PHOTOMETRIC RESEARCHES OF ASTEROIDS ON 1.5-M RUSSIAN-TURKISH TELESCOPE

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ABSTRACT. This work describes some research results based on the photometric studies on Russian-Turkish telescope during last five years. During 2004-2006 observations of minor planets were carried out within the international collaboration between Kazan State University, TÜBITAK National Observatory and Nikolaev Astronomical Observatory for studying the physical parameters and kinematics of asteroids. As a result the photometric characteristics of these objects have been obtained; the lightcurves frequently demonstrating changes of brightness of these objects caused by their rotation around an axis are constructed. The variability periods and amplitudes for asteroids (762) Pulcova, 2000PN9, (6006) Anaximandros have been found.

Key words: Asteroids: photometry: rotation; asteroids: individual: (762) Pulcova, 2000PN9, (6006) Anaximandros.

1. Introduction

During the last decade in connection with the opening of tens of thousands of new objects, detection of the large transneptunians bodies and discovery of some asteroids binarity the tasks of studying Solar system's minor planets were widely extended. The basic tasks of complex astrometric and photometric asteroids researches are a specification of the characteristics of orbits and a definition of the basic physical parameters (mass, rotation period). These researches are very important from the point of view of determinations of the sizes, forms and densities of asteroids, establishment of correlations between rotation and size, specifying taxonomic class of a minor planet (Britt et al., 2002). The significant information about the asteroids characteristics can be obtained with the help of results of multi-color photometric observations of these objects on 1-2 meter telescopes.

Now the rotation characteristics of about 3000 numbered asteroids are known (see the Center of Minor planets of NASA – NASA, 2006). The rotational periods of asteroids are rather various: from the hundredth shares of an hour (2001 WV1, 2004 BV18), up to tens of days (1997 AE12, (288) Glauke), and the amplitudes of brightness changes reach $1.5^m - 2.0^m$, but usually they are about five tenths of a magnitude in R band. In spite of the fact that many minor planets near opposition appear rather bright ($10^m - 15^m$), this precision photometric observations can be possible only on large telescopes. The characteristics of this telescope and its receiver equipment enable us to get the images of asteroids with magnitudes up to 22.

2. Observations

The systematic observations and researches of asteroids in the main belt, and near-Earth, and Kuiper-belt objects have being conducted since 2002 on the 1.5-m Russian-Turkish telescope (RTT150), at the TÜBITAK National observatory (TÜBITAK Ulusal Guzlemevi - TUG) near Antalya (South Turkey), on the Bakirlitepe mountain, on the altitude of 2500 m (Aslan et al., 2001). Now the observatory has Minor Planet Center code A84. At the time of observations the thermoelectrically cooled CCD camera ANDOR (model DW436, 2048 × 2048 with 13.5 × 13.5 m pixels) with an operating temperature of -60 C installed at the Cassegrain focus was used. Observations in 1×1 and 2×2 binned mode of CCD were executed. Most of observations were carried out in the BVR photometric system. The SDSS system filters have been used since December 2006. These equipments of the

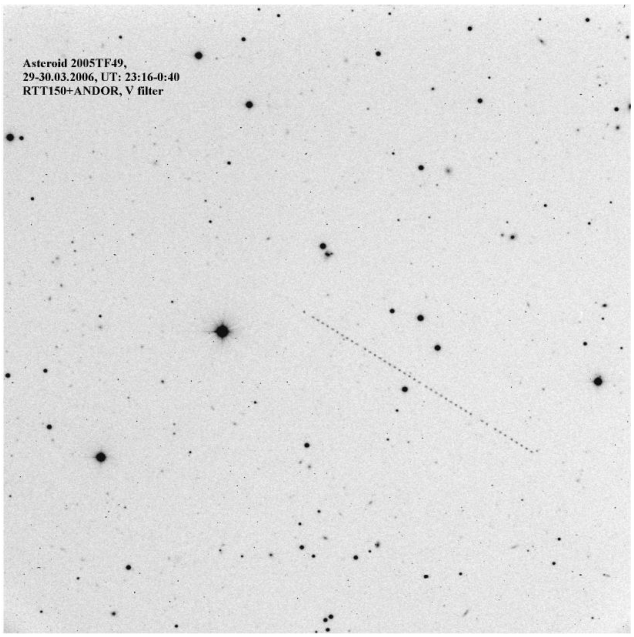

Figure 1: The track image of the asteroid 2005TF49, observed on RTT150.

RTT150 allow to conduct the photometric studies with an accuracy of about 0.01^m at 17 magnitude and about 0.05^m at 20 mag in the Cousins Rc-band and fit the lightcurves of objects with minimal uncertainty (as an example see results researches of asteroid 2002NY40 in Uluc et al., 2007). We execute also an absolute photometry of some observed minor planets. Figure 1 shows the combined image of positions of asteroid 2005TF49, which was observed on RTT150 with CCD Andor in March, 2006 (field of view $8.2' \times 8.2'$).

