DETERMINATION OF PHYSICAL CHARACTERISTICS OF SMALL-SIZE SPACE DEBRIS IN GEO

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ABSTRACT

Results of small-size space debris optical observations in GEO are presented. Optical measurements were performed by the Zeiss-2000 telescope (D=2m, F=16m) at the Terskol observatory (North Caucasus). Initial reduction of CCD observations are processed by Apex II astronomical image processing package developed in the Pulkovo observatory of RAS. The results of optical observations of small objects in GEO in 2011-2012 were analyzed. Determination of space debris orbital parameters, area-to-mass ratios were performed using numerical-analytical theory of artificial near-Earth objects. Detailed data on new faint objects are also given.

1 INTRODUCTION

Determination of physical characteristics of small-size space debris in the geostationary orbit is an urgent task to ensure the monitoring of near-Earth space. The observation of faint objects in orbit altitudes over 35,000 kilometers allow to evaluate the dynamics of space debris near the geosynchronous region, up to objects as small as 10 cm. This article presents the results of small debris' observations in GEO in 2011-2012. In the second section of the article is a brief description of the initial data for the analysis of the physical characteristics of objects. In the third section the main results of the study are presented. In the fourth section estimates of the results precision are given. In conclusion the summary of main results is formulated.

2 INITIAL DATA

The results of optical observations of small objects in GEO in 2011-2012 were analyzed.

Observations were made on the two-meter telescope Zeiss-2000 of Terskol Branch of INASAN in the North Caucasus (Sergeev & Tarady, 2007).

The search, detection and CCD images taking performed using a CameraControl software module, processing of the images is carried out using Apex-II software package. Both sets of programs are developed at the Pulkovo Observatory of Russian Academy of Sciences (Kouprianov, 2008).

Studies of the physical and orbital characteristics of space debris carried using a numerical-analytical theory of the artificial satellites motion which was adapted to space debris research (Bakhtigaraev & Chazov, 2005).

The CCD image of objects in the star field is presented in Fig.1.

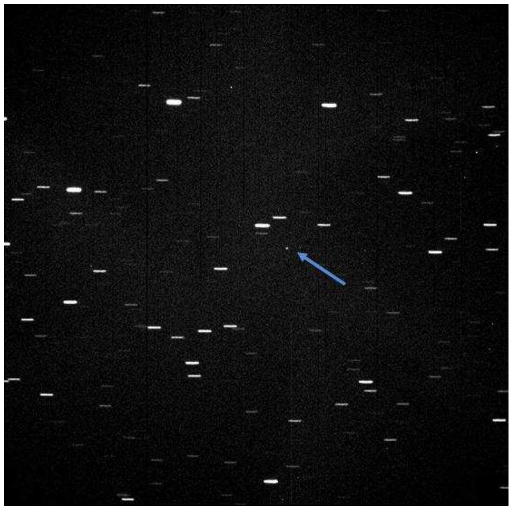

Figure 1. The FITS image

The results of the primary analysis of observations using Apex-II program complex are the equatorial coordinates of the objects and brightness estimations. Area-to-mass ratio assessment, improved orbital elements of objects and their evolution is calculated using a numerical-analytical theory of the motion of artificial satellites.

3 DETERMINATION OF PHYSICAL CHARACTERISTICS

For 127 objects on the geostationary orbit observations were obtained in 2011-2012. For 65 of them orbital parameters were measured, for 54 – empirical coefficient area-to-mass ratio were determined. In the article the results of the most interesting ones in terms of physical characterization are presented.

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In 2011, on the geostationary orbit we observed faint object №90022 (hereinafter in the text - the numbers of objects in the Keldysh Institute database). Estimates of the object brightness are shown in the Fig.2.

