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Automatic telescope for observation of near-Earth asteroids

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The old 64-cm Richter–Slefogt telescope (F=90 cm) of the Crimean Astrophysical Observatory was reconstructed and equipped with the ST-8 CCD camera supplied by The Planetary Society as the Eugene Shoemaker Near Earth Object Grant. The first observations of minor planets and comets were made with the telescope in 2000. The CCD matrix of ST-8 camera in the focus of our telescope covers field of $52.7' \times 35.1'$. With 120-second exposure we obtain the images of stars up to the limiting magnitude of 20.5 mag within S/N=3. The first phase of automation of the telescope was completed in May 2002. According to our estimations, the telescope will be able to cover the sky area of 20 square deg with threefold overlapping during the night. The software for object localization, image parameters determination, stars identification, astrometric reduction, identification and cataloguing of asteroids is worked up. The first observation results obtained with the 64-cm CCD telescope are discussed.

АВТОМАТИЗАЦІЯ ТЕЛЕСКОПА ДЛЯ СПОСТЕРЕЖЕНЬ АСТЕРОЇДІВ, ЩО НАБЛИЖАЮТЬСЯ ДО ЗЕМЛІ, Румянцев В.В., Черних М.С. — У Кримській астрофізичній обсерваторії було відновлено 64-см телескоп Рихтера–Слефогта (F=90 см) за фінансової підтримки Інституту теоретичної астрономії й Міжнародного Інституту проблем астероїдної небезпеки (Санкт-Петербург, Росія) с метою проведення регулярних масових спостережень астероїдів, що наближаються до Землі. В травні 1999 року було проведено перші спостереження в первинному фокусі з ПЗЗ ST-8 (13.8×9.2 мм, 9×9 мкм/пікс, $52.7' \times 35.1'$, SBIG, США), отриманим від Американського Планетного товариства. При спостереженні вибраної ділянки SA-57 за 120 с експозиції були зареєстровані зорі 20.5 зор.вел. з S/N=3. Більшість зоряних зображень покривають 2×2 пікселя. Перша стадія автоматизації телескопу завершилась в травні 2002 р. На телескопі було замінено крокові двигуни та виготовлено новий блок керування ними. Згідно з першим пробним спостереженням, телескоп здатен покривати область неба в 20 квадратних градусів з потрійним перекриванням протягом ночі. Створено й налагоджується програмне забезпечення для локалізації об'єктів, визначення параметрів зображення, ідентифікації зірок, астрометричної редукції, ідентифікації та каталогізації астероїдів. Обговорюються перші результати спостережень, отримані з 64-см CCD телескопом.

АВТОМАТИЗАЦИЯ ТЕЛЕСКОПА ДЛЯ НАБЛЮДЕНИЙ АСТЕРОИДОВ, СБЛИЖАЮЩИХСЯ С ЗЕМЛЕЙ, Румянцев В.В., Черных Н.С. — В Крымской астрофизической обсерватории был восстановлен 64-см телескоп Рихтера–Слефогта (F=90 см) при финансовой поддержке Института теоретической астрономии и Международного Института проблем астероидной опасности (С.-Петербург, Россия) с целью проведения регулярных массовых наблюдений астероидов, сближающихся с Землей. В мае 1999 были проведены первые наблюдения в первичном фокусе с ПЗС ST-8 (13.8×9.2 мм, 9×9 мкм/пик, $52.7' \times 35.1'$, SBIG, США) полученной от Американского Планетного общества. При наблюдении избранной области SA-57 за 120 сек экспозиции были зарегистрированы звезды 20.5 зв.вел. с S/N=3. Большинство звездных изображений покрывают 2×2 пикселя. Первая стадия автоматизации телескопа была закончена в мае 2002. На телескопе были заменены шаговые двигатели и изготовлен новый блок управления ими. Согласно первым пробным наблюдениям, телескоп способен покрывать область неба в 20 квадратных градусов с тройным перекрыванием в течение ночи. Создано и отлаживается программное обеспечение для локализации объектов, определения параметров изображения, идентификации звезд, астрометрической редукции, идентификации и каталогизации астероидов. Обсуждаются первые результаты наблюдения, полученные с 64-см CCD телескопом.

