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RESULTS OF MODERN PROCESSING OF URANUS AND NEPTUNE PHOTOGRAPHIC OBSERVATIONS FROM UKRVO ARCHIVES

The bulk of planet observations was obtained in RI «MAO» and MAO NASU from 1961 to 1994. Plates from AI UAS were used as well. Each plate of RI «MAO» was scanned 6 times, the plates from other observatories were scanned once. All images have been processed, most of them have been identified and the equatorial coordinates of all objects have been obtained. Positional accuracy of the reference stars varies within 0.04"–0.30". Standard deviation of the planet position ranges within 0.10–0.12 pixels, that corresponds, depending on the scale, to the range from 0".08 to 0".26. The comparison of new topocentric planet positions with JPL/HORIZONS ephemeris has been made. Differences (O—C) and their standard deviation have been obtained.

Keywords: astronomical data bases, astrometry, ephemerides, methods: data analysis, catalogs.

Ukrainian Virtual Observatory (UkrVO) has many resources [1—5] that can be used for solving various research problems. Here, we show a research using the UkrVO resources containing images of Uranus and Neptune, which started in 2014 [6]. The archives are mainly taken from RI «MAO» (Zonal Astrograph, ZA (12/204), scale 101"/mm, plate size 20×20 cm, filed of view (FOV) (5×5)°, epoch 1961—1994, exposure 3—5 min) and MAO of NAS of Ukraine (Double Wide Angle Astrograph, DWA (40/200), scale 103"/mm, plate size 30×30 cm, (FOV) (8×8)°, epoch 1977—1983, exposure 0.1—15 min; Double Long Focus Astrograph, DLFA (40/550), scale 38"/mm, plate size 24×24 cm, FOV (2.5×2.5)°, epoch 1963—1974; Zeiss 600 (Z600) (60/750), plate size 6×6 cm, FOV (0.5×0.5)°, epoch 1987—1990, exposure 0.1—18 min). The plates from AI UAS (Tashkent Normal Astrograph, TNA (33/350), scale 60"/mm, size 16×16 cm, FOV (2.5×2.5)°; Double Astrograph Zeiss, DAZ (40/300), scale 69"/mm, size 30×30 cm, FOV (6×6)°, epoch 1961—1983, exposure 3—15 min) were used as well. The number of found in databases and scanned plates is given in Table 1. The majority of plates has three exposures overnight with an interval from 1 to 20 minutes.

PROCESSING OF IMAGES OF PHOTOGRAPHIC PLATES

The images were scanned using *Epson Perfection V750 Pro* scanner (format A4, optical resolution 4800×9600 dpi, transparent region 25×20 cm, maximum dynamic range 4.0D) with a resolution of 1200 and 1600 dots per inch (dpi), at the RI «MAO», and *Epson Expression 10000XL* scanners (format A3, optical resolution 2400×4800 dpi, transparent region 43—30 cm, maximum dynamic range 3.8D) with a resolution 1200 dpi, at the

MAO of the NAS of Ukraine and at AI UAS. Having been processed the images were saved in FITS (Flexible Image Transport System) format. At the RI «MAO», each plate was scanned six times for excluding scanner random errors [7, 8]. The plates of other observatories, except for the trial one for each telescope, were scanned once.

All images were primarily processed in MIDAS environment, Linux OS, by the method described in detail in [9—12]. Further they were processed, including identification of objects based on reference catalogues and astrometric reduction for determination of equatorial coordinates, in Windows OS [12—13]. The content of software package and procedure for photographic observation processing are given in [12]. Using this algorithm all images have been identified and processed. The coordinates of all objects on the plates have been obtained. The current results are presented in Table 2.

The major part of plates has not been identified because of pointing errors in observations, the minor for poor quality of images as a result of large

Table 1

Number of Plates Scanned

Observatory	Telescope, epoch	Found in DB, pieces		Scanned out, pieces	
		Uranus	Neptune	Uranus	Neptune
RI «MAO»	ZA 1961—1994	220	218	201	202
MAO of NAS of Ukraine	DLFA, DWA, Z600 1963—1991	64	41	42	32
AI UAS	TNA, DAZ 1961—1983	15	1	15	1

Table 2

Number of Identified Plates and Angle Planet Coordinates Obtained

Observatory	Telescope	Identified	Not identified	Planet coordinates obtained
RI «MAO»	ZA	396	7	1172
MAO of NAS of Ukraine	DLFA, DWA, Z600	63	11	113
AI UAS	TNA, DAZ	15	1	32

Table 3

Average Intrinsic Accuracy of Determination of Planet Coordinates for Various Telescopes

