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PRELIMINARY RESULTS OF PLANET OBSERVATIONS WITH THE BELGRADE VERTICAL CIRCLE

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SUMMARY: Account is given of the method, organization and results of observations of outer planets with the Belgrade Vertical Circle, carried out in the period April 1983 to November 1984. The O – C differences for all the observed planets, as well as the mean errors of observations are given.

1. INTRODUCTION

Following the dermination of observations involved by the working out of the Bright Stars catalogue of declinations in the zone from +65° to +90°, performed with the Belgrade Vertical Circle (ASK ANIA, 190/2578 mm) the instrument is currently employed on the project: „Determination of declinations of the solar system bodies". Two observers are taking part: Dj. Bozhichovich and the author. Preliminary (experimental) observations were made during 1982 by the first observer which demonstrated that the obtained planet and the Sun's declinations possessed a satisfactory accuracy.

In the present paper are exposed results of this author's own observations of the planets Mars, Jupiter, Saturn, Uranus and Neptune carried out in 1983 and 1984. These will, simultanously, be the very fisrt results of observation with this instrument to have ever been published.

2. METHOD .ORGANIZATION AND RESULTS OF OBSERVATION

Declinations are observed differentially, the reference stars being selected from the FK4. The list of the observed stars is displayed in Table 1, where n – the number of observations, m – apparent magnitude. It goes without saying that the stars have been selected in such a way as to be as near, in right ascension and declination, to the observed planet as possible and, moreover, as symetrically distributed as only feasible. One usually took 4 to 6 stars to be linked with the planet under observation, but this number was, for the sake of better dependability, now and then increased. Each observing tour included determination of the horizontal flexure component, which took about 25 minutes.

Mars, Jupiter, and Saturn observations were executed by setting the micrometer threads on the north and south edges. When, on the E clamp, one started setting on the planet's north edge it was on the south edge that

Table 1. Reference stars actually observed with the planets

N°	N_{FK4}	m	n
1	1335	4.9	5
2	498	1.2	3
3	1348	5.6	6
4	1335	5.2	11
5	510	5.1	6
6	1365	6.4	7
7	523	4.3	3
8	1371	4.6	6
9	1374	6.3	2
10	1381	6.2	3
11	545	4.0	1
12	548	2.9	1
13	1390	5.6	5
14	556	3.4	6
15	559	4.7	11
16	564	2.7	1
17	1404	6.8	1
18	1405	6.7	3
19	1407	5.9	3
20	577	4.0	3
21	1413	5.0	20
22	1415	5.1	12
23	594	2.5	5
24	1419	5.5	3
25	597	2.9	12
26	607	3.1 var.	15
27	616	1.5–5.2 var.	2
28	1430	5.8	1
29	624	5.0	5
30	1437	7.6	12
31	1447	6.2	10
32	1449	6.1	6
33	644	3.4	10
34	1457	4.3	1
35	1463	4.9	9
36	682	4.0	8
37	687	2.8	2
38	1485	5.8	6
39	1493	6.2	8
40	706	2.1	1
41	710	3.6	8
42	1496	3.4	8
43	720	3.0	4
44	722	5.0	1
45	736	4.7	2
46	1517	5.1	2
47	753	4.6	2
48	1529	6.0	2

settings started on the W clamp, and vice – versa. There were in all four settings at each tranit in NSSN or SNNS orders. The planets Uranus and Neptune were observed by bisection. The verical micrometer fixed threads on which the observations were performed were: 1, 1.5, 2 and 3.

Over the period concerned Mars has been observed 13 times, Jupiter 18, Saturn 11, Uranus 16 and Neptune 9 times.

At reduction, it was the mean latitude, resulting from the observations of all stars on a given night, that was used. The latitude has been computed according to the well known formula:

$$\varphi = z + \delta_{app}$$

where z – the observed zenith distance and δ_{app} – the apparent star declination at the time of observation.

