ISSN 2409-9066. Sci. innov. 2017, 13(1): 24—29 doi: https://doi.org/10.15407/scine13.01.024

Pomazan, A.V., and Maigurova, N.V.

Research Institute «Mykolaiv Astronomical Observatory», 1, Observatorna St., Mykolaiv, 54030, Ukraine, tel. +380 512 477 014

THE FIRST RESULTS OF THE PHOTOMETRIC OBSERVATIONS OF SELECTED ASTEROIDS ON KT-50 TELESCOPE OF MOBITEL COMPLEX OF RI «MAO»

The first results of asteroid photometric observations using the KT-50 telescope of Mobitel complex (RI "MAO") in 2016 have been presented. Asteroids were selected based on the NEOWISE infrared survey, SDSS MOC-3 catalog of moving objects, and MPC database. The selected asteroids have a relatively high albedo (pV > 0.2) and are located in the Outer Main Belt (semi-major axis a >0.28 a.u.). The observations were made using a filter close to the Rc standard band of Cousins system. Standard deviations of the instrumental differential magnitude measurements range within 0.01^m — 0.03^m for 10^m—15.5^m reference stars. The light curve based on the results of the differential aperture photometry has been obtained from long series of observations of (2144) Marietta asteroid.

Keywords: asteroids, photometric observations, light curves, and phase-magnitude dependencies.

Photometric observations of asteroids contain information about the asteroid physical characteristics, such as rotation period, surface shape, chemical composition of the surface, etc. For the time being, according to the Minor Planet Center (MPS), robust and reliable light curves have been available for only a little bit more than 11 thousand out of more than 720 thousand discovered asteroids. Among them, only about 200 asteroids have full light curves and photometric observations that enable obtaining the light variation dependence on phase angle. For most of the observed ranges of phase angles, the asteroid phase curves show a linear light variation within the range of phase angles from 7—10° to 20—25° and a nonlinear increase in light at angles less than 5—7° due to the so-called *opposition effect* [1, 2]. The opposition effect can characterize the physical properties and the chemical composition of the asteroid surface [2, 3].

Until recently, the research activities at the Research Institute «Mykolaiv Astronomical Observatory» (RI «MAO») has been focused mainly on observing and determining precise positions of the Solar system bodies, including the asteroids. Specialized photometric observations and their processing for studying the optical properties of asteroid surface and the physical characteristics is a new direction of research.

In 2011, RI «MAO» designed and launched a KT-50 telescope of *Mobitel* complex and started regular astrometric observations of asteroids within the framework of various programs (determination of mass of several large asteroids and the Yarkovsky effect for small asteroids, *alert* observations of asteroids, including the NEA, etc.). The analysis of astrometric processing has showed a high intrinsic accuracy (better than 0,1") of asteroid position measurements by both coordinates for the objects within 15—17 star magnitudes [4, 5]. The KT-50 telescope is equipped with optical filter close to the standard band R_c of Cousins system, which enables photometric observations. Since 2015, trial photometric observations of asteroid and photometric standard stars have been carried out for elaborating a method for specialized observational techniques and study of instrument photometric system.

INSTRUMENTATION AND EQUIPMENT

The *Mobitel* complex was designed at RI «MAO» under supervision of Shulga, A.V. [6]. The KT-50 telescope (D=500 mm, F = 2975 mm) has a CCD-camera *Alta U9000* (3056×3056, 12×12 μm^2) manufactured by *Apogee Instruments Inc*, which enables to get images with a field of view of 42.4'×42.4' and a scale of 0.832"/pix. The camera has a mechanical shutter that may be triggered by external sync pulse. This system has made it possible to get simultaneously with the object a quite large number of reference stars for reliable reduction in modern catalogs. The specific feature of observations is the use of time delay integration (TDI) mode for all observations. The exposure was selected in such a way as to achieve a signal-to-noise ratio (SNR) of, at least, 25 based on the apparent magnitude presented in HORIZONS ephemeris system (JPL, USA). In 80% of cases, the duration of exposure was 120 s, which gave a frame size of 3056×980 pixels and a field of view of 42.4'×13.5'. A *Trimble Resolution*-T GPS-receiver was used to peg to the time scale.

