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ASTEROID OBSERVATIONS WITH NCSFCT AZT-8 TELESCOPE

The small Solar system bodies were observed using AZT-8 telescope (D = 0.7 m, f/4) of the National Center of Space Facilities Control and Testing (NCSFCT) in 2010—2013. The telescope is located near Yevpatoria, the observatory code according IAU is B17. The observational program included perturbed asteroids of the Main belt and NEA within the framework of GAIA FUN-SSO international project. The MPC database contains more than 4500 asteroid positions and magnitudes obtained during this period using AZT-8 telescope. The article presents analysis of the position accuracy of B17 observations obtained by comparison with data from AstDyS-2 and NEODyS-2 web services.

Keywords: asteroids, NEA, and positional optical observations.

Among the numerous scientific problems of GAIA space observatory, emphasis is laid on the small bodies of the Solar system [1]. To raise the effectiveness of their solution an initiative group from the Institute of Celestial Mechanics and Ephemeris Calculation (Paris) has created international project GAIA Follow-Up Network for Solar System Objects (GAIA FUN-SSO) [2]. AZT-8 telescope of the National Center for Space Facilities Control and Testing (NCSFCT) was involved in project observations. From 2010 to 2013, as part of GAIA FUN-SSO, the telescope was used for regular monitoring of perturbed main belt of asteroids and alert observations of near-Earth asteroids (NEA).

EQUIPMENT AND OBSERVATION METHODS

AZT-8 NCSFCT Telescope

The telescope was manufactured in 1968 by the Leningrad Optical and Mechanical Association. Originally it was a Cassegrain telescope designed for observations with photographic plates. For a long time, the telescope stayed idle. At the beginning of 2006, the telescope operability was restored by efforts of RI «MAO» staff. The telescope control system has been restored and a seat for the CCD camera in the telescope prime focus has been made. In the same year, the Keldysh Institute for Applied Mathematics temporarily installed FLI-1001E camera on the telescope and the first observations of 2004 XP14 asteroid were carried out [3]. The result of this research has showed the general possibility of observing such objects by AZT-8 telescope registered in the Minor Planet Center (MPC) under the code B17.

In January 2008, the telescope was equipped with FLI PL09000 camera based on Kodak KAF-9000 CCD matrix [4]. *Trimble Resolution-T* GPS-receiver was installed to bind the measurements to the timescale. In mid-2012, the telescope was equipped with an optical filter in *R* band. The basic parameters of the telescope are given in Table 1.

Method of Asteroid Observations Using AZT-8 NCSFCT Telescope

Asteroid ephemeris was calculated using an appropriate service of the Minor Planet Center [5]. To reduce the influence of refraction the asteroids were observed only in the time period when the inclination angle is less 70°. For each asteroid included in the observation program a series of 8—15 frames per hour was made during the observation night. Time interval between the two consecutive frames with asteroid image was 15—25 minutes. To increase the signal/noise ratio the «binning» mode with exposure of 90—120 s was used. The size of received frames in this case was 1528 × 1528 pix with a scale of 1.768"/ pix.

Processing of observations

In 2010—2011, CoLiTec software for automated detection of low-bright celestial bodies was developed by initiative group of Ukrainian researchers [6]. USNO-B1.0 was used as a reference catalog [7]. Starting with 2012, the observations have been processed by *Astrometrica* software [8] with UCAC3-4 [9, 10] as a reference catalog and cubic polynomial as reduction model for correlation of the measured and the tangential coordinates. In addition to the program objects, other asteroids often appear in the frame. For all asteroids detected in the frame, their topocentric position as equatorial coordinates was calculated and sent to the MPC database as standard measurement report (MPC Report).

The additional asteroids were detected using CoLiTec in an automatic mode under the operator's control and using *Astrometrica*, visually, by blink frame method.