The zenith distance was determined from observation on two clamp positions: circle east (CE) and circle west (CW). The reduction was performed according to the formula:

$$z = \frac{1}{2}(C_W - C_E) + \frac{1}{2}(M_E - M_W)\mu + \frac{1}{4}(LU_E - LU_W)\lambda_U + \frac{1}{4}(LL_E - LL_W)\lambda_L + C_c + C_r + F + B + \rho$$

where:

C_E and C_W – circle readings on CE and CW positions; M_E and M_W – eye–piece micrometer readings on CE and CW positions; μ – mean eye–piece micrometer revolution μ = 19".99; LU_E, LU_W, LL_E, LL_W – upper and lower level readings on E and W clamps, λ_u and λ_L – mean division values of the upper and lower lavels, resp. computed by the expressions: $\lambda_u = 1".0408 - 0.0063\,(T - 1970.0) + 0.0037\,(t - 12^{s}.0) - 0.0004\,(l - 22.0)$, $\lambda_L = 1".0615 - 0.0083\,(T - 1970.0) + 0.0029\,(t - 12^{s}.0) + 0.0007\,(l - 22.0)$ (M. Mijatov, V. Trajkovska, 1984); C_c – correction to the circle division; C_r – correction for the run; F – correction for the curvature of the parallel; B – flexure (B = b sin z, b – horizontal flexure component measured on the particular night); ρ – refracton, computed according to the Pulkovo Tables.

The planet declination is deduced from the mean latitude furnished by the observed stars and the measured zenith distance using the familiar relation. Using these values and those obtained from the ephemeris (computed at the Pukovo Observatory according to VSOP–82 theory developed at the Bureau des Longitudes at Paris) one formed the (O–C) differences, exhibited in Table 2.

Table 2.

Date	JED	Initial instr. position	δ	O–C	Edge	Δπ	n	Note
			MARS					
	2445							
1984 5 18.91	839.41247	E	−17° 42' 13".23	0".36	N/S	14".65	6	4)
1984 5 19.91	840.40872	E	17 39 4.44	0.43	N/S	14.64	5	4)
1984 7 10.76	892.25621	W	18 13 3.23	0.60	I/II	11.06	9	2)
1984 7 11.75	893.25418	E	18 18 26.12	0.61	II/I	11.00	11	
1984 7 12.75	894.25219	E	18 23 57.57	−0.16	I/II	10.92	12	2)
1984 7 13.75	895.25022	E	18 29 34.76	0.78	II/I	10.85	10	
1984 7 14.75	896.24829	E	18 35 20.27	0.54	II/I	10.78	9	
1984 7 15.75	897.24638	E	18 41 12.30	0.60	I/II	10.71	6	2)
1984 7 19.74	901.23899	E	19 05 43.23	0.28	II/I	10.44	10	
1984 7 20.74	902.23720	E	19 12 12.57	0.73	I/II	10.36	10	2)
1984 7 22.73	904.23372	E	19 25 3.08	0.72	II/I	10.25	11	
1984 10 19.65	993.14609	W	25 02 40.81	0.85	II/I	6.43	6	2)
1984 10 22.64	996.14445	W	24 49 43.48	−1.18	I/II	6.34	4	
			JUPITER					
	2445							
1983 7 9.81	525.31179	E	−19° 43' 32".18	−0".36	S/N	1".73	4	4), 1)
1983 7 10.81	526.30889	W	19 3 4.33	−0.39	S/N	1.73	5	4)
1983 7 17.79	533.28886	E	19 40 46.84	0.31	I/II	1.69	3	
1983 7 18.79	534.28602	E	19 40 34.87	1.27	I/II	1.69	4	
1983 7 19.78	535.28321	E	19 40 26.05	1.30	N/S	1.68	4	4)
1983 7 20.78	536.28040	E	19 40 20.96	−0.21	I/II	1.68	0	1), 4)
1983 7 22.77	538.27480	W	19 40 13.58	0.64	I/II	1.67	3	2
1983 7 24.77	540.26924	E	19 40 15.73	0.83	I/II	1.66	2	2), 3)

Table 2. (continued)