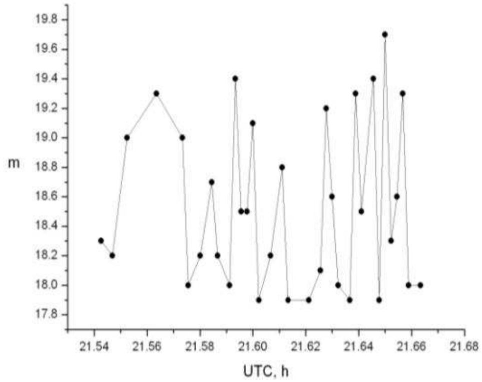

Figure 2. Light curve of the object №90022

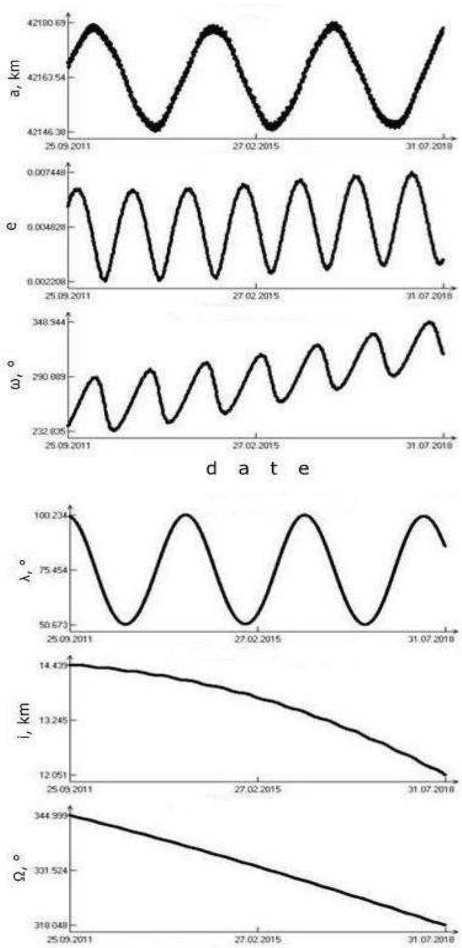

Figure 3. The evolution of the orbital elements of the object №90022

Using a numerical-analytical theory of the artificial satellites motion, adapted for space debris, evolution of the orbital elements for an object №90022 up to 2018 was calculated (Fig.3). In 2012, this object was successfully observed.

Furthermore, in 2011, we have found several objects have been lost, i.e. objects that have long been not observed. Their orbital parameters have experienced a significant change under the influence of disturbing factors of attraction of the Moon and the Sun, etc. We have been able to observe, evaluate the brightness change and predict the evolution of the fragments for six years in advance (evolution is not shown here). Light curves of the two of them are shown in Fig.4.

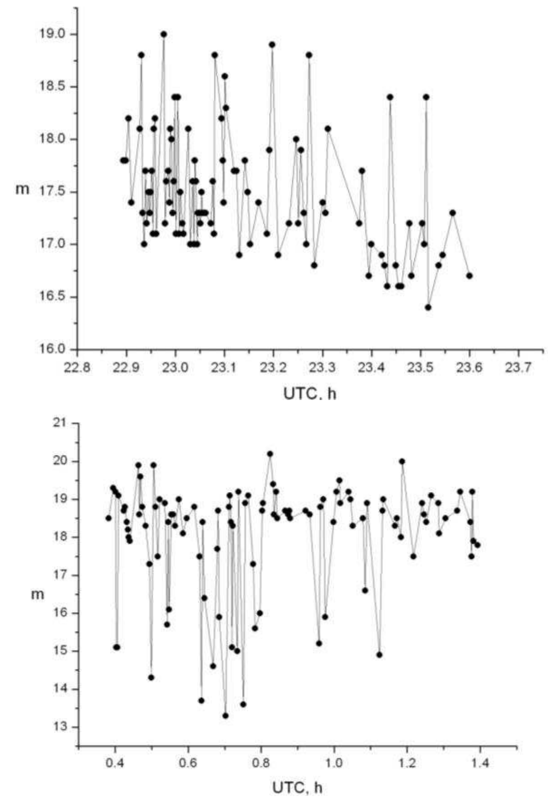

Figure 4. Light curves of small objects using optical measurements in 2011

In 2011, on the geostationary orbit we also observed objects with high area-to-mass ratio. We assume as high empirical coefficient values higher than 0.50 m^2/kg.

The Tab.1 shows the orbital parameters of objects with a high area-to-mass ratio. The Tab.2 shows the orbital elements of objects with "normal" estimates of area-to-mass ratio. N – is the number of positions obtained for the object.

