CCD OBSERVATIONS OF MINOR PLANETS IN MYKOLAIV IN 2002–2003

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The Zone Astrograph ($D = 0.12$ m, $F = 2.04$ m) of the Nikolaev Astronomical Observatory was equipped with the CCD camera of original manufacture (ISD017A, 1094×1160, 16×16 mkm^2) in 2000. After some modernization and refinement of the equipment and observation software the regular position observations have begun for bright (up to 13 magnitude) minor planets since August 2002. For evaluation of the quality of the obtained observations and to study the resources of the Astrometrica software [http://www.astrometrica.at] of the 4.3.2.346 version, the CCD images, obtained from August 2002 till the end of 2003, were processed. The results of the processing of 14 minor planets observations using UCAC2 catalogue, as a reference one, are presented in the paper. Evaluation of the accuracy for these observations was made from the comparison of observed and ephemeris positions.

INTRODUCTION

Ground-based astronomical observations are still the only means for determination of accurate positions and magnitudes for outer planets, their satellites, for a constantly increasing number of minor planets and comets. The principal tasks of celestial mechanics, connected with observations of minor planets and comets, are to determine or to improve their orbits, and also to identify them. Especially great interest to this problem is caused by the notably changed ideas about their number, a possibility for direct study with space missions Dawn, Muses-C, Hera, and also the necessity to identify, as in GAIA, *etc.*

The best ground-based differential observations of minor planets at contemporary telescopes, equipped with CCD detectors, have a high position accuracy at $0.06''$ [4], which is enough for determination of asteroid masses [1].

The regular CCD observations of selected minor planets began for improvement of minor planet's orbits and also for determining masses of perturbing asteroids at the Nikolaev Astronomical Observatory (NAO) in 2000. The programme is coordinated with the Institute of Applied Astronomy of the Russian Academy of Sciences and the French Observatory in Bordeax [2].

OBSERVATIONS AND THEIR REDUCTION

CCD observations of minor planets in 2002–2003 were made at the Zone Astrograph ($D = 0.12$ m, $F = 2.04$ m), equipped with a multipurpose CCD camera (ISD017P, 1040×1160, 16×16 mkm^2) made by NAO, in a tracking mode. Field of view of such a system is $28' \times 32'$, the scale is $1.61''$/pixel. At typical accumulation time of 2÷3 minutes for one image the limiting magnitude is 13÷14 magnitude. Accurate timing for observations was made with quartz synchronometer of the NAO time service, not worse than 0.5 ms.

There were obtained more than 400 images of 16 minor planets by observers L. A. Hudkova, A. V. Ivantsov in 2002–2003.

With a purpose to study astrometric properties of the Astrometrica 4.3.2.346 software for Windows [http://www.astrometrica.at], and also for selecting optimal turning, there was made its testing. The studying object was one of the images of the Milky Way field (RA = $03^h 19.8^m$, DEC = $+41°30'$), made by L. A. Hudkova and N. V. Maigurova on December 2, 2003. The image was obtained at the 9° of zenith distance, and it is rather densed with stars (more than 100 stars). Reference stars were taken from the UCAC2 Catalogue, and a cubic model was adopted for the link between measured and ideal coordinates.

The cubic model was adopted for such reasons, as it has shown two times smaller RMS (Root Mean Square) values of residuals for the stars, presented in the image, and there are enough stars for sure determination of its coefficients (20 for the complete model). We have not found a great difference between the quadratic and cubic models, but the RMS residuals of the cubic model looks regularly better, and we believe this is the best available in the Astrometrica software choice.

The subject for study was a dependence of RMS for residuals of reference stars from aperture radius for measuring. The residual is a difference (with a proper sign) between calculated position (observed position) and catalogue position at the epoch of observation. Aperture radius has been chosen from all other variables because the other parameters, such as “Detection Limit” (the minimum signal to noise ratio, required for the central pixel), “Minimum FWHM” (the minimum full width at half modulus for real objects), “PSF-fit RMS” (the maximum RMS for the difference between the model point spread function and the actually fitted profile) can influence on the number of stars found in the measurement and are useful for separation between stars and mess. Appropriate values for these parameters can be easily estimated from the comparison of the number of actually found stars with the number of catalogue stars presented in this field. The “Aperture Radius” (the radius of the synthetic aperture around the brightest pixel) determines a field where the approximation of star profile by Gaussian model takes place. The mentioned parameters are the only parameters which we consider can influence on the measurement process.

There have been chosen 63 stars, which are presented in all 24 measurements of one image. Their presence doesn’t depend on the value of the aperture radius. In Fig. 1 one can see the empirical dependence of RMS residuals (in arcseconds) in right ascension versus aperture radius in pixels. In Fig. 2 one can see the same dependence in declination.