The main purpose of observing the Main belt asteroids was to obtain positions of objects perturbed during close encounters for estimating mass of the perturbing asteroids. Further, these positions were transferred to RI «MAO» researchers for processing. The NEA observations were carried out according to GAIA FUN-SSO lists. The obtained data on asteroid positions were prompt-

Table 1

Basic Parameters of AZT-8 NCSFCT Telescope

Components	Info
CCD camera	FLI PL09000
Matrix size, pix	3056 × 3056
Pixel size	12 μm
Field angle with camera	44.6' × 44.6'
Focal distance	2827 mm
Scale	0.884"/pix
Threshold of magnitude at a *signal/noise* ratio of 3 and exposure of 10 s	17.5^m
Optical filter (since 2012)	OC-12

Table 2

Number of Asteroid (including NEA) Positions Obtained Using AZT-8 NCSFCT Telescope in 2010–2013

Year	MPC data	Data of AstDys-2 and NEODys-2
2010	1274 (85)	1251 (85)
2011	454 (24)	454 (24)
2012	1491 (7)	1483 (7)
2013	1319 (113)	1319 (113)
Total	4538 (229)	4507 (229)

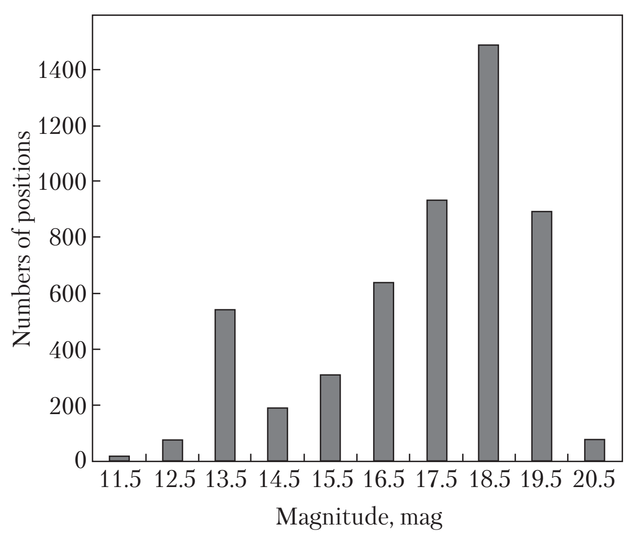

Fig. 1. Diagram of distribution of asteroid observations by magnitude using AZT-8 NCSFCT telescope (based on AstDys-2 data)

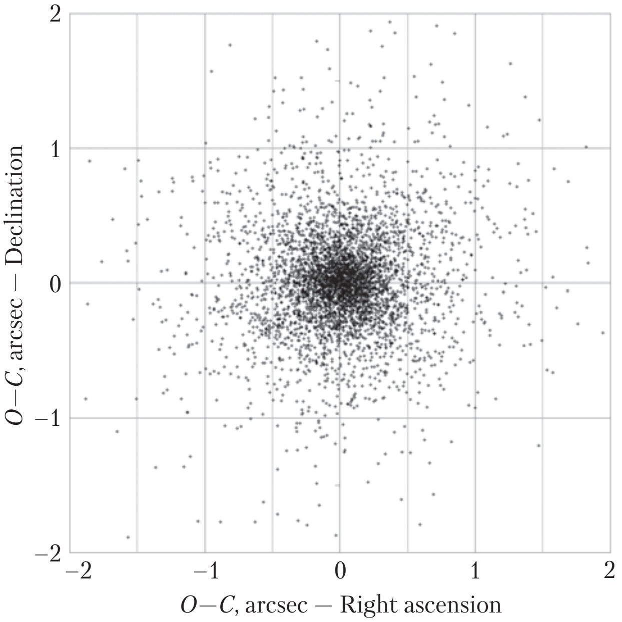

Fig. 2. Cross-distribution of differences (*O–C*) for declination and right ascension for B17 observations (based on AstDys-2 data)

