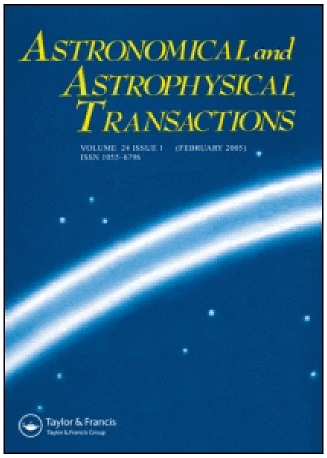

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Positional photographic observations of saturn, uranus, neptune, their satellites and pluto in 1990 with the telescope ZTA-2.6 m at byurakan in armenia

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POSITIONAL PHOTOGRAPHIC OBSERVATIONS OF SATURN, URANUS, NEPTUNE, THEIR SATELLITES AND PLUTO IN 1990 WITH THE TELESCOPE ZTA-2.6 m AT BYURAKAN IN ARMENIA

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The experimental astrometrical observations in the main focus of the high-lightpower telescope ZTA-2.6 m at Byurakan observatory have been carried out with the aim of providing precise coordinates of the outer planets and their satellites. 5 nights were used for the observations and 38 plates with about 150 images of planets and their satellites were obtained. The "two-step" method of reduction was applied with the FOCAT-S catalogue as a basis. The mean error is $\pm(0.24 - 0.56)''$ for a single "Satellite minus Satellite" or "Satellite minus Planet" measurement.

A strong distorsion of the projection was found in the astrometric treatment of the plates, with the magnitude of the order of $8 \times 10^{-6}\,\mathrm{mm}^{-2}$.

KEY WORDS Planet's satellites, positions.

In 1990, the astronomers of the Pulkovo Observatory proposed an experimental astrometric programme for the 2.6 m telescope of the Byurakan astrophysical observatory. The main purpose of the programme was to obtain accurate relative positions of outer planets and their satellites and the astrometric positions of Pluto. As far as we know, high-precision positional observations with an astrophysical lightpower telescope have been carried out for the first time. The great lightpower of the Byurakan telescope ($D = 2.6$ m, $F = 10$ m) and a favorable geographic latitude of the site had promised successfull observations.

Since astrophysical observations are the main purpose of this telescope, it was possible to realize only a short programme of planet observations. These observations were carried out in May 1990 during 5 nights. In total, 38 plates with about 150 images of outer planets and their satellites have been obtained. The plates were taken in the main focus of the telescope using a correction lense, which gives a round field of 45′ in diameter. The plates ORWO ZU-21, 16×16 cm were used. The exposures 1–5 min were chosen. The moments of exposure start and end were fixed with the accuracy of about $+-1$ sec.

OBSERVATIONS OF PLUTO

During 4 nights (26, 27, 29 and 31 of May), 14 plates with 46 images of Pluto have been obtained. The plates were measured using the semi-automatic Ascorecord Zeiss-machine. The astrometric reduction was made using the method of two steps of reference stars. The positions of faint reference stars in the vicinity of Pluto were obtained using the plates taken with the wide-angle astrograph in Bolivia in 1988. These plates were kindly put at our disposal by H. I. Potter. The coordinates of faint stars were calculated in the system of the reference catalogue FOCAT-S (FK5, J2000), consequently those of the Pluto maintain the same system.

The positions observed were compared with the theoretical ones using the theory DE-200 by N.I.Glebova (Institute of Theoretical Astronomy, St.-Petersbourg). The list of Plutonian positions and "O–C" is given in Table 1. The mean errors of positions can be found in Table 3.

