УДК 520:52.14
PACS 95.85.Kr, 96.25.De, 96.25.Vt
DOI 10.24144/2415-8038.2018.43.41-49

V.P. Epishev[1], I.I. Motrunich[1], V.M. Perig[1], P.P. Sukhov[2], K.P. Sukhov[2], R.K. Pawlaszek[3]

[1]Space Research Laboratory of the Uzhhorod National University, Dalekaya 2A, Uzhhorod, 88000, Ukraine, e-mail: lkd.uzhgorod@gmail.com

[2]Astronomical Observatory of I. Mechnikov Odessa National University, str. Marazlievskaya 1b, Shevchenko Park, Odessa, 65014, Ukraine, e-mail: psukhov@ukr.net

[3]NCAC of PAS, ul. Bartycka 18, 00-716 Warszawa, Poland, Sybilla Technologies, Torunska str., 59/004, 85-023 Bydgoszcz, Poland, e-mail: pawlaszek@sybillatechnologies.com

ON THE POSSIBILITY OF CONTROLLING BEHAVIOR OF GEOSYNCHRONOUS OBJECTS USING RESULTS OF GROUND-BASED OBSERVATIONS

Introduction. The problem of geosynchronous satellites (GCS) behavior in their orbits is very relevant. The data of positional and photometric observations of the GSS allow us to study the behavior of these vehicles in their orbits.

Purpose. Based on complex observations, the possibility of controlling the behavior of the GSS in orbit is shown on example of 3 satellites: “Cosmos 2397”, “SBIRS-GEO 2” and “DSP-18”. Their characteristics are determined: satellite orientation, components that contribute to flares on the light curve, period of brightness, etc. other GSS photometric characteristics.

Methods. The proposed algorithm, including astrometry, astrophysical methods and computer simulation, allow to show the behavior of GSS in orbit. The authors used their own method to modelate the dynamics of the behavior of the satellites in orbit.

Results. As a result of comprehensive research model of a behavior of "SBIRS-GEO 2" in orbit is presented that differs from the published information. It is also shown that “Cosmos 2397” does not have stabilization around the axis Z.

Conclusion. DSP satellites provide the coverage of the Earth's surface to latitudes 83° with a period of 50 sec. For a full coverage all Earth's surface, including the Polar Regions, at intervals of about 15-16 seconds, it is sufficient to have four SBIRS satellites on GEO located 90° along the equator.

Keywords: GEO, light curve, phase angle, photometry.

Introduction

The Russian missile early warning satellite "Cosmos 2397" was launched in 2003. After unsuccessful attempts to enter regular mode, this satellite was transferred to drifting mode, which was observed in September 2004.

Currently, several DSP satellites and one "SBIRS-GEO 2" can be observed from Ukraine. Four years of observations of these satellites produced more than 40 light curves in the B, V, R bands of the Johnson system.

The new, geosynchronous satellites (GSS) of SBIRS series shall replace the DSP satellites. The "SBIRS" that relies on Lokheed-Martin’s platform A2100M is equipped with two infrared Schmidt-system telescopes and two infrared sensors by the Northrop Grumman. The scanner sensor is a wide field sensor that allows for step-viewing the Earth's surface in a short time (the screen wiper mode) with 14deg FOV. The starrer sensor is a narrow field sensor with 4deg FOV dedicated to a detailed viewing of a specific area. The sensors can operate independently. The estimated size of the GSS on orbit is 14.81 x 6.83 x 6.00 m. The longitude of the satellite's sub-point is λ = 23°E, the orbit inclination i = 4°.9, eccentricity e = 0.0003. The DSP series consists of 23 satellites. Part of the launch was unsuccessful.

GSS Observations

During the pass in our field of view, 3 light curves for "Cosmos 2397" were obtained at small phase angles showing informative phase light curves of the GSS after coming out of the Earth's shadow. The most interesting light curve with diffuse and specular components for this GSS is presented in **Fig.1**.