For the time being, the telescope has been equipped with only one optical glass OC-14 (GOST 9411-91) filter. The filter provides a passband close to that of R_c standard filter of the Cousins system. The filter's transmission curve [7], atmospheric transmission, reflection on aluminum, and sensitivity of CCD camera *Alta U9000* taken from the technical specifications are showed in Fig. 1. The normalized transmission curves of resulting instrumental band and R_c filter of Cousins system standard passband [8] are presented in Fig. 2.

Table 1 compares the characteristics of the KT-50 telescope instrumental system and the R_c filter of standard Cousins system [9].

METHOD AND SOFTWARE FOR THE MEASUREMENTS

The obtained images were processed using GAIA (Graphical Astronomy and Image Analysis Tool, version 4.4.6) software developed within *Starlink* project [10]. This software operates in Linux and enables working with user's scripts. The program performs reduction of photometric measurements

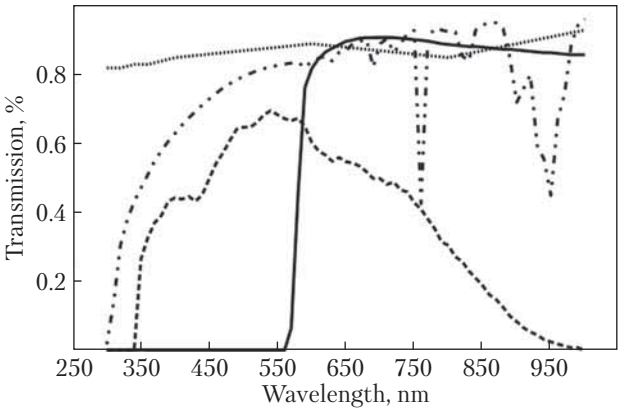

Fig. 1. Curve of reflection in aluminum (*dot*), atmospheric transmission curve (*dot and dash*), *Alta U9000* CCD matrix sensitivity curve (*dash and dash*) and transmission curve of selected optical filter OC-14 (*solid line*)

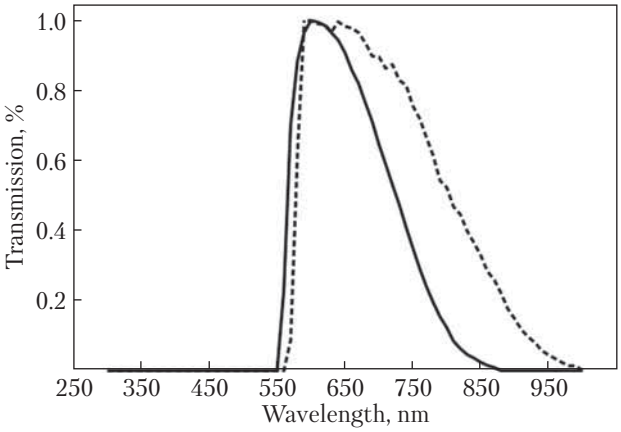

Fig. 2. R_c standard Cousins filter transmission curve (*solid line*) and resulting transmission of instrumental system (*dash and dash*)

Table 1

Parameters of Instrumental Photometric System of KT-50 Telescope and R_c Filter of Standard Cousins System

	Instrumental system	R_c filter of standard Cousins system
$\lambda_{эфф}$, nm	707	641
$\Delta\lambda$, nm	224	158

of object's brightness taking into account exposure, aperture, and gain. The images of objects and reference stars were measured by the aperture photometry method.

The next scripts were developed to batch processing of the following stages:

- sequential measurement of brightness of the selected object and average background around the object with different apertures;
- selection of aperture and background for getting the highest SNR in order to reduce the error of instrumental magnitude calculations. The algorithm for calculating background for each object is relatively uninfluenced by other objects. The aperture adjustment makes it possible to adjust all measurements for a small bias depending on the object brightness.

The initial identification of the stars in images was done using *Astrometrica* software package [11] in the UCAC-4 reference catalog [12]. This catalog contains information about the 5-band (B, V, g, r, and i) photometry from APASS (AAVSO Photometric All-Sky Survey) catalog for more than 50 million stars. The identified stars across all frames were recognized using the script, with only the stars featured in each frame used as reference stars to determine the object brightness.

