

# Observations of the satellites of the major planets at Pulkovo Observatory: history and present

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**Abstract.** In connection with long on-orbit European space satellite Gaia and the opportunity that now provides ESA, to use the results of observations of the space telescope, we would like to present some results of our long-term observations of the major planets satellites at Pulkovo Observatory. We hope to translate into reality these opportunities, namely the use of new observations and new ephemeris and a practical possibility of a new reduction for modern and old observations. The essential facilities can appear in the space, we give the shortest presentation of space project Orbital Stellar Stereoscopic Observatory.

**Keywords.** natural satellites of great planets, observations, space project OStSO

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The astrometric positional observations of the major planets and their satellites started almost since the foundation of Pulkovo observatory. The first photographic observations made with Pulkovo Normal Astrograph (PNA) since 1894 yr and continued during one hundred years. Now we have about 6500 plates with the bodies of the Solar System from of total quantity 48 000 plates collected in Pulkovo glass library. The most positions and the list of publications took place in our database [www.pulldb.ru](http://www.pulldb.ru) which is updated.

In the late nineteenth A. A. Belopolsky and S.K. Kostinsky received the first observations of the satellites of Mars on PNA . In 1899-1902 Kostinsky received positions of the satellite of Neptune, these observations were continued until 1930. In 1908-1922 Kostinsky also received the relative positions of six satellites of Saturn. Later the photographic observations of major planets and their satellites were continued at Pulkovo by means of the PNA and with 26-inch refractor that was established in 1956. In general, the bodies of the Solar System were observed in Pulkovo Observatory and in Pulkovo expeditions, on more than ten instruments, see [www.pulldb.ru](http://www.pulldb.ru).

Some of the most old plates of the late XIX and early XX century were lost during the Second World War, however, remained intact results of the measurements of planets and satellites and reference stars. Currently, observations are fulfilling also with automatic telescopes complexes ZA-320M at Pulkovo and MTM-500M at Pulkovo Mountain Station in Kislovodsk (North Caucasus).

The main telescopes that are now working at Pulkovo: 26-inch refractor (D=65 cm; F=10400 mm), PNA (D=330 mm, F=3467 mm), ZA-320 - complex automatic mirror astrograph ZA-320 (D=320 mm, F= 3200 mm ) Now Pulkovo telescopes are completely automated and equipped with modern CCD-cameras. The time distribution of the observations of major planets and their satellites is presented in table 1 , by asterisk the first photographic observations are noted.

We represent the astrometric observations in 2004-2006 of Jupiter's and Saturn's satellites, table 2 , which were made in Pulkovo Observatory with ZA-320 Mirror Astrograph. Processing was done by means of APEX program system in USNO-A2.0 and USNO-B1.0

Table 1. Observations, distributed in time

Mars	1960-1973	Saturn, satellites	1908-1922, 1971-2009
Mars,satellites (old)*	1894-1909	Pluton	1930-2010, 2003-2006
Mars,satellites (modern)	1973, 1986, 1988	Neptune,satellites	1899-1955, 1990, 1993
Jupiter, satellites	1974-2015	Uranus, satellites	1919-2016

Table 2. Observations with ZA-320 in 2004-2006

Satellites	N	$(O - C)_{\alpha \cos \delta}$	$\sigma_{\alpha \cos \delta}$	$(O - C)_{\delta}$	$\sigma_{\delta}$
Himalia	45	+0.13	$\pm 0.21$	+0.24	$\pm 0.18$
Elara	39	+0.11	$\pm 0.28$	+0.17	$\pm 0.32$
Pasiphae	33	+0.18	$\pm 0.30$	+0.16	$\pm 0.32$
Hyperion	56	+0.24	$\pm 0.24$	+0.25	$\pm 0.22$
Yapetus	62	+0.14	$\pm 0.22$	+0.20	$\pm 0.23$
Phoebe	91	+0.11	$\pm 0.26$	+0.16	$\pm 0.23$

catalogues system, see Devyatkin *et al.* 2006. Values of (O-C) and errors of observations are given in arcsecs.

We fulfilled the comparison some of old observations with the new ephemerides. As an example we give the results of Neptune's positions in 1899-1902.

We had  $(O - C)$  for relative distances  $S$  and for positional angles  $P$ . The mean values for 1899-1901 are equal  $(O - C)_s = -0''.25$  and  $(O - C)_p = -0^\circ.48$  in comparison of observations with calculations by means of Hermann Struve ephemerides and  $-0''.26$  and  $-0^\circ.11$  which are calculated with new ephemerides of Emel'yanov, 2015. In 1902 correspondingly  $(O - C)_s = -0''.51$  and  $(O - C)_p = -0^\circ.91$  with old ephemerides and  $(O - C)_s = -0''.53$ ;  $(O - C)_p = -0^\circ.35$  with new ones. We used the database UAI/IMCCE/SAI.

The old photographic images of Saturnian Satellites 2-6 recorded with the 26-inch refractor and the PNA at Pulkovo from 1972 to 1974 have been recently digitized see Kiseleva *et al.* 2016. The observed position of the satellites and Saturn time were compared with the ephemeris using the software at MULTI-SAT Emel'yanov & Arlo 2008. Authors note the remarkable increasing of precision. The errors after new reduction reached to  $0''.08$  and  $0''.17$  for each instrument correspondingly. At Pulkovo the project of creation of the Orbital Stellar Stereoscopic Observatory (OStSO) has been developed, which is designed to meet the multi-program action for fundamental researches in space, see:

[mmg.tversu.ru/images/publications/2016-vo14-n3/Chubey-2016\\_12\\_08.pdf](http://mmg.tversu.ru/images/publications/2016-vo14-n3/Chubey-2016_12_08.pdf)

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