POSITIONAL CATALOGUES OF SATURN'S AND JUPITER'S MOONS

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ABSTRACT. In the framework of the UkrVO national project (http://ukr-vo.org/) we have started the processing of photographic observations of Saturn's (S1-S8) and Jupiter's (J6-J8) moons. Observations were conducted during 1961–1993 with three astrographs DLFA, DWA, DAZ and Z600 reflector. Plate images were digitized as tif-files with commercial scanners. Image processing was carried out by specific software package in the LINUX-MIDAS-ROMAFOT environment with Tycho2 as reference. The software was developed at the MAO NASU. Obtained positions of objects were compared with theoretically predicted ones in IMCCE (Paris) (www.imcce.fr/sat) online. Rms error of divergence between observed and calculated positions is of 0.20″ – 0.35″.

Key words: UkrVO, JDA, LINUX-MIDAS-ROMAFOT

1. Introduction

Position coordinates of the Solar System bodies are the necessary basis for the solution of a number of scientific and applied problems. According to Harper & Taylor (1994), there are significant gaps in the coverage of observations of Saturn's satellites in the world, there are no published data on their observations in 1948-1966. Therefore, plates obtained in MAO NASU (Goloseevo) in 1961-1993 may occur of particular interest to fill up and complement the global database of their observations.

2. Observations

Observations were made with two refractors DLFA (D/F = 400/5500mm, scale = 37,5″/mm), DWA (D/F = 400/2000 mm, scale = 103″/mm), sited in Goloseevo and with DAZ (D/F = 400/3000 mm, scale = 103″/mm) in Kitab as well as with Z600 reflector (D/F = 600/7500 mm, scale = 27.5″/mm) at the mount Maidanak in Uzbekistan. We pay tribute to the most active observers E.A.Hertz, O.M.Yizhakevych, I.V.Ledovskaya (Kulyk), R.F.Ly- siakova, S.P.Major, G.V.Moroz, A.B.Onegina, E.M.Sereda, Yu.K.Philippov.

After creating the archive of the photographic observations DBGPA (http://gua.db.ukr-vo.org/vo-mao/DB/) an opportunity arises to expand the list of observations through the plates of expected satellite images from other observational programs. In addition, there were found 70 previously untreated observations of these objects. Currently observational material consists of more than 320 plates.

3. Reduction

In 1980th, as the observations were accumulated, the step-by-step processing of Saturn's moons was carried out (Yizhakevich et al. 1980, 1991, 1994, 2012; Natural Satellites Ephemeride (IMCCE.Paris) http://www.imcce.fr/hosted_sites/saimirror/nssephe.php; IMCCE (Paris), NSDC, Observations, Astronomical positions. http://www.imcce.fr/hosted_sites/saimirror/bsapomaf.htm). Then the measurements were made with the measuring machines of the ASCORECORD type, lately with the automatic measuring machine PARSEK. Reference systems were built using different catalogs: AGK3, PPM, ACT, Tycho2. Particular attention was paid to the choice of models for the reduction of wide-angle shots and for Z600 shots with a small field. Basically it was the third-order polynomial using distortion terms. Number of reference stars on the wide angle plates was approximately from 20 to 50. For the reduction of Z600 reflector observations the method of two-step binding was used.

After the implementation of digital techniques in the photographic images processing we decided to reprocess the total accumulated material in the unified reference system of Tycho2. Plates were digitized on the commercial scanners of two types: Microtek ScanMaker 9800XL TMA (MSM) and Epson Expression 10000XL (EE) with the image resolution 1200 dpi.

The new methods of plate reduction have been developed by V.N. Andruk at the (Andruk et al. 2005, 2010). The proposed algorithms and debugged programs were designed to work in the LINUX-MIDAS-ROMAFOT environment.

Initially programs were developed to work with wide angle plates of DWA having dot star images and one or two expositions per plate. To process DLFA plates with several expositions of different durations, this software required to be modified in order to separate object images on expositions.

The sequence of positional determinations on photographic observations is well developed: first the rectangular coordinates xs, y of objects are determined, while program identifies and eliminates the errors for emulsion irregularities. Then Tycho-2 reference stars' identification in x,y array was made. The connection between tangential and measured coordinated is presented as infinite power series. The terms of polynomial depend on number of factors: quality of optical system, aberrations of the objective, scale and inclination of the plate to the focal plane and so on. The accuracy of the reduction also depends on errors of the measuring appliance and defects of the plate itself, as well as on the number of the polynomial terms. In our case for DWA plates (8°x8°) we use sixth-order

polynomial, and for DLFA plates (2°x2°) – third-order one. The accuracy of the reduction, or the r.m.s. error of unit weight over the whole plate field is 0.05″ – 0.15″. The number of reference stars is some hundreds for DWA and about 100 for DLFA plates. For the plates with small fields such as Z600 (0.5°x 0.5°) the method of two step binding is usually applied, using the plates with wide field as intermediate ones, DWA plates for example.

We demonstrate the accuracy of determination of equatorial coordinates as an example in Figure 1. In the left panel from top to bottom, respectively, it is shown the course of systematic differences Δα and Δδ between the measured and catalog coordinates for the right ascension and declination (α,δ) of TYCHO-2 before making the correction for scanners instrumental error for the studied astroplates. In the right panel, there are results of the reduction of the measured coordinates after correction for scanners instrumental error and accounting aberrations of telescope optics.