DISTORSION IN THE POSITIONS OF PLUTO

In the course of the astrometric treatment of the plates with Pluto images, it was found that the local scale, as determined by close configurations of reference stars, differs essentially at different points on the photographs and depends on distance from the plate center and on the direction of the measurement. These facts indicate a strong distortion of the projection which takes place in the main focus of the Byurakan telescope. The following values of the local scale in the center of a plate and also along the radial and transversal directions (M_r and M_t) for the adopted distance of 45 mm (15′) were obtained:

$r = 0$	$M_0 = 20.919''/\text{mm}$	$F_{0\,\text{eff}} = 9860$ mm
$r = 45$	$M_r = 20.107''/\text{mm}$	$F_{\text{eff}} = 10{,}258$ mm
$r = 45$	$M_t = 20.579''/\text{mm}$	$F_{\text{eff}} = 10{,}023$ mm

If we approximate this distorsion effect by a cubic law,

$$\Delta r = cr^3 \tag{1}$$

the following values of the distorsion coefficient can be obtained (separately along and across the radius):

$$c_r = +6.6 \cdot 10^{-6}\,\text{mm}^{-2}; \qquad c_t = +8.2 \cdot 10^{-6}\,\text{mm}^{-2}. \tag{2}$$

We stress a great magnitude of the distorsion of the projection in the main focus of ZTA-2.6 m and to the unequality of c_r and c_t which implies that the distortion is asymmetric.

The correction of the distorsion of the coordinates of Pluto was applied in the following form (Kisselev, 1989):

$$\begin{aligned} \Delta\alpha^s &= \tfrac{1}{15}\sec\delta M_x c_r\left(\sum_{J=1}^{n} D_J x_J r_j^2 - x_0 r_0^2\right), \\ \Delta\delta'' &= M_y c_t\left(\sum_{J=1}^{n} D_j y_j r_j^2 - y_0 r_0^2\right). \end{aligned} \tag{3}$$

Table 1 The geocentric positions of Pluto (FK5; J2000.0; DE200)

The moment of observations in UTC.	*AR*	*Decl*	*(O–C)AR*	*(O–C)D*
1990 05 26.793940	$15^h12^m16^s.943$	$-1°18'32''.16$	$+0^s.160$	$-1''.46$
05 26.796570	15 12 16.901	−1 18 32.01	+0.134	−1.34
05 26.798300	15 12 16.885	−1 18 32.18	+0.129	−1.53
05 26.803840	15 12 16.854	−1 18 31.71	+0.131	−1.12
05 26.850930	15 12 16.543	−1 18 31.13	+0.105	−1.08
05 26.853700	15 12 16.543	−1 18 31.07	+0.122	−1.05
05 26.855780	15 12 16.515	−1 18 30.94	+0.106	−0.95
05 26.865470	15 12 16.480	−1 18 30.80	+0.140	−0.92
05 26.869630	15 12 16.459	−1 18 30.83	+0.134	−0.99
05 26.875170	15 12 16.408	−1 18 30.71	+0.116	−0.94
05 26.877250	15 12 16.383	−1 18 30.86	+0.104	−1.11
05 26.879330	15 12 16.375	−1 18 30.95	+0.108	−1.22
05 26.897670	15 12 16.256	−1 18 30.72	+0.100	−1.20
05 26.898770	15 12 16.251	−1 18 30.72	+0.102	−1.22
05 26.908410	15 12 16.185	−1 18 30.15	+0.094	−0.76
05 26.911530	15 12 16.165	−1 18 30.36	+0.093	−1.00
05 26.912630	15 12 16.144	−1 18 30.66	+0.078	−1.31
05 27.804810	15 12 10.856	−1 18 20.16	+0.163	−0.65
05 27.806900	15 12 10.837	−1 18 20.10	+0.157	−0.61
05 27.808970	15 12 10.837	−1 18 20.13	+0.169	−0.67
05 27.811050	15 12 10.821	−1 18 20.01	+0.166	−0.57
05 27.817970	15 12 10.771	−1 18 20.39	+0.157	−1.02
05 27.820060	15 12 10.770	−1 18 20.22	+0.159	−0.87
05 27.823170	15 12 10.734	−1 18 20.51	+0.151	−1.20
05 27.827330	15 12 10.713	−1 18 20.50	+0.155	−1.23
05 27.834580	15 12 10.657	−1 18 20.62	+0.143	−1.43
05 27.836670	15 12 10.654	−1 18 20.48	+0.152	−1.31
05 27.840820	15 12 10.636	−1 18 20.64	+0.159	−1.52
05 27.852590	15 12 10.567	−1 18 20.17	+0.161	−1.17
05 27.854660	15 12 10.561	−1 18 20.18	+0.167	−1.20
05 27.856740	15 12 10.516	−1 18 20.24	+0.135	−1.29
05 27.858820	15 12 10.536	−1 18 20.16	+0.167	−1.23
05 29.890760	15 11 58.389	−1 18 00.19	+0.132	−1.44
05 29.892850	15 11 58.386	−1 18 00.11	+0.142	−1.38
05 29.894580	15 11 58.369	−1 18 00.14	+0.135	−1.43
05 29.896310	15 11 58.354	−1 18 00.07	+0.130	−1.37
05 29.905020	15 11 58.302	−1 17 59.49	+0.130	−0.87
05 29.906820	15 11 58.295	−1 17 59.30	+0.133	−0.70
05 29.907920	15 11 58.285	−1 17 59.29	+0.130	−0.70
05 29.910340	15 11 58.271	−1 17 59.51	+0.130	−0.94
05 31.869380	15 11 46.751	−1 17 43.04	+0.113	−1.05
05 31.874910	15 11 46.733	−1 17 43.00	+0.127	−1.06
05 3.1875950	15 11 46.719	−1 17 43.10	+0.119	−1.16
05 31.894310	15 11 46.616	−1 17 42.89	+0.123	−1.10
05 31.896030	15 11 46.603	−1 17 42.63	+0.120	−0.85
05 31.897770	15 11 46.590	−1 17 42.62	+0.117	−0.85