RESULTS AND ANALYSIS

The 2144 Marietta (1975 BC1) asteroid was observed in 2016 for six nights. About 200 frames with images of the object and reference stars were obtained. Table 2 contains statistical data by series of the asteroid observations.

For each series of observations light curves in the instrumental band were built both for the reference stars and for the object studied. The stars with variable brightness that has not manifested itself on other reference stars for given series of observations were excluded. Fig. 3 shows light curves for several reference stars for one of observation series.

Intrinsic accuracy of determination of magnitude on reference stars ranges within $(0.01—0.03)^m$ magnitudes for the stars having a magnitude within $(10—15.5)^m$. The obtained accuracy estimates are quite high for the telescopes with a mirror diameter of up to 1 m and testify to the fact that further photometric observations using the *Mobitel* telescope are promising.

Fig. 4 shows a cumulated light curve in the instrumental photometric system for the 2144 Marietta (1975 BC1) asteroid. The curve is built on the two long series of observations. It covers the whole period of asteroid revolution, which has enabled to estimate its value (5.45 hours). This estimate is in good agreement with the value obtained in 2014 [13] (5.489 hours).

Data of series were obtained at phase angles less than 0.5°, and visible increase in amplitude of brightness variation on the second part could testify to influence of opposition effect.

Table 2

Statistics of 2144 Marietta (1975 BC1) Asteroid Observations by Series

Date	Number of frames in the series	Duration of the series, hour	Average asteroid coordinates in the series	
			RA, degree, min, s	Dec, degree, min, s
2016.07.27	14	0.39	21 11 10.73	-15 41 32.66
2016.07.28	15	0.39	21 10 24.33	-15 45 51.42
2016.07.30	10	0.25	21 08 50.09	-15 54 34.06
2016.08.02	15	0.56	21 06 25.06	-16 07 52.23
2016.08.05	73	2.14	21 03 57.47	-16 21 16.24
2016.08.06	68	1.97	21 03 09.17	-16 25 38.18

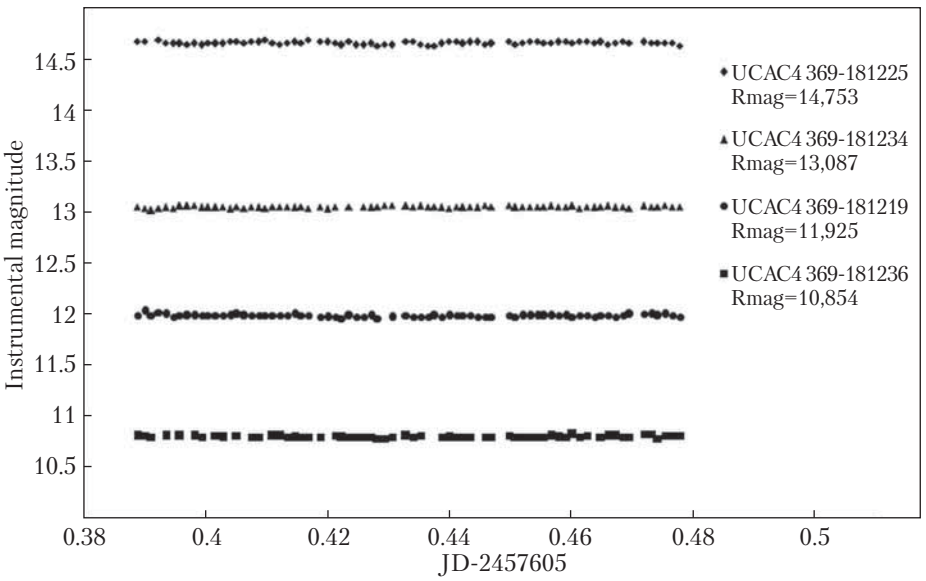

Fig. 3. Light curves in the instrumental band for selected reference stars in the frames with the object studied; obtained based on measurements of one series of observations dated 04.08.2016