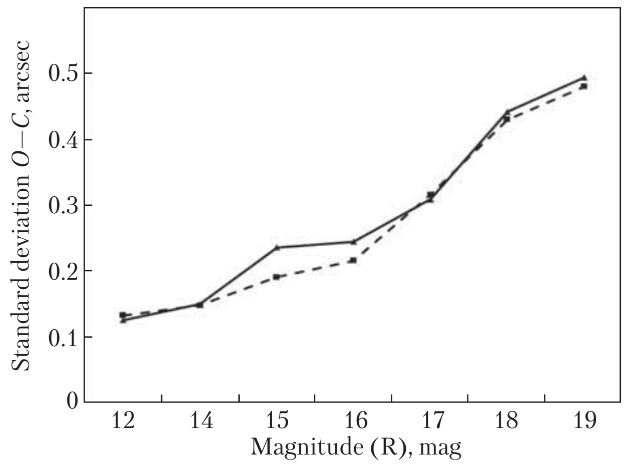

Fig. 3. Dependence of standard deviation of differences (*O–C*) on asteroid apparent brightness for observations with *R*-filter (based on AstDys-2 data). Solid line: right ascension, dashed line: declination

ly sent to the MPC data center and to the Institute of Celestial Mechanics and Ephemeris Calculation (Paris) as project coordinator of GAIA FUN-SSO.

OBSERVATION RESULTS

General Statistics of Observations

Totally, in 2010—2013, 4507 topocentric positions for 532 asteroids were obtained and transferred to MPC database [11]; little less data were recorded in AstDys-2 [12] and NEODys-2 databases [13]. Table 2 shows statistical data on the number of asteroid positions obtained within the reporting period.

As can be seen from histogram of distribution of the apparent asteroid brightness (Fig.1), the magnitudes of studied asteroids range 12—20.5^m according to AstDys-2 data, with the most of them having magnitudes in (17–19)^m range. Table 3 shows estimates of B17 observation accuracy based on data from MPC and AstDys-2 service.

Fig. 2 shows distribution between differences of the observed and the ephemeris coordinates

Table 3

Averages Differences (O–C) and Their Standard Deviation for B17 Observation Array Obtained Using AZT-8 NCSFCT Telescope in 2010– 2013

Year	*O—C* based on MPC data [13]		*O—C* based on AstDys-2 data	
	RA, ''	Dec, ''	RA, ''	Dec, ''
2010	–0.15 +/– 0.47	0.16 +/– 0.50	–0.07 +/– 0.44	0.04 +/– 0.48
2011	–0.11 +/– 0.47	0.04 +/– 0.43	–0.03 +/– 0.45	–0.05 +/– 0.43
2012	0.07 +/– 0.47	0.05 +/– 0.48	0.03 +/– 0.47	0.03 +/– 0.48
2013	0.07 +/– 0.38	0.02 +/– 0.38	0.07 +/– 0.39	–0.00 +/– 0.36
Average	–0.03 +/– 0.45	0.07 +/– 0.45	0.00 +/– 0.44	0.01 +/– 0.44

(*O*—*C*) for right ascension and declination. As one can see in Fig. 2, 90% of differences does not exceed 1".

As mentioned above, the asteroid observations were made as series of several frames. This enables to use standard deviation of differences (*O*—*C*) for estimate of position accuracy of the observations. Fig. 3 features dependence of standard deviation of differences (*O*—*C*) on magnitude. The Figure data show that the accuracy of obtained positions varies within (0.2—0.5)" for both coordinates depending on object's magnitude.

Results of Perturbed Asteroid Observations

Totally, during the entire period of observations, 997 positions of 43 perturbed asteroids have been obtained. It should be noted that the number of observations obtained for each asteroid, can vary essentially, from 3—5 positions overnight to more than 40 positions for several nights.