During 2004-2007 observations of minor planets were carried out within the international project on studying the physical parameters and kinematics of asteroids. This project includes the decision of the following tasks. 1) Definition of orbits of asteroids, which are brighter than 20^m; 2) Specification of the position of the Solar system baricenter; 3) Search for binarity and estimation of masses of some main belt asteroids; 4) Determination of the rotation periods, form and density of the fast-rotating asteroids; 5) Observations of Near-Earth asteroids and definition of their main parameters. At present more than 20000 observations for about 100 various asteroids have been obtained, including chiefly main belt asteroids (for example, (60) Echo, (133) Syrene, (673) Edda etc.), also more than 10 near-Earth objects (1998OX4, 2004XL14, (4179) Toutatis) and the most interesting transneptunian objects (Pluto, 2003UB313 – Erida). Some observing information about several asteroids studied on RTT150 is shown in Table 1. The columns of this table include date of observation, name (number) of the asteroid, exposure times and number of images for filters indicated in the last column of the table. The authors have full table with observational data.

Table 1: The journal of observations of asteroids on RTT150 in 2004-2007 (fragments).

Date of obs.	Number of aster.	Exp. times, s	Quantity of exp.	Filters
...	...	...	...	...
23.09.04	846	20	25	R
23.09.04	416	5	50	R
24.09.04	133	20	25	R
24.09.04	718	20	23	R
...	...	...	...	...
03.07.05	381	20	9,8	V,R
03.07.05	34	10	3,3	V,R
19.08.05	Erida	30-60	3,3,3,3	B,V,R,I
20.08.05	Erida	60-120	3,3,3,3	B,V,R,I
...	...	...	...	...
05.11.06	6006	30-40	45,45	V,R
10.11.06	253	30	1,3,3	B,V,R
13.12.06	965	20-30	55,50,50	r,g,u
15.12.06	6006	30	66,63	g,r
...	...	...	...	...
23.07.07	5303	60-120	3,6,6	B,V,R
23.07.07	110	30-90	3,6,6	B,V,R
24.07.07	673	30	6,12,12	B,V,R
25.07.07	209	60-120	3,6,6	B,V,R
...	...	...	...	...

3. Photometry of (762) Pulcova

During September 16, 20-23, 2003 in unfiltered light and in filters B, V, R observations of the main belt binary asteroid (762) Pulcova were carried out. Each night observations cover a full 5.8 h variation period. The differential photometry was made with the help of nearby stars, among which asteroid was moving during the observational night. The accuracy of photometrical measurements is in the range 0.01-0.02 magnitude, which agrees with observational accuracy of other authors. The data of each night were plotted as differential instrumental magnitude vs UT, and they show two maxima and two minima. The main minimum is more sharper than the secondary. Perhaps, peculiarities of lightcurves for various filters in the phase of growth after the main minimum and near secondary minimum can be explained by different albidos of the corresponding areas of Pulcova surface. The minima and maxima of lightcurves in different filters coincided. The time interval between maxima after a secondary minimum was used for estimating the rotational period of the asteroid. This have led to values of 5.88 hours in filter

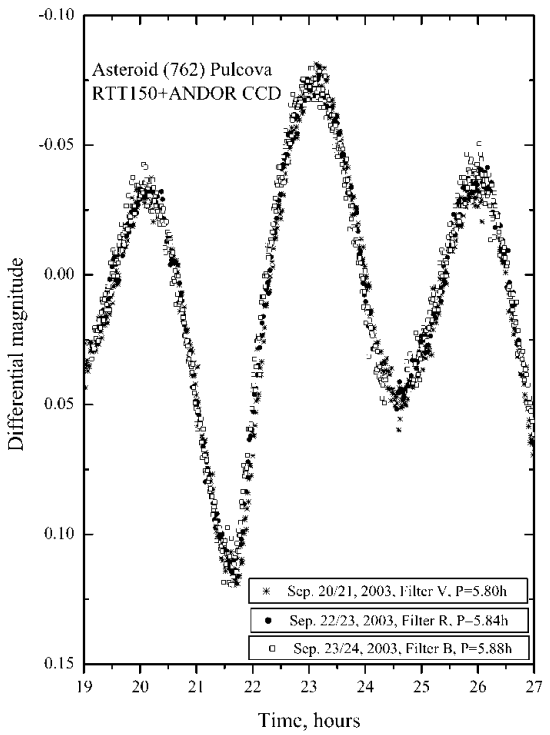

Figure 2: The lightcurves for (762) Pulcova in three filters.

B, 5.80 h in V and 5.84 h in red light (see penultimate column in Table 2), which give the mean period, which equals 5.839 ± 0024 hours. This result confirm the recent observations of Davis (2001). But amplitude of brightness variations for Pulcova from our lightcurves is less than in cited work. It was 0.20 magnitudes (Figure 2).