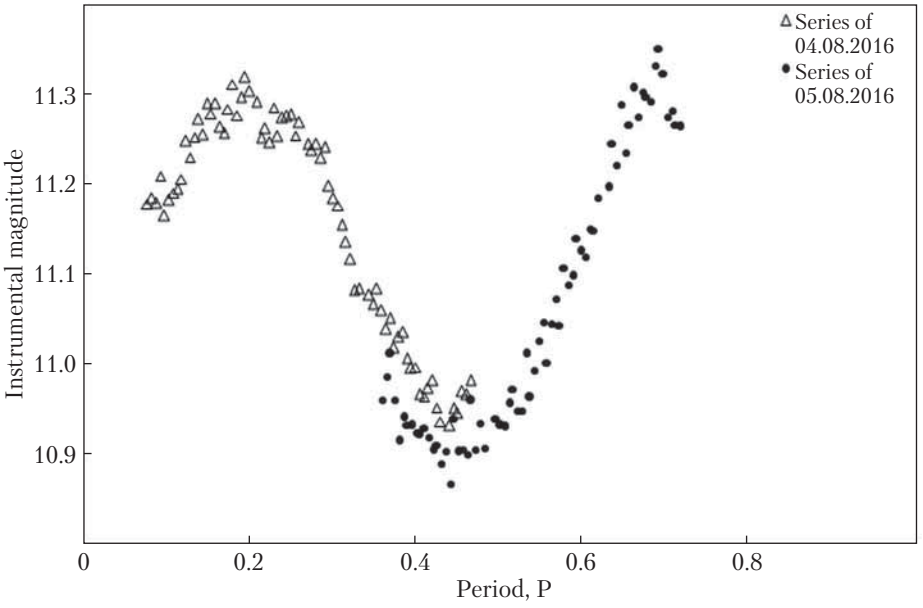

Fig. 4. Cumulative light curve within instrumental band of 2144 Marietta (1975 BC1) asteroid obtained based on observations of August 4, 2016 (*light triangles*) and August 5, 2016 (*dark dots*)

CONCLUSIONS

The first results of processing of photometric observations made using the KT-50 telescope of *Mobitel* complex at RI «MAO» have been presented. In 2016, an array of observations of selected asteroids from the Main Belt has been obtained. The results of photometric reductions have showed a high accuracy of brightness measurements in the instrumental band ranging within $(0.01—0.03)^m$ for the reference stars having a magnitude of $(10—15.5)^m$ imaged on the same frame with the object studied.

For the (2144) Marietta asteroid long series of observations have been obtained and light curve has been built based on the results of differential aperture photometry, which makes it possible to estimate the asteroid period of revolution that is in good agreement with the estimates of other researchers.

The results have showed that use of KT-50 telescope is promising for further photometric observations of Solar system bodies.

REFERENCES

1. Belskaya I.N., Shevchenko V.G. Opposition effect of asteroids. *Icarus*. 2000. 146: 490—499.
2. Tereschenko I.A., Shevchenko V.G., Chiorny V.G., Kruglyj Ju.N., Bel'skaja I.N., Gaftonjuk N.M. Povedenie bleska asteroidov na maliyh fazoviyh uglah. Rezul'taty nabluydeniy. *Visnyk astronomichnoyi shkoly* (Astronomical school's report). 2009. 6(1): 83—87 [in Russian].
3. Lagerkvist C.-I., Magnusson P. Analysis of asteroid lightcurves. II — Phase curves in a generalized HG-system. *Astronomy and Astrophysics Supplement Series*. 1990. 86: 119—165.
4. Ivantsov A., Pomazan A., Kryuchkovskiy V., Gudkova L. Results of observations of selected asteroids at the new telescope Mobitel of NAO in 2011-12. *Odessa Astronomical Publications*. 2012. 25(1): 66—68.
5. Pomazan A.V., Maigurova N.V. Optical observations of the selected asteroids with measurable Yarkovsky effect. *Advances in Astronomy and Space Physics*. 2013. 3(2): 113—115.
6. Shulga A.V., Kozyrev E.S., Sibiryakova E.S., Halolej M.I., Chernozub V.M. Mobil'niy complex telescopov NII NAO dlya nablyudeniy ob'ectov okolozemnogo kosmicheskogo prostranstva. *Kosmichna nayka i tehnologiya* (Space science and technology). 2012. 18(4): 70—76 [in Russian].
7. *Steklo opticheskoe cvetnoe*. Tehnicheskie usloviya: GOST 9411-91. [Deystvitelen s 1993-01-01]. Moskva: Izdatel'stvo standartov, 1992 [in Russian].
8. Strayzys V.L. (ed.). *Multicolor stellar photometry*. Vilnius: Mokslas, 1977 [in Russian].
9. Bessell M.S., Standard Photometric Systems. *Annual Review of Astronomy & Astrophysics*. 2005. 43(1). 293—336.
10. Disney M.J., Wallace P.T. STARLINK. *Quarterly Journal of the Royal Astronomical Society*. 1982. 23: 485
11. *Astrometrica* [Electronic resource] http://www.astrometrica.at
12. Zacharias N., Finch C., Girard T., Henden, A., Bartlett, J.L., Monet, D.G., Zacharias, M.I. The Fourth US Naval Observatory CCD Astrograph Catalog (UCAC4). *The Astronomical Journal*. 2013. 145: 44.
13. Arredondo A., Hartt A., Yazdi S. Rotation Periods and R Magnitudes of Three Koronis Family Members. *The Minor Planet Bulletin*. 2014. 41: 252—254.