Average differences (*O*—*C*) and their standard deviations for the perturbed asteroids are estimated as (0.03 ± 0.30)" and (–0.01 ± 0.27)" for right ascension and declination, respectively. As one can see, the accuracy of perturbed asteroid observations is a little bit higher than the average accuracy of observations across the whole array of positions obtained. This is explained by the fact that because of being a main target, usually, the images of such objects are located in the center of frames and have a relatively high *signal/noise* ratio. A significant improvement of observation accuracy in 2013 seems to be explained by replacement of reference catalog UCAC-3 by UCAC-4 for astrometric reductions. Average differences (*O*—*C*) and their standard deviations for the array of positions of 2013 are estimated as (0.05 ± 0.19)" and (0.01 ± 0.19)" for right ascension and declination, respectively.

Results of NEA Observations

NEA for observations were selected from the list given by GAIA FUN-SSO. Totally, within the mentioned period, 229 positions of 9 NEA have been obtained. A large share in this array belongs to potentially dangerous 99942 Apophis asteroid during its close encounter with Earth. 83 Apophis positions with a relatively high accuracy have been obtained during 7 nights [15]. Average differences (O—C) and their standard deviations for the array of positions are estimated as (0.01 ± ± 0.24)" and (0.02 ± 0.20)" for right ascension and declination, respectively.

CONCLUSIONS

1. In 2010—2013, array of 4507 positions of 532 asteroids of the Main Belt and NEA was obtained using AZT-8 NCSFCT and transferred to MPC. Average standard deviation of differences (O—C) has been estimated as 0.4" for the objects having a magnitude in range of 13—20.5^m for rights ascension and declination. It should be noted that in the case of bright asteroids with a high *signal/noise* ratio the position accuracy, as a rule, does not exceed 0.2".

2. The array of obtained positions includes perturbed asteroids of the Main Belt during close encounters with heavier asteroids. These positions can be used in combination with other highly precise observations (including Gaia) for solving the tasks requiring long-term observations (detection of Yarkovsky effect, asteroid mass estimation by dynamic method, etc.).

3. The array of NEA positions can be used for more accurate determination of parameters of their orbits, which is one of the most important components of solving the problem of asteroids and comets that could pose an impact hazard to the Earth.

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СПОСТЕРЕЖЕННЯ АСТЕРОЇДІВ НА ТЕЛЕСКОПІ АЗТ-8 НЦУВКЗ

У 2010—2013 рр. на телескопі АЗТ-8 (D = 70 см, f/4) Національного Центру управління і випробувань космічних засобів проводилися спостереження малих тіл Сонячної системи. Телескоп знаходився біля м. Євпаторія, код обсерваторії B17 відповідно до класифікації МАС. Програма спостережень включала збурені астероїди головного поясу і АЗЗ в рамках міжнародного проекту GAIA FUN-SSO. База даних MPC містить понад 4500 положень і зоряних величин 532 астероїдів, отриманих в цей період на телескопі АЗТ-8. У статті представлено аналіз позиційної точності спостережень B17, отриманої в результаті порівняння з даними Інтернет-сервісів AstDyS-2 та NEODyS-2.

Ключові слова: астероїди, АСЗ, позиційні оптичні спостереження.

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НАБЛЮДЕНИЯ АСТЕРОИДОВ НА ТЕЛЕСКОПЕ АЗТ-8 НЦУИКС

В 2010—2013 гг. на телескопе АЗТ-8 (D = 70 см, f/4) Национального Центра управления и испытаний космических средств проводились наблюдения малых тел Солнечной системы. Телескоп находился возле г. Евпатория, код обсерватории B17 согласно классификации МАС. Программа наблюдений включала возмущенные астероиды главного пояса и АСЗ в рамках международного проекта GAIA FUN-SSO. База данных MPC содержит более 4500 положений и звездных величин 532 астероидов, полученных в этот период на телескопе АЗТ-8. В статье представлен анализ позиционной точности наблюдений B17, полученной в результате сравнения с данными интернет-сервисов AstDyS-2 и NEODyS-2.

Ключевые слова: астероиды, АСЗ, позиционные оптические наблюдения.