.20
Mars	0.002	0.000	0.017	0.012	0.03	0.02	0.16	0.10
Saturn	–0.005	–0.002	0.030	0.016	0.01	0.00	0.30	0.21
Uranus	–0.023	–0.012	0.024	0.013	0.21	0.15	0.22	0.15
Neptune	–0.025	–0.015	0.013	0.008	0.00	0.00	0.36	0.18
Pluto	0.145	0.117	0.057	0.031	–0.48	–0.48	0.33	0.24

Table 2. Photographic positions of Venus in the system of the Tycho-2 catalogue.

Nn	Date	UTC	α	δ	$(O–C)_\alpha$	$(O–C)_\delta$
1	2	3	4	5	6	7
1	1991, Febr. 21	15h59m15.0s	23h58m30.024s	$-1^o20'16.17''$	-0.019^s	$0.05''$
2	1991, Febr. 21	15 59 55.9	23 58 30.157	–1 20 15.44	–0.013	–0.11
3	1991, Febr. 21	16 00 37.0	23 58 30.299	–1 20 14.24	0.001	0.20
4	1991, Febr. 22	15 48 29.5	00 02 56.484	–0 49 12.41	0.015	0.19
5	1991, Febr. 22	15 49 29.4	00 02 56.631	–0 49 11.14	–0.024	0.16
6	1991, Febr. 22	15 50 29.5	00 02 56.856	–0 49 10.03	0.014	–0.03
7	1991, Febr. 22	16 03 39.5	00 02 59.268	–0 48 53.03	–0.027	0.21
8	1991, Febr. 23	15 55 25.0	00 07 25.906	–0 17 43.87	–0.003	0.32
9	1991, Febr. 23	15 56 34.7	00 07 26.098	–0 17 42.92	–0.027	–0.25
10	1991, Febr. 23	15 57 44.5	00 07 26.311	–0 17 41.21	–0.031	–0.06
11	1991, Febr. 23	16 02 45.0	00 07 27.264	–0 17 34.41	–0.010	0.20
12	1991, Febr. 25	16 07 42.0	00 16 23.811	0 45 12.94	0.013	0.09
13	1991, Febr. 25	16 11 13.1	00 16 24.445	0 45 17.34	–0.007	–0.10
14	1991, Febr. 25	16 14 32.0	00 16 25.053	0 45 21.89	–0.015	0.12
15	1991, Mar. 1	15 58 52.0	00 34 11.745	2 50 11.62	0.003	–0.15
16	1991, Mar. 1	16 01 53.6	00 34 12.279	2 50 15.94	–0.025	0.23
17	1991, Mar. 1	16 02 02.0	00 34 12.317	2 50 16.22	–0.013	0.33
18	1991, Mar. 1	16 04 47.0	00 34 12.811	2 50 19.33	–0.029	–0.14
19	1991, Mar. 8	16 15 43.0	01 05 28.669	6 27 01.57	–0.018	0.33
20	1991, Mar. 8	16 22 53.0	01 05 30.027	6 27 10.41	0.004	0.05
21	1991, Mar. 8	16 23 37.9	01 05 30.173	6 27 11.66	0.011	0.34
22	1991, Mar. 8	16 24 23.0	01 05 30.284	6 27 12.55	–0.018	0.28
23	1991, Mar. 10	16 21 22.0	01 14 27.206	7 27 54.64	-0.013	–0.22
24	1991, Mar. 10	16 25 11.5	01 14 27.945	7 27 59.90	0.011	0.22
25	1991, Mar. 10	16 25 24.9	01 14 27.978	7 27 59.70	0.002	–0.26
26	1991, Mar. 10	16 29 41.5	01 14 28.776	7 28 05.30	0.001	–0.05
27	1991, Mar. 11	16 22 12.0	01 18 56.656	7 58 05.08	0.001	0.31
28	1991, Mar. 11	16 26 06.9	01 18 57.355	7 58 09.65	–0.033	–0.03
29	1991, Mar. 11	16 30 01.5	01 18 58.122	7 58 14.38	0.002	–0.19
30	1991, Oct. 10	15 59 43.5	01 18 59.782	7 58 25.77	0.008	0.12

When reducing the Pluto observations we only accounted for the proper motions of the reference stars. The equinox was not transformed to the epoch of the observation, thus we obtained astrometric coordinates for this planet.