The deviation between values of main and secondary minima detected here equal 0.06^m. Similar discrepancy was obtained by Devis in February the 9th, 2000. It is accounted for by the vicinity of phase angles of asteroid (then it was 5.83 degree). Distinct from this is that in our lightcurves the intensity of the main maximum is 0.04 magnitudes more than that of the secondary. Thus maximal amplitude of variability of (762) Pulcova in this observational set attains 0.2 magnitudes, and the difference in magnitude between second maximum and second minimum for this session was 0.1^m. These data for three filters were presented in table 2.

Table 2: Photometrical data from lightcurves of (762) Pulcova.

Filter	Maximal amplitude	Minimal amplitude	Phase angle	Period, hours
B	0.199	0.100	6.2	5.876
V(20.09)	0.201	0.097	6.8	5.827
V(21.09)	0.196	0.089	6.6	5.812
R	0.192	0.093	6.4	5.841

4. Observations for international project

Last three years positional and photometric observations for large group of asteroids were carried out in the international collaboration between Astronomy department of Kazan State University, TÜBITAK National Observatory and Nikolaev Astronomical Observatory. Almost all the internal observational errors for the observed objects up to 17 magnitude are within 0.1", with a mean value less than 0.05" in both coordinates (Aslan et al., 2007). Accuracy of asteroid positions from the observations at RTT150 is good enough for use in mass determinations by the dynamical method, based on the analysis of the perturbations of small asteroids by big ones (Ivantsov, 2007). The papers of Aslan et al. (2006, 2007) present the preliminary calculations of mass determinations for 21 asteroids.

As we can see in Table 1 first observations were made only with one filter (R). Later, the availability of the filter wheel at the Cassegrain focus provided us with the opportunity for multi-color observations. For photometric researches we used long-time (more than 10 images) observations of asteroids. Besides some objects (for example, (121) Hermione, (253) Mathilde, (673) Edda, (1042) Amazone etc.) during these three years were observed scores of times. Also on RTT150 we can observe asteroids with possible short rotation periods ($P_{rot} < 3$ hours). This permits us to determine and specify the rotation periods of these objects.

In March 29-30, 2006 on RTT150 long-time observations in V-filter for asteroids (846) Lipperta, 2000PN9, 2005TF49 and (673) Edda were carried out. The asteroid 2000PN9 demonstrated brightness variations with amplitude of 0.11^m and period of 1.77 hours. These observations show similar results to the ones got earlier by Pravec (2003), who obtained $P_{rot} = 2.5325$ h and amplitude 0.15^m. At the end of 2006 the basis of two-color observations in November, 2006 a minimum in the lightcurve of mail belt asteroid (6006) Anaximandros was discovered. The special observations of this asteroid during 2.5 hours in December, 2006 have confirmed this result. The lightcurves in SDSS filters g and r for this object with respect to a standard star are shown in Figure 3. Thus (6006) Anaximandros has the variability with a rotation period of 1.37 hr and amplitudes of 0.32 and 0.30 mag in g and r

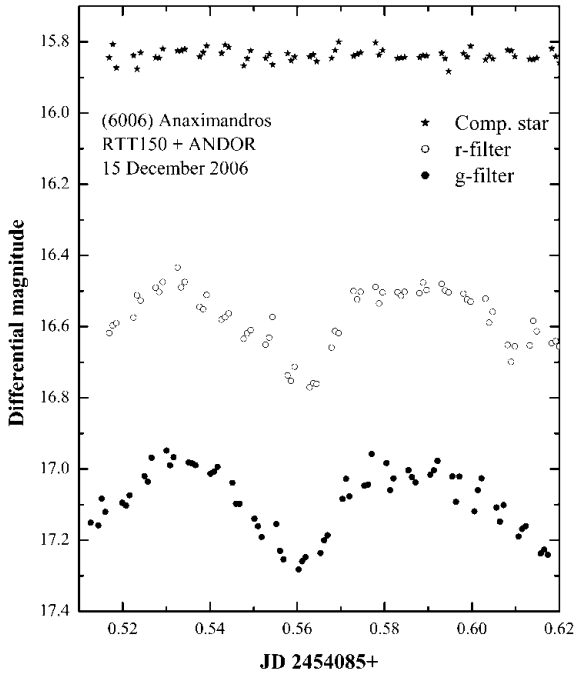

Figure 3: The lightcurves for (6006) Anaximandros in two filters.

bands, respectively. The lightcurves of this object in different filters demonstrate obvious asymmetry and distinctions, which are explained by the features of the nonspheric form and mineral structure of the asteroid surface.

5. Results

Last five years the international project for determination of physical characteristics of asteroids is realized on 1.5-m Russian-Turkish Telescope in TÜBITAK National Observatory. More than 100 different asteroids have been observed and the photometric characteristics of these objects have been derived. The lightcurves frequently demonstrating changes of brightness of these objects caused by their rotation around an axis are constructed with an accuracy of $0.01^m - 0.05^m$. The variability periods for two asteroids (2000PN9 - 1.77 hours and (6006) Anaximandros - 1.37 hours) have been found.

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