Crimean program of observing Near Earth Asteroids is a logical continuation of the photographic review of minor planets conduct in the Crimean Astrophysical Observatory (CrAO) since 1963 to 1997 [1]. In 1993 the work was started according to the initiative of A.G.Sokolsky and N.S.Chernykh on the reconstruction of old 64-cm telescope in order to use it for observing of the asteroids, approaching to the Earth.

Table 1.

	ST-8
CCD size	1530×1020
Area	13.8×9.2 mm
Field of view	$52.7'\times35.1'$
Pixel	9μ
Well Depth	80 Ke
Digital resolution	16 bit
Dark signal	36 e/min·pix @ 0°C
Read noise	15 e^{-1}

Table 2. Limit magnitude with CCD

	64-cm telescope			
	$S=1700$ cm^2			
T, sec	10	30	60	120
m	19.1	19.7	20.1	20.5

64-cm telescope of Richter–Slefogt system was designed and built by the German company Carl Zeiss Jena during the Second World War. Telescope has a spherical mirror of diameter $D=675$ mm and focal length 905 mm. Correction system consists of two lenses of diameter 643 mm.

Flat surface of second lens has an aluminum covering of diameter 285 mm and serves a secondary mirror, shortening an optical system. Focal length of the whole system is 894 mm. Field of view is 80 mm and has a radius of curvature 90 cm. Flat field correction lens, installed before focal surface, ensures a flat field of diameter 60 mm (4 degrees) and shortens an equivalent system focal length to $F=822$ mm. Focal surface is inside the tube, on the distance of 35 cm from back edge of the cassette tube.

In March 1999 we have got CCD camera SBIG St-8 for a grant of the American Planetary Society, given to us in October 1997 for the developing of the ITA-CrAO observing program. Its main features are presented in the table 1.

Limiting magnitude registered by CCD telescope, depends on acting area of telescope, technical features of CCD matrixes, time of accumulations and background of the sky and it can be determined by following expression:

$$m=7.1+0.5\mu+2.5\lg\frac{\sqrt{S\eta T}}{k\Delta}$$

where S — effective area of telescope in sq.cm., η — quantum efficiency of CCD matrix, T — exposure in seconds, Δ — side of square of number of elements, covered by image of the star on matrix in arcsecond, k — signal to noise ratio, μ — brightness of the sky background in stellar magnitudes for square arcsecond. Considering constructive particularities of the optical system of our telescope and taking the values $\mu=21.0^m$/sq.arcsec, $\eta=0.4$, $k=5$, $\Delta=4$, one find the values of limiting magnitude depending on exposures (table 2):

In May of 1999 we had begun the first test observations with the matrix ST-8, installed in the