Date	JED	Initial instr. position	δ	O–C	Edge	Δπ	n	Note
1983 7 27.76	543.26096	W	19 40 37.43	−0.75	I/II	1.65	3	2)
1984 7 10.91	892.41102	W	23 14 14.74	0.13	I/II	1.92	9	
1984 7 11.91	893.40791	W	23 14 44.50	0.62	II/I	1.92	11	
1984 7 12.90	894.40482	E	23 15 14.61	0.20	II/I	1.92	12	
1984 7 14.90	896.39864	E	23 16 11.84	0.59	II/I	1.92	9	
1984 7 19.88	901.38327	W	23 18 26.36	−0.50	II/I	1.92	10	
1984 7 20.88	902.38022	W	23 18 50.48	0.21	II/I	1.91	10	
1984 7 21.88	903.37716	W	23 19 15.11	−0.21	II/I	1.91	7	
1984 7 22.87	904.37410	E	23 19 38.87	−0.36	II/I	1.91	11	
1984 10 19.65	993.13609	E	−23 24 48.74	0.76	II/I	1.50	6	
			SATURN					
	2445							
1983 4 8.99	433.48604	E	− 9° 37' 35".82	0".19	S/N	0".81	2	
1984 4 19.90	839.39800	E	12 56 56.42	0.43	I/II	0.84	6	
1984 5 19.90	840.39508	W	12 55 45.61	0.66	I/II	0.84	5	
1984 5 21.89	842.38924	E	12 53 28.43	−0 67	II/I	0.83	7	
1984 5 26.87	847.37466	W	12 47 57.56	0.84	II	0.82	7	4)
1984 5 28.87	849.36885	E	12 45 55.38	−1.13	S/N	0.82	6	1)
1984 6 2.85	854.35437	E	12 41 6.13	−0.46	II/I	0.82	5	
1984 6 3.85	855.35149	E	12 40 11.81	0.15	II/I	0.82	4	
1984 6 17.81	869.31138	E	12 30 17.21	−0.71	I/II	0.81	5	
1984 6 23.79	875.29440	E	12 27 39.04	0.06	II/I	0.80	6	2)
1984 7 2.77	884.26922	W	−12 25 43.34	0.65	I/II	0.79	5	2)
			URANUS					
	2445							
1983 7 10.82	526.32003	E	−21° 08' 38".67	0".22	C	0".44	5	
1983 7 19.79	535.29483	E	21 06 28.68	1.84	C	0.44	4	4)
1983 7 22.79	538.28646	E	21 05 55.16	0.54	C	0.44	3	2),4)
1983 7 24.78	540.28091	W	21 05 35.32	−0.42	C	0.44	2	3), 4)
1983 7 27.77	543.27257	W	21 05 7.85	−0.51	C	0.44	3	
1984 5 26.96	847.46209	W	22 10 15.86	1.22	C	0.45	6	
1984 7 2.85	884.35395	W	21 58 37.94	1.03	C	0.45	7	
1984 7 10.83	892.33137	W	21 56 34.46	−0.45	C	0.44	9	
1984 7 11.83	893.32855	W	21 56 20.35	−0.71	C	0.44	11	
1984 7 12.83	894.32573	W	21 56 5.31	−0.28	C	0.44	12	
1984 7 13.82	895.32292	W	21 55 51.08	−0.77	C	0.44	10	
1984 7 14.82	896.32012	W	21 55 38.88	−0.46	C	0.44	9	1)
1984 7 15.82	897.31731	W	21 55 25.17	0.14	C	0.44	6	
1984 7 19.81	901.30609	E	21 54 36.51	−0 50	C	0.44	10	
1984 7 21.80	903.30050	E	21 54 12.98	0.37	C	0.44		
1984 7 22.80	904.29771	W	−21 54 2.65	−0.11	C	0.44	11	
			NEPTUNE					
	2445							
1984 7 10.89	892.38954	E	−22° 13' 47".92	0".99	C	0".28	9	3)
1984 7 12.88	894.38393	E	22 13 50.22	0.82	C	0.28	12	3)
1984 7 13.88	895.38113	E	22 13 50.99	1.17	C	0.28	10	3), 4)
1984 7 14.88	896.37833	E	22 13 51.53	1.79	C	0.28	9	3), 4)
1984 7 15.88	897.37553	E	22 13 53.75	0.76	C	0.28	6	3), 4)
1984 7 19.86	901.36432	W	22 13 59.27	0.18	C	0.28	10	3), 4)
1984 7 19.86	901.36432	W	22 13 59.27	0.18	C	0.28	10	
1984 7 21.86	903.35872	W	22 14 2.17	−0.17	C	0.28	7	
1984 7 22.86	904.35593	W	−22 14 3.30	−0.00	C	0.28	11	