Table 1. Orbital parameters of the objects with high area-to-mass ratios

№	a (km)	e	i (°)	Ω (°)	N	σ (″)	C_r (m^2/kg)
43031	40179.413	0.100917	10.1508	320.3031	30	2.83	4.42
43096	41427.991	0.063757	6.2073	315.3534	113	1.88	2.40
43133	40964.266	0.066151	5.7546	314.8257	103	1.50	3.36
90023	40129.371	0.045732	11.9059	340.2389	42	1.96	2.51
90085	42831.315	0.027840	13.3411	40.1551	55	0.58	1.47
90096	40396.176	0.005912	8.0740	328.6012	32	1.36	4.38
90110	41589.641	0.067491	13.3364	350.4501	39	0.65	1.23
90196	42162.508	0.051380	14.4911	354.8798	85	3.45	0.92
95468	42972.431	0.017431	15.6983	349.7105	59	0.47	0.51
95507	43644.889	0.040616	7.4033	336.3131	40	1.15	2.79

Table 2. Orbital parameters of the objects with normal area-to-mass ratios

№	a (km)	e	i (°)	Ω (°)	N	σ (″)	C_r (m^2/kg)
33108	42160.734	0.000256	0.7594	36.6624	159	1.39	0.022
37344	42164.123	0.000319	0.0670	57.9650	160	0.84	0.018
43149	42208.947	0.017397	9.2118	329.2202	114	0.68	0.016
43219	42521.926	0.009234	15.3511	347.3619	72	0.40	0.063
90021	42704.620	0.011744	14.9088	346.6221	74	0.74	0.421
90022	42167.543	0.005820	14.4386	345.0198	146	2.01	0.191
90031	42148.776	0.001621	14.4104	354.1439	163	0.34	0.011
90112	41509.317	0.023695	13.1127	350.9665	48	0.43	0.081
95354	42055.873	0.006556	14.1950	353.3725	69	0.28	0.096

In 2012, we carried out routine monitoring of space debris fragments that lie at altitudes of operating satellites (in the vicinity of the geostationary orbit), and the movement of which can serve as a threat to their efficiency.

Such object is the №90073. The Fig.5 shows the phase curves of this object according to the observations in 2012.

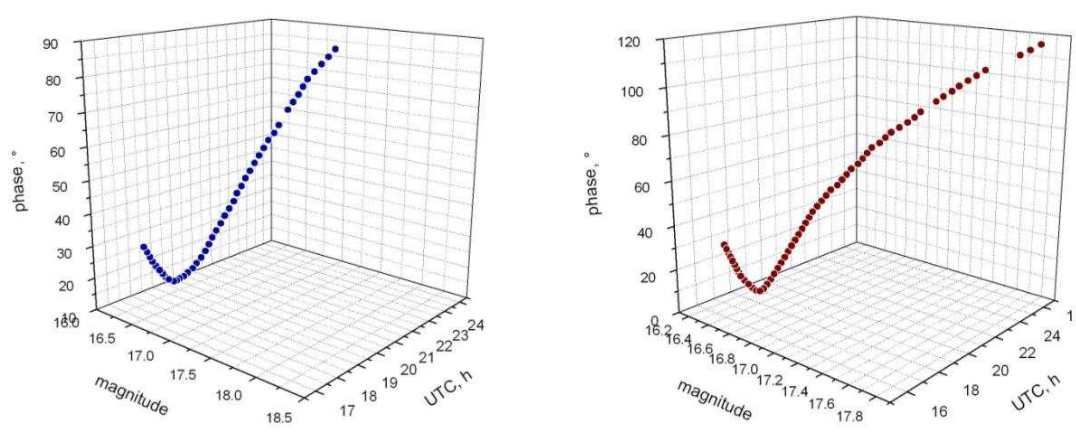

Figure 5. Phase curves of the object №90073

Object №90073 stable observed since 2009, and its brightness is significantly weakened for the first time in May 2012. In September, due to a significant unpredictable weakening of brightness this object was discovered only in the exploratory observations. After images processing, a significant deviation from the predicted orbit and weakening to the ~ 2.5 magnitude were detected. On the basis of previous observations the prediction for the orbital elements of the object up to 2012 was effected (Fig.6). The May 2012 observations is significantly different from these predicted values.