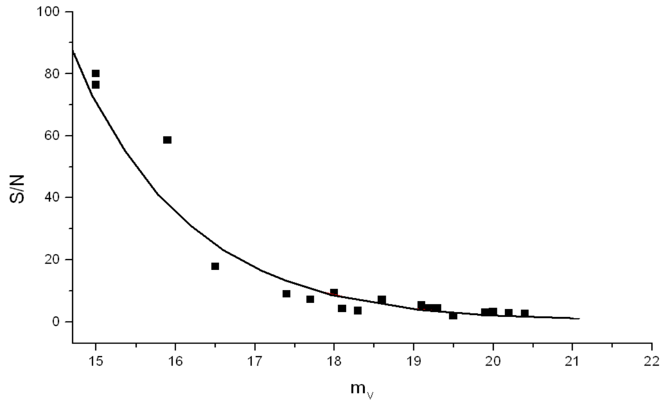

Fig. 1. Dependence of relations S/N on magnitude for 2 minute exposures

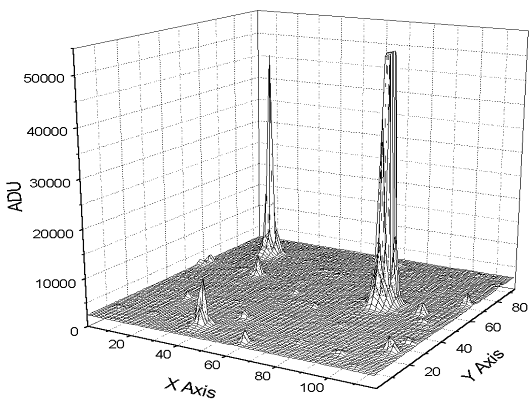

Fig. 2. Fragment of frame $3'\times4'$

Table 3. Accuracy of astrometric observations of some objects

Object	Number	Period of observation	$\sigma\ \alpha$ (arcsec)	$\sigma\ \delta$ (arcsec)
C/1999 H1	6	08.11.1999 – 10.11.1999	0.4	0.2
C/1999 J2	6	16.07.2000	0.4	0.4
2000 NM (Motion = $10''$/min)	64	04.07.2000 – 28.07.2000	0.1	0.3
1999 KW4 (Motion = $45''$/min)	36	24.05.2001	0.4	0.4

Table 4. Possible number of Near Earth Asteroids of corresponding limiting magnitude

Limiting magnitude V	16	17	18	19	20	21
Number of NEA	0.3	0.7	1.8	4.6	11.7	22.5

primary focus of the telescope. We found that limit magnitude for stars is 20.5^m with for exposure of 2 minutes that is in well agreement with theoretical evaluations. Fig. 1 presents values of a signal to noise ration S/N for stars of field. Limit magnitude was estimated from observations of selected areas SA 51 and SA 57 [2].

Telescope gives image of the stars of the diameter $2\sigma = 18\mu$, that corresponds to an area of 2×2 pixels. Fragment of frame $3'\times4$ with the stars of different brightness is shown on fig. 2.

Evaluation of an overexposed stars shows that stars brighter then 11.7^m cause an overflow of charge in pixels. Amount of the overexposed stars in the frame can be several dozens.

V.V.Rumyantsev had developed a software AstroMet ver.1.2 that allows to make a preliminary image preprocessing, localization of the registered stars, determination of parameters of image of stars and astrometric and photometric reduction. Profiles of star are presented by the fixed Gauss model functions [3]

$$D_{x_i,y_i} = a_1 + a_4 \exp\left\{-\frac{1}{2(1-a_9^2)}\left[\left(\frac{x_i-a_5}{a_6}\right)^2 + \left(\frac{y_i-a_7}{a_8}\right)^2 - 2a_9\left(\frac{x_i-a_5}{a_6}\right)\left(\frac{y_i-a_7}{a_8}\right)\right]\right\}$$

Here a_1 refers to local background density, a_4 describes peak density in image, a_5 and a_7 describe image center coordinates and a_6, a_8 and a_9 describe the axis and orientation of general elliptical figure of star image.

From June 2000 to July 2002 first working observations of several asteroids (including NEA 2000 NM, 1999 KW4 and 2002 NX) and comets were carried out (Fig. 3). Simultaneously the work on the improving of the software and developing of the methods of observation was made. Altogether about 2500 frames were received. At present the work on automations of telescope and the improvement of programs of image processing is in progress.

Accuracy of astrometric observations of some objects is present in the table 3.

Telescope productive capacity, i.e. area of the sky covered by the observations for unit of time for the fixed limiting magnitude, depends strongly on degree of automations of telescope.

At the beginning of 2002 year the first phase of automation of telescope was ended. We replaced an old stepper motors by faster ones and installed the motion controller, which permits us to operate by telescope from computer. Without angle encoders, we can control telescope position by calculating number of steps of motors. Telescope modernization allows us to raise covering sky area to 10 sq.degrees per hour. This productivity is limited only by readout time of CCD and can be improved by replacing CCD camera by new one, with more large area and faster readout time. We haven't enough financial support now for this update. Additional feature of the new controller is the capability to follow fast moving objects with angular velocity up to 120 arcsec per second. For average 6-hours night it is possible to get 100–120 frames, or 15 000–18 000 frames per year. It corresponds to 2 500–3 000 square degrees per year for the triple overlapping of observed areas. Probability of discovery of the NEAs in such area of the sky during a year is evaluated according to the results of E.Helin and R.Dunbar [4]. Possible number of Near Earth Asteroids of corresponding limiting magnitude is presented by the table 4.