Received 21.10.16

А.В. Помазан, Н.В. Майгурова

Науково-дослідний інститут
«Миколаївська астрономічна обсерваторія»,
вул. Обсерваторна, 1, Миколаїв, 54030, Україна,
тел. +380 512 477 014

ПЕРШІ РЕЗУЛЬТАТИ ФОТОМЕТРИЧНИХ СПОСТЕРЕЖЕНЬ ОБРАНИХ АСТЕРОЇДІВ НА ТЕЛЕСКОПІ КТ-50 КОМПЛЕКСУ МОБІТЕЛ НДІ «МАО»

У статті наведено перші результати фотометричних спостережень астероїдів, виконаних на телескопі КТ-50 комплексу Мобітел (НДІ «МАО») у 2016 р. Астероїди були обрані на основі аналізу інфрачервоного огляду NEOWISE, каталогу рухомих об'єктів SDSS MOC-3 і бази даних MPC. Обрані астероїди мають відносно високе альбедо ($pV > 0,2$) і розташовані у зовнішній частині головного поясу астероїдів (велика піввісь $a > 0,28$). Спостереження проводилися в фільтрі, близькому до стандартної смуги R_c системи Казінса. Стандартні відхилення вимірювання інструментальної величини знаходяться в діапазоні $(0,01—0,03)^m$ для опорних зірок $(10—15,5)^m$. Для астероїда (2144) Marietta, для якого були отримані тривалі серії спостережень, наводиться крива блиску за результатами диференціальної апертурної фотометрії.

Ключові слова: астероїди, спостереження, фотометрія, криві блиску, фазові залежності блиску.

А.В. Помазан, Н.В. Майгурова

Научно-исследовательский институт
«Николаевская астрономическая обсерватория»,
ул. Обсерваторная, 1, Николаев, 54030, Украина,
тел. +380 512 477 014

ПЕРВЫЕ РЕЗУЛЬТАТЫ ФОТОМЕТРИЧЕСКИХ НАБЛЮДЕНИЙ ИЗБРАННЫХ АСТЕРОИДОВ НА ТЕЛЕСКОПЕ КТ-50 КОМПЛЕКСА МОБИТЕЛ НИИ «НАО»

В статье представлены первые результаты фотометрических наблюдений астероидов, выполненных на телескопе КТ-50 комплекса Мобител (НИИ «НАО») в 2016 году. Астероиды были выбраны на основе анализа инфракрасного обзора NEOWISE, каталога подвижных объектов SDSS MOC-3 и базы данных MPC. Выбранные астероиды имеют относительно высокое альбедо ($pV > 0.2$) и расположены во внешней части главного пояса астероидов (большая полуось $a > 0,28$). Наблюдения проводились в фильтре, близком к стандартной полосе Rc системы Казинса. Стандартные отклонения измерений инструментальной звездной величины находятся в диапазоне $(0,01—0,03)^m$ для опорных звезд $(10—15,5)^m$. Для астероида (2144) Marietta, для которого были получены продолжительные серии наблюдений, приводится кривая блеска по результатам дифференциальной апертурной фотометрии.

Ключевые слова: астероиды, наблюдения, фотометрия, кривые блеска, фазовые зависимости блеска.