Table 2 The relative coordinates of the satellites

Data UT		*X*	*Y*	*(O–C)X*	*(O–C)Y*
		S2–S6			
1990	05 28.970756	+207″56	−35″96	−0″31	+0″42
	28.972833	+207.48	−36.73	−0.15	−0.22
	28.974912	+207.46	−36.70	+0.07	−0.06
	28.976989	+207.74	−36.52	+0.58	+0.24
		S3–S6			
1990	05 26.988644	+126.17	+15.44	−0.26	−0.04
	26.992108	+126.28	+15.70	−0.85	+0.19
	28.970756	+150.78	−33.47	+0.48	+0.05
	28.972833	+150.64	−33.68	−0.42	−0.19
	28.974912	+150.38	−33.42	−0.45	+0.02
	28.976989	+150.80	−33.38	+0.02	+0.01
	31 967015	+90.92	−69.08	−0.37	+0.53
	31.968747	+91.27	−68.99	+0.10	+0.71
	31.970824	+91.27	−69.11	+0.10	+0.71
	31.973247	+91.33	−69.33	+0.25	+0.62
		S4–S6			
1990	05 26.988644	+94.81	+42.14	−0.70	+0.09
	26.992108	+95.20	+41.86	−0.64	−0.23
	26.994878	+95.46	+41.92	−0.64	−0.21
	27.002842	+95.93	+42.23	−0.94	0.00
	27.005612	+96.66	+42.21	−0.49	−0.05
	28.979756	+165.22	−43.78	−1.12	−0.06
	28.972833	+164.88	−43.74	−1.18	−0.01
	28.974912	+165.37	−44.08	−0.42	−0.35
	28.976989	+165.16	−43.88	−0.36	−0.16
	31.967015	+6.74	−78.76	+0.34	+0.44
	31.968747	+6.63	−78.63	+0.49	+0.49
	31.970824	+6.37	−78.39	+0.54	+0.64
	31.973247	+5.81	−78.28	+0.35	+0.64
		S5–S6			
1990	05 26.988644	+161.49	−2.93	−1.11	+0.18
	26.992108	+161.84	−3.53	−0.54	−0.33
	26.994878	+161.17	−3.46	−1.03	−0.20
	27.002842	+160.70	−3.35	−0.99	+0.10
	27.005612	+160.64	−3.88	−0.87	−0.37
	28.970756	+137.08	+4.71	−0.18	+0.02
	28.972833	+137.37	+4.54	−0.06	−0.12
	28.974912	+137.62	+4.61	+0.03	−0.03
	28.976989	+138.12	+4.75	+0.35	+0.13
	31.967015	+16.98	−93.57	+0.38	+0.67
	31.968747	+16.81	−93.57	+0.51	+0.62
	31.970824	+16.71	−93.46	+0.75	+0.68
	31.973247	+16.60	−93.51	+1.05	+0.56