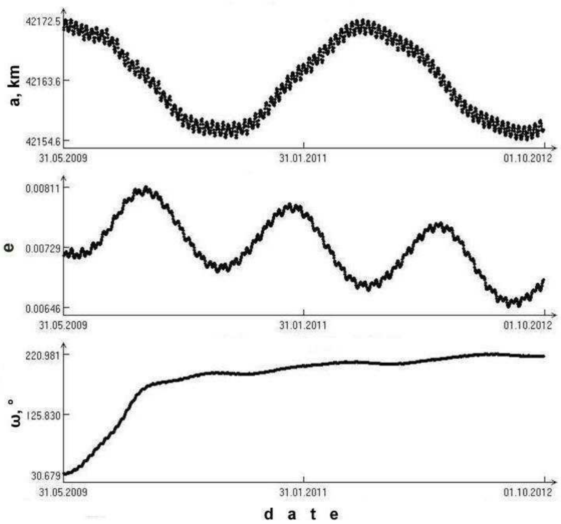

Figure 6. The evolution of the eccentricity, semi-major axis and argument of perigee using measurements in 2009-2010.

After the September observations inverse prediction was calculated (Fig.7), which significantly different from the previously performed measurements of the object position. When comparing the orbits a significant variation of the eccentricity was revealed. Residuals were calculated for the object №90073 from observations in May-June (Fig.8) and September (Fig.9). In May and June orbit deviation from the previous orbit are within the allowable range, in September the observations are significantly different from the ephemeris.

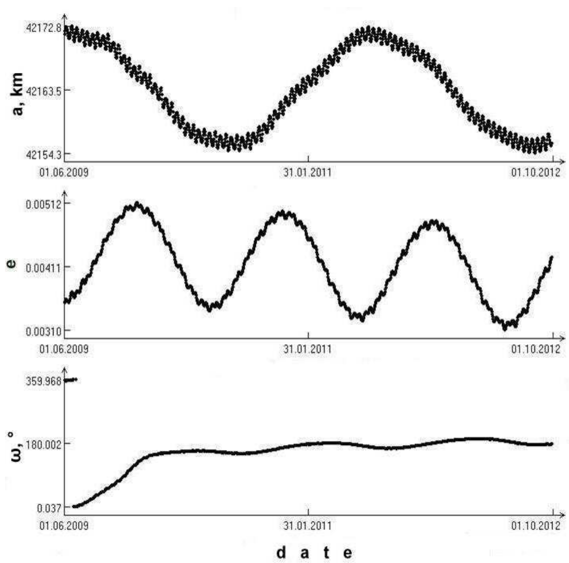

Figure 7. The evolution of the orbital elements a, e, ω (for the 2009 epoch) using measurements data in 2012

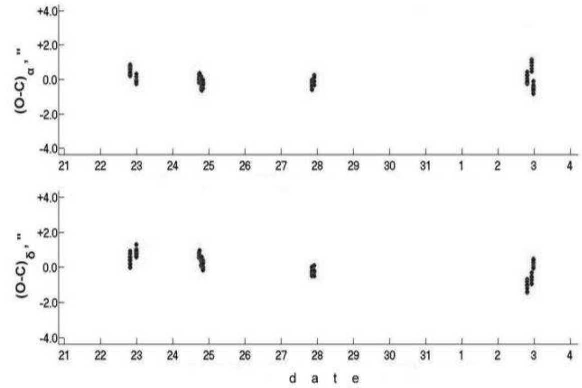

Figure 8. The residuals in right ascension (top) and in declination (bottom) using measurements in May-June 2012

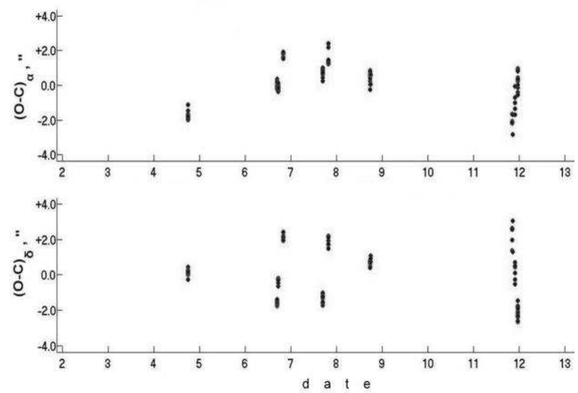

Figure 8. The residuals in right ascension (top) and in declination (bottom) using measurements in September 2012

In an observation night of 11 to 12 September, with a good sky, residuals significantly exceed the allowable value. There was a significant deviation of the eccentricity obtained from observations before, from the new value of *e* revealed.