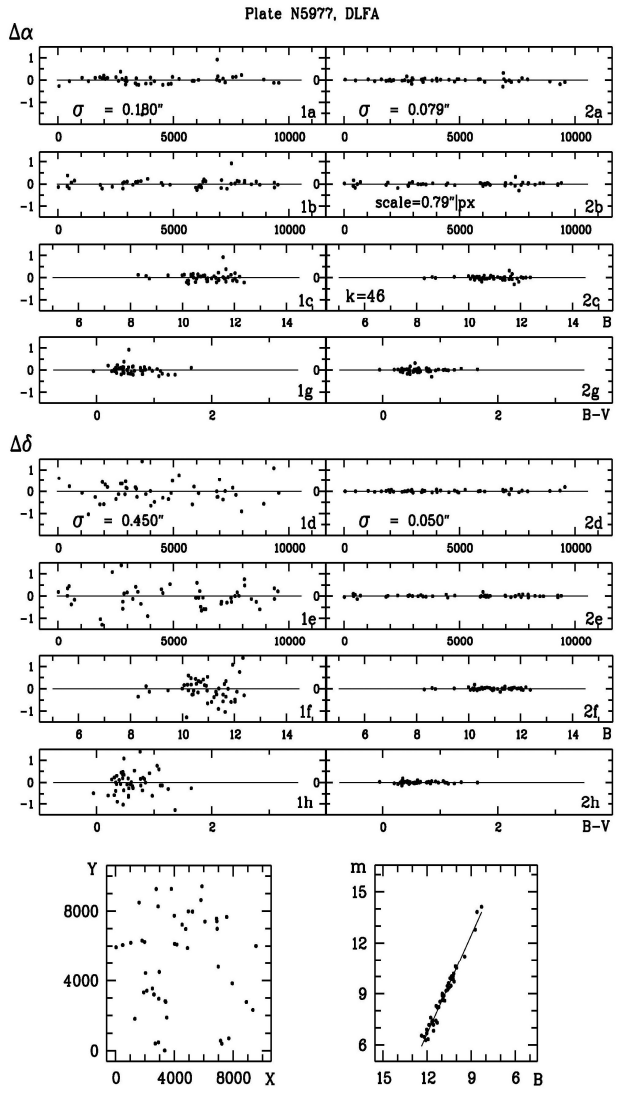

Figure 1: Systematic (left) and random (right) differ-ences between measured and catalog coordinates Δα and Δδ. At the bottom of the left – the distribution of stars TYCHO-2 on the plate field, on the right – the characteris-tic curves of DLFA's plate №5977.

The project of positional catalogs of Saturn's and Jupiter's moons is starting. Thanks to IMCCE (Paris) [IMCCE (Paris), NSDC, Observations, Astronomical positions. http://www.imcce.fr/hosted_sites/saimirror/bsapomaf.htm) ephemerides: (O-C)α (O-C)σ and their rms. errors are derived simultaneously and the error range is 0.20-0.35″.

Brief summary

The archive of photographic observations accumulated at the MAO NASU embraces the information about near space events never occur again. One of the important problem is the processing of astronegatives to obtain positions of different objects including Saturn's and Jupiter's moons. While the planets at all times are subjects to perturbations by the giant planets and satellites neighbors, their orbit parameters constantly need to be improved. The proposed new method for the reduction of photographic observations qualitatively improves and facilitates the processing of photographic observations. It becomes possible to identify and treat those satellites, which images were previously inaccessible due to a poor separation of planetary images.The work is in process as well as it is a part of our UkrVO project (Vavilova et al., 2010, 2011, 2012a, 2012b; Pakuliak et al., 2013; Shatokhina et al., 2015).

References

Andruk V. et al: 2005, *Kinematics and Physics of Celestial Bodies*, **21**, N5, 396.

Andruk V.M. et al: 2010, *Kinematics and Physics of Celestial Bodies*, **26**, N3, 75.

Izhakevich E.M., Pakuliak L.K., Kulyk I.V.: 2012, *Proc. of the Conf. NAROO- GAIA*, June 20-22, 2012, France, Paris, p. 161.

Pakuliak L.K. et al.: 2013, *Odessa Astron. Publ.*, **26**, 236.

Shatokhina et al.: 2015, *Kinematics and Physics of Celestial Bodies*, **31**, No. 1 (accepted).

Vavilova, I.B. et al.: 2012, *Kinematics and Physics of Celestial Bodies*, **28**, 85.

Vavilova, I.B. et al.: 2012, *Baltic Astronomy*, **21**, 356.

Vavilova, I.B. et al.: 2011, *Kosmichna Nauka i Tekhnologiya*, **17**, 74.

Vavilova, I.B. et al.: 2010, *Kosmichna Nauka i Tekhnologiya*, 16, 62.

Yizhakevych O.M.: 1980, Scientific paper deposited in All-russian institute of scientific and technical information**, No. 4553-B91**, 1.

Yizhakevych O.M., Kaltygina S.V., Major S.P., et al.: 1991, *Kinematics and Physics of Celestial Bodies*, **7**, №2, 98.

Yizhakevych O.M., Kaltygina S.V., Ledovskaya I.V. et al.: 1994, *Kinematics and Physics of Celestial Bodies*, **10**, №1, 88.