Table 2 (continued)

Data UT		*X*	*Y*	*(O–C)X*	*(O–C)Y*
		S8–S6			
1990	05 26.988644	−133.40	−2.12	+1.65	−0.29
	26.992108	−133.42	−2.55	+1.61	−0.65
	26.994878	−133.87	−2.52	+1.14	−0.57
	27.002842	−133.58	−2.68	+1.39	−0.57
	27.005612	−133.46	−2.72	+1.49	−0.56
	27.009422	−133.76	−2.78	+1.17	−0.54
	28.970756	−166.53	−42.68	+0.93	+0.01
	28.972833	−166.78	−43.24	+0.77	−0.50
	28.974912	−167.56	−43.80	+0.08	−1.02
	28.976989	−167.92	−44.11	−0.21	−1.30
	28.995689	−167.75	−43.52	+0.74	−0.34
	29.000190	−167.42	−43.27	+1.25	0.00
	29.003307	−167.38	−43.28	+1.42	+0.05
		U1–U			
1990	05 28.952751	−12.97	+1.35	+0.09	+0.17
	28.954137	−12.63	+0.95	+0.43	−0.28
	28.958291	−12.52	+1.27	+0.52	−0.10
	29.931626	+10.37	+7.10	−0.75	−1.09
	29.942071	+11.36	+7.49	+0.04	−0.40
	29.944437	+10.84	+6.94	−0.51	−0.88
	29.946513	+10.66	+6.94	−0.72	−0.82
	29.956679	+11.39	+6.39	−0.17	−1.06
	29.960375	+11.50	+6.60	−0.11	−0.74
	29.964186	+11.46	+6.55	−0.20	−0.68
	30.949872	−3.19	+13.16	+0.07	−0.37
	30.951950	−2.50	+12.83	+0.68	−0.71
	30.954240	−2.59	+12.42	+0.53	−1.14
	30.956624	−2.37	+12.45	+0.68	−1.14
		U2–U			
1990	05 29.944437	−1.40	+18.96	−0.21	−0.63
	29.946513	−1.21	+19.00	−0.07	−0.60
	29.956679	−0.81	+18.35	+0.04	−1.28
	29.960375	−0.87	+18.70	−0.12	−0.94
	29.964186	−0.77	+18.53	−0.11	−1.12
		U3–U			
1990	05 28.952751	−8.71	+29.36	+0.21	−1.04
	28.954137	−8.73	+29.49	+0.15	−0.93
	29.931626	+11.36	+29.00	−0.56	−1.20
	29.944437	+11.68	+28.96	−0.50	−1.14
	29.946513	+11.78	+29.06	−0.44	−1.03
	29.956679	+12.19	+28.91	−0.23	−1.19
	29.960375	+12.37	+29.00	−0.13	−0.98
	29.964186	+12.57	+28.88	−0.52	−1.07
	30.949872	+28.61	−8.30	−0.22	−0.33
	30.951950	+28.52	−8.79	−0.30	−0.77
	30.954200	+28.45	−8.45	−0.36	−0.38
	30.956624	+28.90	−8.68	+0.11	−0.56

Table 2 (continued)