Observatory/ telescope	Scale, "/pixel	Standard deviation of planetary position by RA,		Standard deviation of planetary position by DEC		Range of standard deviation of instrument star magnitude
		arcsec	pixel	arcsec	pixel	
RI «MAO» ZA	1.60—2.14	0.19	0.11	0.19	0.11	0.01—0.07
MAO NAS DLFA	0.79	0.09	0.11	0.08	0.10	0.01—0.03
MAO NAS DWA	2.17	0.22	0.10	0.26	0.12	0.04—0.05
MAO NAS Z600	0.59	0.10	0.17	0.09	0.15	0.04—0.06
AI UAS TNA	1.26	0.12	0.10	0.15	0.12	0.02—0.05
AI UAS DAZ	1.45	0.10	0.07	0.12	0.08	0.03—0.05

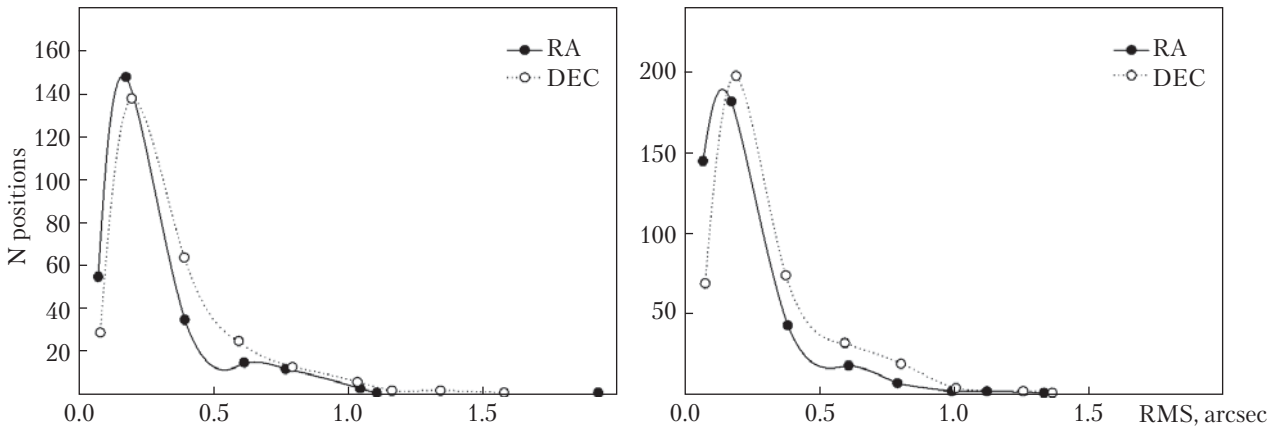

Fig. 1. Distribution of internal accuracy of positions of Uranus (*left*) and Neptune (*right*) for the RI «MAO» observation array

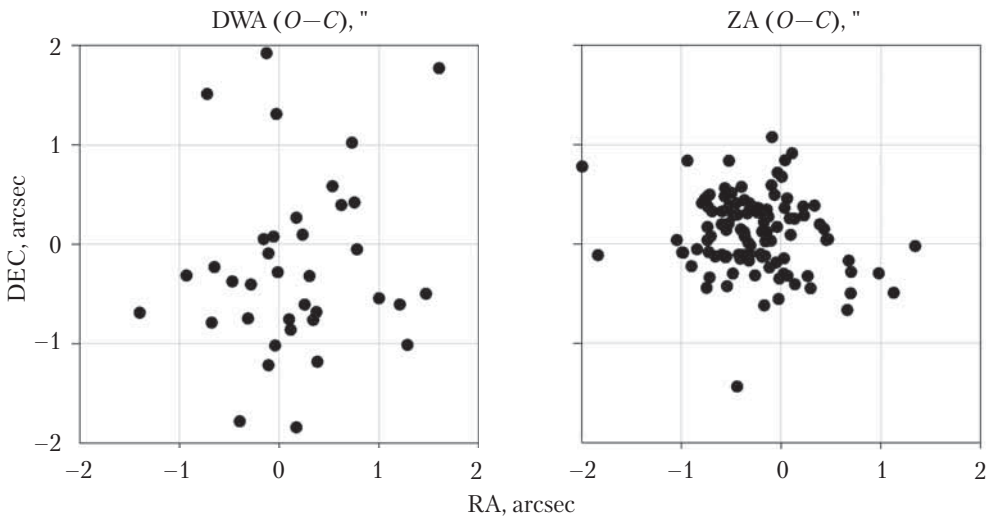

Fig. 2. Distribution of (*O*−*C*) differences for Neptune observations with DWA (*left*) and ZA (*right*) telescopes

veil on emulsion. Out of 396 identified plates from RI «MAO» 96 pieces were scanned with a resolution 1200 dpi and 300 ones were scanned with a resolution of 1600 dpi. The position accuracy of reference starts for the processed array ranges from 0.04 to 0.30". The standard deviation of planetary position by 6 scans varies within 0.10—0.12 pixels that corresponds to the range from 0.08" to 0.26", depending on the scale (Table 3).