It has been suggested that the object has experienced a collision with another body at a fairly high speed, which resulted in orbital characteristics change. There is reason to believe that the collision occurred with the some space debris fragment.

4 EVALUATION OF THE MEASUREMENTS PRECISION

In the Fig.10 shows an example of determining the residuals in right ascension (top) and declination (bottom). The residuals obtained after observations processing of the short series (about ten minutes) as the difference between observed and calculated values of the coordinates (O-C). The standard deviation in right ascension – 0.14", in declination - 0.12". The average precision of our observations is ~ 0.15". This corresponds stellar catalog USNO-B1.0 precision (about 0.20"), which we use in image processing.

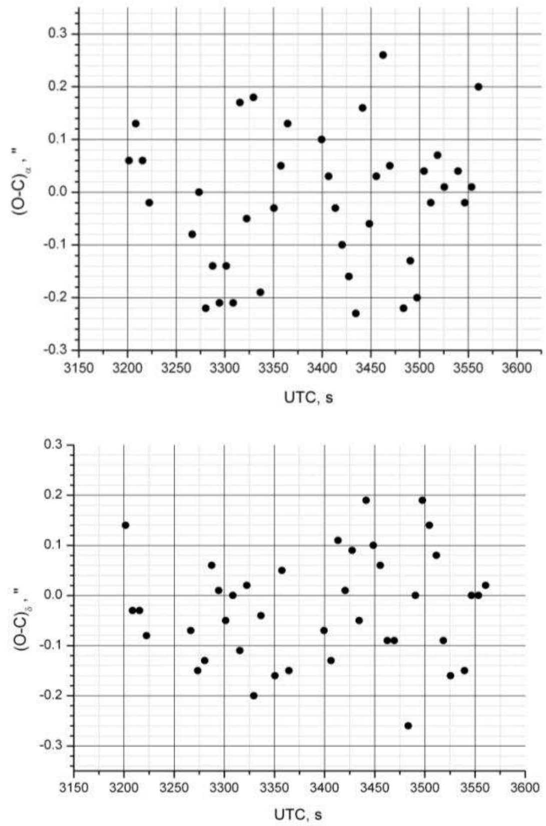

Figure 10. Example of the residuals in right ascension (top) and declination (bottom)

The Fig.11 shows the accuracy of the observations in September 2012. The residuals (O-C) in seconds of arc in right ascension (top) and declination (bottom) for 23 objects in 1344 positions plotted in this figure.

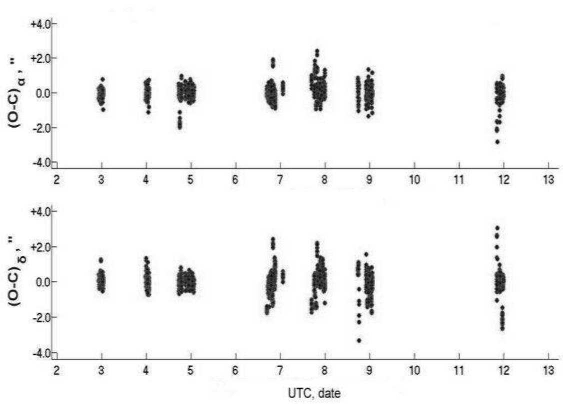

Figure 11. Evaluation of observations precision in 2012

5 CONCLUSIONS

In the 2011-2012, we have observed the small fragments of space debris in the geostationary orbit. Positioning precision is ~ 0.15". Orbital elements of faint objects were identified and long-term evolution of the orbital parameters. In addition to routine measurements was conducted surveillance of space debris that is a threat for the operating spacecrafts and are classified as hazardous objects. The results of observations of objects with a high area-to-mass ratio are presented. The resulting observations also contribute to the modeling of near-Earth space and will be the basis for a detailed study of the individual objects motion in Earth orbit.

6 REFERENCES

1. Bakhtigaraev, N.S. & Chazov, V.V. (2005). Information Support for Space Experiments Based on a Numerical-Analytical Theory of Satellite Motion. *Cosmic research*, 43(5), 369-372.

2. Sergeev, A.V. & Tarady V.K. (2007). The Terskol Observatory in the Northern Caucasus. Astrophys. Investigaions. Bulgarian Acad. Sci. 9, 000.

3. Kouprianov V.V. (2008). Distinguishing features of CCD astrometry of faint GEO objects. *Advances in Space Research,* 41, 1029-1038.