4. Results

We used the PPM and Tycho-2 catalogues to reduce our observations. The PPM catalogue consists of two parts. The first includes 181 731 northern stars (Roser & Bastian 1991). The average errors in the stellar positions and their proper motions are about 0.27 arcsec and 0.43 arcsec/century. The second part has 197 179 southern stars (Bastian & Roser 1993), the average errors in the positions and proper motions are 0.11 arcsec and 0.30 arcsec/century. Tycho-2 catalogue (2000) includes 2 539 913 stars. The proper motions given in the catalogue were obtained by comparing positions from Tycho-2 with positions from the Astrographic Catalogue. Therefore they are considered to be highly accurate. The accuracy of stellar positions in Tycho-2 is about 60 mas and the accuracy of their proper motions is 2.5 mas/yr.

The accuracy of reductions of the observations with PPM and Tycho-2 are given in Table 1 where the following notations are used: $(O–C)^S_\alpha$, $(O–C)''_\delta$ are mean values of (O–C) (along

α and δ accordingly); rms_α, rms_δ are mean-square errors of $(\mathrm{O–C})^S_\alpha$ and $(\mathrm{O–C})''_\delta$.

The mean (O–C) values for Pluto given in Table 1 are calculated for observations taken between 1985 and 1991. However, if we look at the period 1988–1991 in detail, the values of $(\mathrm{O–C})_\alpha$ for Pluto with the Tycho-2 catalogue increase from $1.32''$ to $2.25''$. The values of $(\mathrm{O–C})_\delta$ are in the limits of $-0.41''$ to $-0.57''$.

The large (O–C) values for Pluto in both coordinates can be explained by the uncertainties of its ephemeredes and by the oscillations of the photometric centre of the Pluto-Charon system. Similar results were obtained earlier at the EnAO and Pulkovo observatories (Ryl'kov et al. 1995). The values of (O–C) for the other planets are within the accuracy of the photographic method. Photographic positions of Venus, Mars, Saturn, Uranus, Neptune and Pluto in the system of the Tycho-2 catalogue are given in Tables 2–7. The coordinates of the planets are apparent with the exception of Pluto, which are astrometric.

Column headers: the serial numbers of the observations: nn; date - year, month, day, time of the observations - UT; observed geocentric values of coordinates -α, δ; $(\mathrm{O–C})_\alpha$, $(\mathrm{O–C})_\delta$ in sense "observation minus ephemeredes DE200".

5. Conclusion

Table 1 shows that the accuracy of the reduction of our planet observations based on the Tycho-2 catalogue is higher than that of the reduction with the PPM catalogue, especially in right ascension. This is not surprising since both the systematic and random errors are smaller in the Tycho-2 catalogue (Nefedjev et al. 2003; Schwan 2000). This demonstrates that re-reduction of photographic observations with improved catalogues can significantly improve the accuracy and thus the value of old and, in the case of planets, unrepeatable observations.

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References

Andersen, J., Kraft, R. P. 2001, Information Bulletin IAU No. 88, 40

Bastian, U., Roeser, S., et al. 1993, PPM Star Catalogue, Positions and Proper Motion of 197179 Stars South of –2.5 degrees declination for Equinox and Epoch J2000 (Heidelberg, Berlin, New York: Spectrum Akademischer Verlag)

ESA 1997, The Hipparcos and Tycho Catalogue, 1200

Nefedjev, Ju., A., Rizvanov, N. G., Shaymukhametov, R. R. A comparative estimation of the accuracy of modern astrometric catalogues. 2003, Kinematics and physics celestial bodies, 19, 379 (in rus.)

Roeser, S., Bastian, U., et al. 1991, PPM Star Catalogue, Positions and Proper Motion of 181731 Stars North of –2.5 degrees declination for Equinox and Epoch J2000 (Heidelberg, Berlin, New York: Spectrum Akademischer Verlag)

Rilkov V. P., Dementjeva A. A., Narighnaj, N. V., Kitkin V. N. Photographic positional observations of Pluto with telescope EAO Zeiss 400, 1995, Deponirovano in VINITI 03.05.95, No. 1219-095, 7 (in rus.)

Rizvanov N. G., Dautov I. A., Astrometry with wide field astrograph, 1998, Kinematics and physics celestial bodies, 14, 5, 457 (in rus.)

Rizvanov N., Dautov, I., & Shaimukhametov, R. 2001, A&A, 375, 670

The Tycho-2 Catalogue, position, proper motion, and two color photometry of the 2.5 million stars. – Copengagen, 2000

Schwan, H. Systematic relations between the Hipparcos catalogue and major (fundamental) catalogues of the 20th century (Paper I). 2000, A&A, 373, 1099