For the comparison let us note that known program with the Spacewatch telescope of the Observatory

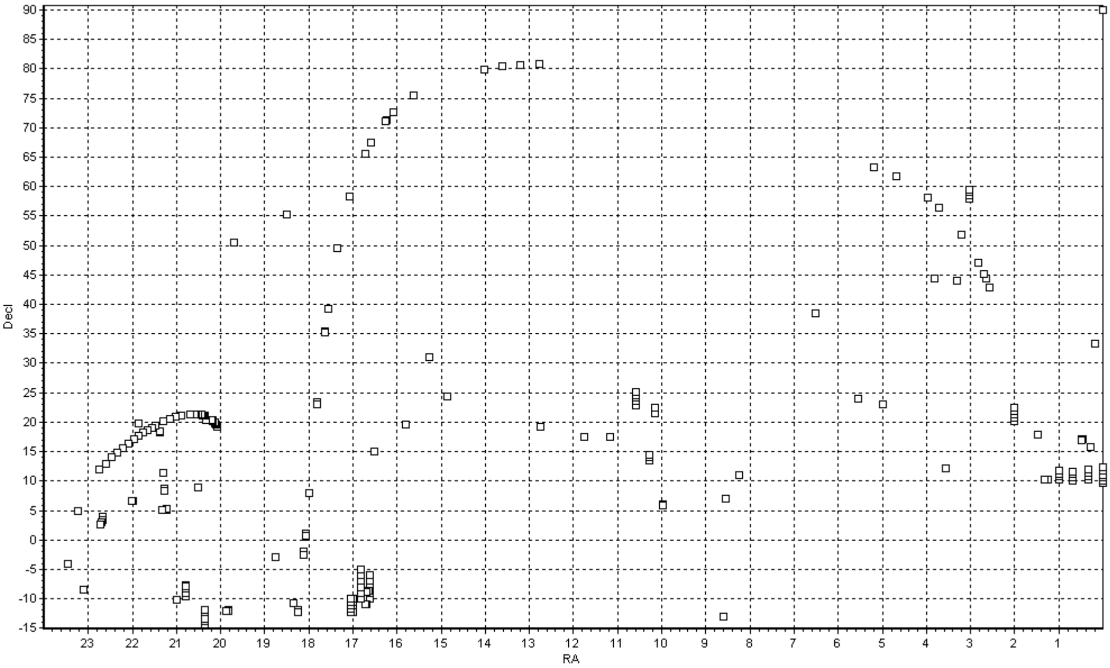

Fig. 3. The positions of frames observed from June 2000 to July 2002

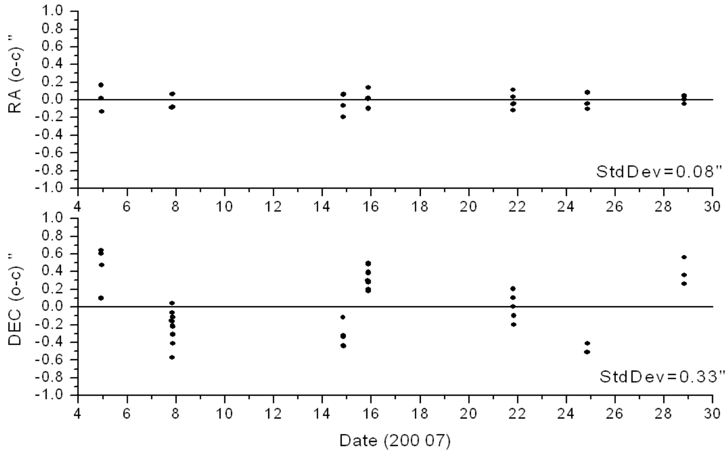

Fig. 4. Residuals of observed positions of asteroid 2000 NM

Kitt Peak, using a method of scan when observing, gets at the average 1250 square degrees per year under the triple overlapping of observed areas and registers near 20 000 asteroids to 21^m.

1. *Chernykh N.S.* Crimean minor planet survey: Dissertation...for Dr. Sc. Degree. — S.-Petersburg, 1999. (in Russian)
2. *Everhart E.* Finding Your Telescope's Magnitude Limit // Sky & Telescope. — 1984. — **77**, № 1.
3. *Sanders W.L., Schroder R.* Membership in the cluster NGC 6494 // Astron. Astrophys. — 1980. — **88**, № 1/2. — P. 102–107.
4. *Helin E., Dunbar R.* Search techniques for near-Earth asteroids // Vistas in astronomy. — 1990. — **33**. — P. 21–37.

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