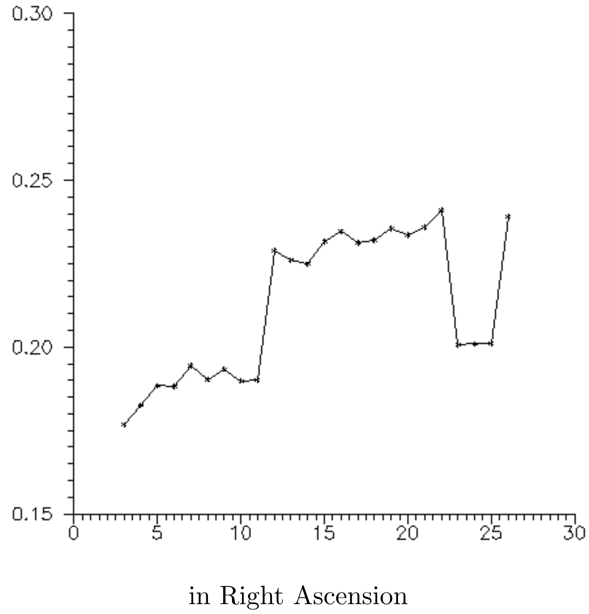

Figure 1. RMS residuals (in arcseconds) in RA versus aperture radius in pixels

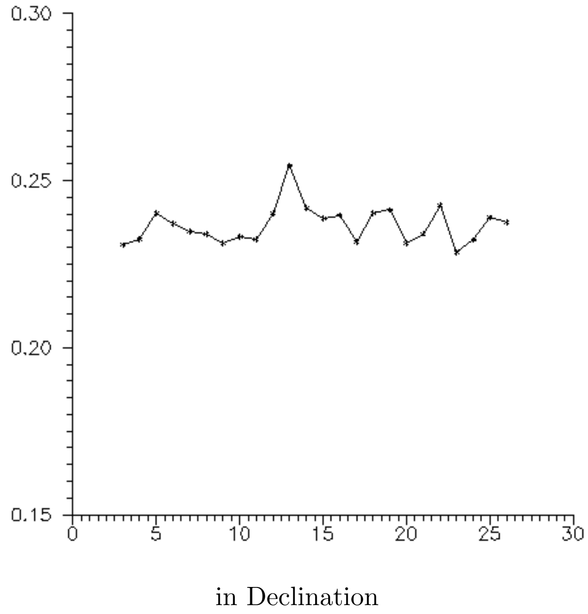

Figure 2. RMS residuals (in arcseconds) in DEC versus aperture radius in pixels

The found leap at the aperture radius of 12 pixels and greater (see Fig. 1) in RA tells us about the increasing of the RMS residuals and the worse position determination. The reasons for such leap can be due to inadequate model for star profile or to inadequate model for the link between measured and ideal coordinates. Figure 2 shows the fact that measurements are stable in declination.

REDUCTIONS

Ephemeris positions of the minor planets were calculated with the Ceres 2.34 software and elements of 2000 epoch, made by the Institute of Applied Astronomy of the RAS. Residuals (O–C) were calculated for 14 asteroids. In Table 1 one can see mean square residual for every planet after subtracting means at every night. This elimination allowed us to evaluate the observation error for every planet in supposing of the constant mean during one night observation.

The measurements of 287 images for 14 minor planets were made. Weighted mean error for a single position of minor planet in 287 observations was estimated to be $0.22''$ in right ascension and $0.23''$ in declination.

Table 1. Estimates for (O–C)

Minor planet	Number of positions	σ''_α	σ''_δ
Pallas (2)	13	0.39	0.30
Juno (3)	5	0.15	0.19
Iris (7)	9	0.19	0.27
Thetis (17)	44	0.18	0.19
Euphrosyne (31)	7	0.27	0.10
Pomona (32)	73	0.21	0.21
Doris (48)	5	0.15	0.12
Europa (52)	34	0.29	0.27
Cybele (65)	13	0.28	0.32
Freia (76)	16	0.38	0.45
Undina (92)	12	0.20	0.22
Alkeste (124)	40	0.18	0.18
Pompeja (203)	6	0.15	0.28
Polyxo (308)	10	0.10	0.16
Total	287	0.22	0.23

CONCLUSIONS

Obtained results show that the error in right ascension is 1.5 times less and in declination is 2 times less in comparison to the preliminary reductions in 2001 [3], made by us, due to such reasons, as

1. we have used the UCAC2 Catalogue, which has more accurate positions than the USNO-A2.0;
2. we have used cubic model for dependencies between measurements and ideal coordinates in comparison to the linear one in the Astrometrica software for MS-DOS;
3. the number of reference stars has been increased due to the automatic mode for choosing almost all stars presented in the image.

[1] *Fienga A., Bange J. F., Bec-Borsenberger A., et al.* Close encounters of asteroids before and during the ESA GAIA mission // Astron. and Astrophys.–2003.–**406**.–P. 751–758.

[2] *Ivantsov A., Kovalchuk A., Martynov M., et al.* Observations of asteroids with CCD telescopes according to the programme of international co-operation between Mykolaiv Astronomical Observatory (MAO), Institute of Applied Astronomy (IAA), and Bordeaux Astronomical Observatory (BAO) // Kinematics and Physics of Celestial Bodies. Suppl. Ser.–2000.–**3**.–P. 225–226.

[3] *Ivantsov A. V., Kovalchuk A. N., Pozhalova Zh. A., et al.* Results of the First Observations of Selected Minor Planets at Nikolaev CCD Zone Astrograph // Extension and Connection of Reference Frames Using Ground-Based CCD Technique: Intern. Astron. Conf. / Ed. G. Pinigin.–Mykolaiv: Atoll, 2001.–P. 127–133.

[4] *Stone R. C.* Accurate FASTT Positions and Magnitudes of Asteroids: 1997–1999 Observations // Astron. J.–2000.–**120**, N 5.–P. 2708–2720.