Data UT		*X*	*Y*	*(O–C)X*	*(O–C)Y*
		U4–U			
1990	05 28.952751	+23.10	−32.71	−0.74	+0.91
	28.954137	+23.37	−33.06	−0.46	+0.57
	28.958291	+22.97	−33.42	−0.79	+0.27
	29.931626	+6.14	−41.83	−0.89	+0.29
	29.944437	+6.33	−41.79	−0.46	+0.38
	29.946513	+6.38	−41.90	−0.37	+0.28
	29.956679	+6.16	−42.06	−0.33	+0.16
	29.960375	+6.26	−42.11	−0.22	+0.13
	29.964186	+6.23	−42.62	−0.17	−0.36
	30.949872	−27.53	−32.04	+0.58	+0.41
	30.951950	−27.66	−32.06	+0.47	+0.36
	30.954200	−27.68	−32.25	+0.49	+0.16
	30.956624	−27.44	−32.35	+0.75	+0.01
		N1–N			
1990	05 26.931517	+15.81	+1.57	−0.31	−1.21
	26.978609	+16.00	+1.03	−0.24	−0.92
	26.981381	+15.89	+0.91	−0.35	−0.99
	29.974921	−16.31	−1.04	+0.03	−0.13
	29.976999	−15.99	−1.16	+0.35	−0.29
	29.979076	−15.87	−0.93	+0.47	−0.09
	29.980808	−15.76	−1.18	+0.58	−0.37
	29.995526	−16.13	−0.81	+0.22	−0.27
	29.996737	−15.94	−0.95	+0.42	−0.43

Here $\Delta\alpha$ and $\Delta\delta$ are the corrections to the coordinates of Pluto calculated with the linear method; D_j are the "dependences" of the reference stars; x_j, y_i and x_0, y_0 ($j = 1, \ldots, n$) are the measured coordinates of the reference stars and the objects; M_x, M_y are the local scales in close configurations of reference stars; c_r and c_t are the coefficients of the distortion. The formulae (3) are valid if the radius vector of the planet coincides with the x direction (to the East) and the tangential direction defines the y-axis (to the North).

The distortion corrections for the coordinates of Pluto reach $+0^s\!.30$ in Ar and $-1.5''$ in Decl when Pluto is near the edge of a plate, and $+0^s\!.02$ and $-0.40''$, respectively if the planet is near the center. Owing to the inaccuracy of the model of distortion, the correction errors can be about 10%.

The distortion corrections calculated using (3) have been taken into account in the positions of Pluto given in Table 1.

OBSERVATIONS OF SATURNIAN, URANIAN AND NEPTUNIAN SATELLITES

In the main focus of the telescope ZTA-2.6 m, 15 plates with planets Saturn, Uranus, Neptune and their satellites have been obtained. The optimal exposures were 2 and 5 minutes for the satellites of Saturn, 3 and 4 minutes, for the satellites of Uranus and Neptune. The 3rd–8th satellites of Saturn, the 1st–4th

Table 3 Precision of the results

Objects, the kind of the coordinates	*N*	*(AR)*	*(Decl)*
Neptune (relative to stars)	8	±0.24″	±0.26″
Pluto (relative to stars)	46	±0.34	±0.26
Sat. of Saturn–Titan	52	±0.56	±0.36
Sat. of Uranus–Uranus	39	±0.44	±0.34
Sat. of Neptune–Neptune	9	±0.36	±0.41

satellites of Uranus and the 1st satellite of Neptune have been photographed. The images of Saturn were overexposured and could not be measured. The images of Uranus and Neptune were measured and their positions were obtained. The astrometric reduction has been made by the "two-steps" method with the help of intermediate faint stars of 12–15 magnitude whose coordinates were obtained from the plates of the expeditional astrograph in Bolivia. The positions of the planets and their satellites were reduced by the linear method of 6 constants with the catalogue FOCAT-S. The equatorial coordinates of the planets and satellites thus obtained were used to compute the relative positions of the satellites and planets. These relative coordinates in the form "satellite minus planet" ($X = \Delta\alpha \cos\delta$, $Y = \Delta\delta$, for Uranus and Neptune and "satellite minus Titan" for Saturn are presented in Table 2.

The relative coordinates of the satellites were compared with the theoretical ones given by the DE200 theory developed in the Institute of Theoretical Astronomy. "O–C" are given in Table 2. The mean errors of the coordinates presented in Table 3 characterize the precision of our observations, the errors of the reference catalogue (FOCAT-S) and the theoretical ones.

Table 3 confirms the possibility of applying the Byurakan telescope ZTA-2.6 m to astrometrical observations of outer planets and their satellites. The highest accuracy can be obtained after a detailed analysis of all the factors which distort the projestion of planets and stars.

Reference

Kisselev, A. A. (1989). Theoretical foundations of photographic astrometry. Moscow, Science, 260 p. (in Russian).