The same Table gives also:

- Date according to universal time up to 0^d01;
- Julian ephemeris date up to 1.10^{-5};
- Initial instrument position (E or W);
- δ – Observed apparent geocentric declination, of the disc's centre
- Order of the observed edges (N, S, Center obtained from I – NSSN or II – SNNS orders of measurings);
- $\Delta\pi$ – correction for the parallax, computed by the formula:

$$\Delta\pi = 0.997\ \pi_o \sin(44^o48'13 - \delta);$$

- n – the number of the reference stars for the given planet observation;
- Note on the circumstances of observation (1 – through the cluds, 2 – image unsteady, 3 – image indinstinct, 4 – settings dubious).

The differences of the observed apparent semi–diameter R_o and the ephemeris apparent semi–diameter R_e are listed in Table 3.

The mean square errors σ of the (O–C) values for each planet separately, as well as m.s. errors ϵ of the differences $(R_o - R_e)$ are shown in Table 4. The $\overline{O-C}$ and $\overline{R_o - R_e}$ values, along with number of observation n are also given.

A comparison of the (O–C) values and their mean errors, resulting from the Belgrade Vertical Circle observations with those associated with the Wanschaff Verti cal Circle at the Kiew Observatory (Harin et al., 1980) disclosed the former to be somewhat smaller. This might in part be attirbuted to the Belgrade instrument being geographically more favourably located (lower latitude). The problem of the site selection for the instruments involved in the solar system bodies observation (refraction getting larger with the higher latitudes) was pointed at by these same authors.

These observations of ours are continually going on. Complete analysis will ensue after the observing programme will have been finished.

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Table 3. Differences of the observed and ephemeris semi–diameters of the planets

MARS

Date	$R_o - R_e$	Date	$R_o - R_e$
18.5.1984	1".96	14. 7.1984	0".75
19.5.1984	2.65	15. 7.1984	1.70
		19. 7.1984	0.71
10.7.1984	1.11	20. 7.1984	0.83
11.7.1984	0.92	22. 7.1984	1.09
12.7.1984	1.26	19.10.1984	1.56
13.7.1984	1.18	22.10.1984	1.29

JUPITER

Date	$R_o - R_e$	Date	$R_o - R_e$
10.7.1983	–0".58	10. 7.1984	3".07
17.7.1983	2.28	11. 7.1984	3.48
18.7.1983	1.06	12. 7.1984	3.42
19.7.1983	1.08	14. 7.1984	3.93
20.7.1983	1.60	19. 7.1984	2.39
22.7.1983	1.94	20. 7.1984	2.32
24.7.1983	0.78	21. 7.1984	2.60
27.7.1983	1.95	22. 7.1984	2.66
		19.10.1984	0.53

SATURN

Date	$R_o - R_e$	Date	$R_o - R_e$
		28. 5.1984	2".00
8.4.1983	1".83	2. 6.1984	1.18
18.5.1984	1.00	3. 6.1984	2.12
19.5.1984	2.01	17. 6.1984	1.82
21.5.1984	1.52	23. 6.1984	1.54
26.5.1984	1.94	2. 7.1984	1.22

Table 4.

Planet	$\overline{O-C}$	σ	$\overline{R_o - R_e}$	ϵ	n
Mars	0".40	±0".54	1".31	±0".55	13
Jupiter	0.23	±0.61	2.19	±1.00	18
Saturn	0.00	±0.65	1.75	±0.49	11
Utanus	0.20	±0.73	–	–	16
Neptune	0.75	±0.65	–	–	9

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