In general, the results in terms of accuracy are little bit worse than the theoretical limit for the internal accuracy [8], which is explained by a small number of reference stars on the plates with bright planets. The distribution of internal accuracy of the planet coordinates obtained for the largest array of RI «MAO» is given in Fig. 1.

COMPARISON OF RESULTS WITH EPHEMERIS

For the exact moments of observations of all processed images the calculated (C) topocentric positions of planets from ephemerid JPL/HORIZONS [14] have been obtained. The calculated coordinates have been compared with the observed (O) ones. Differences (*O*−*C*) have been

obtained to vary within ±1 pixel for all telescopes, which corresponds to ±(0.8—2)". The distribution of ($O-C$) for the largest arrays of Neptune observations with ZA (RI «MAO») and DWA (MAO NAS of Ukraine) telescopes is showed in Fig. 2. For the RI «MAO» data the Figure features ($O-C$) differences only for the plates having three processed exposures. Average ($O-C$) right ascension and declination values for Neptune amount to (—0.220 ± 0.650)" and (0.099 ± 0.390)" respectively, for the ZA telescope and (0.165 ± 0.642)" and (—0.165 ± 0.893)" for the DWA telescope.

CONCLUSION

About 550 photo plates bearing images of Uranus and Neptune have been found in UkrVO; 88% of them have been scanned and nearly 85% have been processed. The internal accuracy of planet positions ranges within 0.10—0.12 pixels or (0.08—0.26)". Over 1300 topocentric positions for Uranus and Neptune have been obtained for the observation period from 1961 till 1994. Differences ($O-C$) between the processed observations and JPL/HORIZONS ephemeris have been obtained. The project is ongoing.

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РЕЗУЛЬТАТИ СУЧАСНОЇ ОБРОБКИ ФОТОГРАФІЧНИХ СПОСТЕРЕЖЕНЬ УРАНА ТА НЕПТУНА З АРХІВІВ УкрВО

Основна частина спостережень планет була отримана в НДІ «МАО» і ГАО НАНУ від 1961 до 1994 року. При обробці спостережень також були використані пластинки з АІ АН РУз. В МАО пластинки сканувалися по шість разів, у інших обсерваторіях — по одному разу. Більшість пластинок мають по 3 експозиції. Всі зображення оброблені. Більша частина ототожнена й отримані екваторіальні координати всіх об'єктів. Отримана позиційна точність опорних зір від 0,04" до 0,30". Стандартне відхилення положення планет знаходиться в діапазоні 0,10—0,12 пікселів, що відповідає в залежності від масштабу від 0,08" до 0,26". Проведено порівняння отриманих топоцентричних положень планет з ефемеридою JPL/HORIZONS. Отримано значення ($O-C$) та їх стандартне відхилення.

Ключові слова: астрономічні бази даних, астрометрія, ефемериди, методики аналізу даних, каталоги.

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РЕЗУЛЬТАТЫ СОВРЕМЕННОЙ ОБРАБОТКИ ФОТОГРАФИЧЕСКИХ НАБЛЮДЕНИЙ УРАНА И НЕПТУНА ИЗ АРХИВОВ УкрВО

Основная часть наблюдений планет была получена в НИИ «НАО» и ГАО НАНУ с 1961 по 1994 год. При обработке также использовались пластинки из АИ АН РУз. В НАО пластинки сканировались по шесть раз, в других обсерваториях — по одному разу. Большинство пластинок имеют по 3 экспозиции. Все изображения обработаны, большая часть отождествлена и получены экваториальные координаты всех объектов. Получена позиционная точность опорных звезд от 0,04" до 0,30". Стандартное отклонение положения планет находится в диапазоне 0,10—0,12 пикселей, что соответствует, в зависимости от масштаба, от 0,08" до 0,26". Проведено сравнение полученных топоцентрических положений планет с эфемеридой JPL/HORIZONS. Получены значения ($O-C$) и их стандартное отклонение.

Ключевые слова: астрономические базы данных, астрометрия, эфемериды, методики анализа данных, каталоги.