THE DETERMINATION OF COORDINATES OF SATURN BY OBSERVATIONS OF IT'S SATELLITES WITH 26-INCH REFRACTOR AT PULKOVO

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ABSTRACT. The results of determination of coordinates of Saturn from the observations of it's satellites without measuring the images of the planet are presented. 25 positions of Saturn have been determined from photographic observations with 26-inch refractor at Pulkovo in 1994–2003. The accuracy of Saturnian coordinates estimated by comparison of observational data with the theory DE405 is about ± 0.15" for both right ascension α and declination δ.

1. INTRODUCTION

Regular CCD and photographic observations of eight major satellites of Saturn with the aim of determination of relative positions of satellites are carried out at Pulkovo observatory with the 26-inch refractor. The results of observations are reduced by the "scale-trail" method [1] and are characterized by high inner and external accuracy. For photographic observations the inner standard error of one relative position of pair of satellites is equal to ± 0.06", and the external one is ± 0.12" [2]. For CCD observations the errors are ± 0.01" and ± 0.14" correspondingly. The "scale-trail" method does not require reference stars for the determination of relative positions of satellites. But the presence of at least one reference star with accurate position in the small field of view of telescope allows us to determine the coordinates of the planet without measuring it's image on the plate or CCD-frame. The problem may be solved if accurate coordinates of some reference star and theoretical cronocentric coordinates of satellite are known. The precision of coordinates of Saturn in this case is conditioned by precision of theory of motion of satellites, precision of coordinates of reference stars and errors of observations. The errors of theory of motion plays the main part because the errors of coordinates of stars in cosmic catalogues Hipparcos and Tycho-2 are small enough, not exceeding 0.1", and the errors of measurements are the same. The errors of theories of motion of different satellites do not exceed 0.1" - 0.2". Such method of determination of coordinates of Saturn has essential advantage since it does not require measurement of images of planet distorted by phase, rings and other atmospheric factors. Systematic errors of positions of Saturn caused by that factors run up to 0.4" in δ [2].

2. RESULTS

In this papier we present the results of our photographic observations of Saturnian satellites in 1994–2003. 25 positions of Saturn on 25 photographic plates have been determined by measuring satellites and stars of Hipparcos or Tycho-2 catalogues without measurement of images of Saturn.

From 1 to 6 stars and from 1 to 6 satellites were used on each plate and mean values were taken. Method of 6 constants was used for 5 plates, but 20 plates were reduced by the "scale-trail" method. The differences of positions of satellites and stars were determined. The cronocentric coordinates of satellites were taken from Harper and Taylor's ephemerides. Combining these values with coordinates of stars from Tycho-2 or Hipparcos catalogues we were able to calculate the topocentric coordinates of Saturn. The equatorial topocentric coordinates of Saturn (right ascension α and declination δ) at the epoch 2000 are presented in the Table 1.

Table 1: Topocentric coordinates of Saturn.

N of plate	Date (UTC)			α_{2000}			δ_{2000}			$(O-C)_\alpha$	$(O-C)_\delta$
				h	m	s	°	'	"	s	"
19690	1994	08	09.007930	22	52	04.650	-09	18	24.26	-0.005	-0.12
19988	1995	08	27.986915	23	36	55.330	-05	01	25.64	-0.015	-0.35
20107	1995	10	15.809035	23	23	55.805	-06	25	29.56	+0.016	+0.05
20108	1995	10	15.830485	23	23	55.516	-06	25	31.02	+0.010	+0.23
20109	1995	10	21.855919	23	22	41.950	-06	32	36.20	-0.008	-0.03
20110	1995	10	21.878699	23	22	41.690	-06	32	37.46	-0.010	-0.23
20751	1998	11	10.803692	01	50	54.728	+08	28	23.58	-0.002	+0.06
20752	1998	11	10.826522	01	50	54.322	+08	28	21.86	-0.022	+0.28
20953	1999	11	18.864532	02	44	20.014	+13	10	34.77	+0.010	-0.23
20963	2000	02	10.692300	02	37	31.753	+13	01	02.36	+0.009	+0.04
21117	2001	02	16.756527	03	30	41.797	+16	58	52.99	-0.002	+0.15
21202	2001	08	28.961833	04	52	18.131	+20	45	09.33	-0.006	+0.06
21214	2001	09	01.027415	04	52	56.053	+20	45	48.50	0.000	0.00
21215	2001	09	01.053163	04	52	56.351	+20	45	48.95	0.000	+0.13
21227	2001	09	20.100971	04	55	20.425	+20	47	12.48	+0.008	+0.06
21241	2001	10	23.026501	04	52	57.741	+20	39	46.39	+0.020	-0.10
21263	2002	02	01.769459	04	26	15.323	+19	59	15.03	+0.021	-0.04
21375	2002	12	10.945572	05	43	13.787	+22	03	34.60	+0.018	-0.32
21380	2003	02	01.826670	05	27	32.908	+22	02	10.32	+0.015	+0.04
21381	2003	02	04.925570	05	27	04.880	+22	02	26.10	+0.002	-0.19
21384	2003	02	15.747327	05	26	02.192	+22	03	52.56	+0.014	-0.01
21386	2003	02	20.752281	05	25	52.109	+22	04	48 43	+0.005	+0.04
21387	2003	02	21.742356	05	25	51.545	+22	05	00.53	-0.006	-0.11
21392	2003	03	02.711277	05	26	08.312	+22	07	09.02	+0.010	-0.08
21396	2003	03	04.793896	05	26	17.779	+22	07	43.26	+0.002	-0.01

The mean value of error in results depending on 4 satellites (measuring and theories) is about ± 0.07" for both α and δ. The comparison of coordinates of Saturn with DE405 ephemerides gives the following mean results: $(O-C)_\alpha = +0.003^s$, mean $(O-C)_\delta = -0.04$". The analysis of accuracy of Saturnian coordinates on the basis of (O-C) gives the following estimates: $\sigma_\alpha \cos\delta = \pm 0.15$", $\sigma_\delta = \pm 0.16$". From the results obtained we can conclude, that this method of determination of precise coordinates of far planets may be used for both photographic and CCD observations.

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3. REFERENCES

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