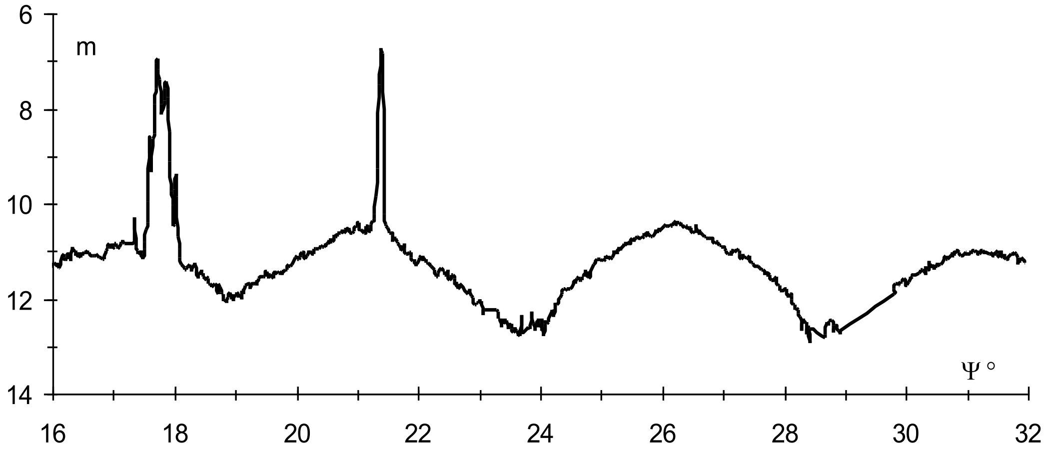

Fig.1. The light curve of "Cosmos 2397" after exiting the shadow. V-filter. 12 Sep 2004. T_{exp} = 5 sec.

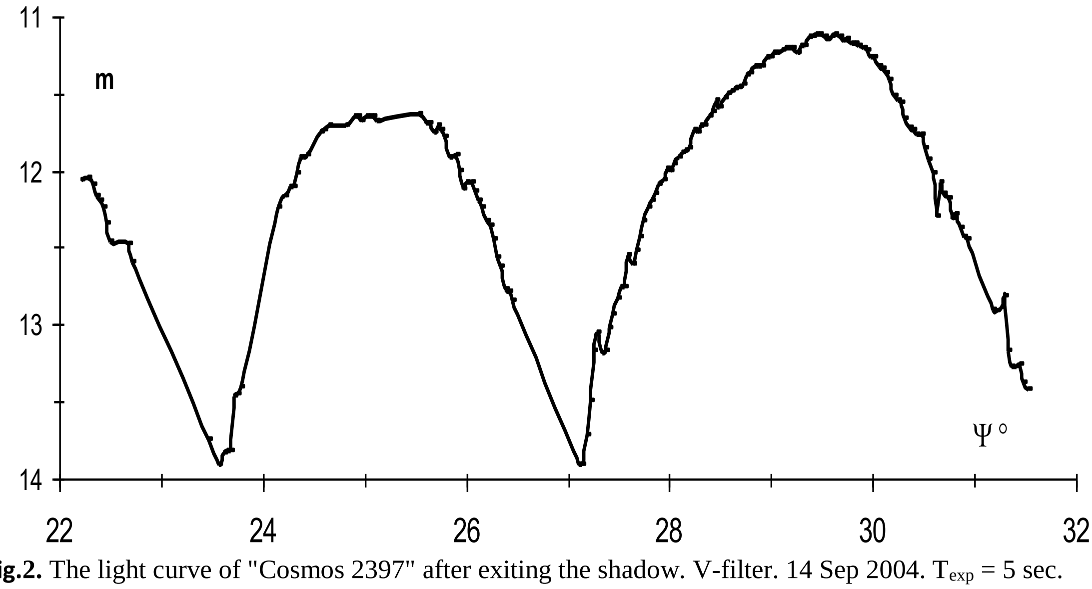

Fig.2. The light curve of "Cosmos 2397" after exiting the shadow. V-filter. 14 Sep 2004. T_{exp} = 5 sec.

T_{exp} – is the time of exposure of a single measurement. The satellite's solar panels (SP) rotate with maximum speed of one rotation per 18 minutes. At the time of the first flare the SP tilt towards the Sun was 6.5 degrees, and at the time of the second flare – 8.7 degrees. The minimum inclination of the panels towards the Sun was ~5 degrees. That is a typical inclination of an active GSS solar panels towards the Sun. The SP orientation remains unaltered relative to the Sun, although the satellite slowly drifts along the orbit (~1° per day). The components of the unit normal vector to the SP surface in the light curve corresponding to the second peak in brightness at ψ from 19°.13 to 23°.65 are given in **Table 1**. After one night **(Fig.2)**, the observation conditions changed slightly. Only a diffuse light curve was observed.

As can be seen from Table 1, the Y component is perpendicularly oriented to the observer. The SP orientation by two mirror flares in **Fig. 1** demonstrates that they were moving perpendicularly in the ecliptic plane. Thus, the angles of the orientation of normal for the first flare was α = 176°.96, δ = 4°.94, and for the second flare α = 179°.22, δ = 4°.96

Table 1. The normal vector orientation towards SP related to the observer at the phase angles from 19°.13 to 23°.65 for 12.09.2004.

Ψ°	Xn	Yn	Zn
19.130	0.023	0.994	-0.104
20.196	0.013	0.995	-0.096
21.044	0.004	0.996	-0.090
21.413	0.001	0.996	-0.088
21.766	-0.003	0.996	-0.086
22.855	-0.014	0.997	-0.081
23.652	-0.021	0.997	-0.077

Ψ – the satellite-centric phase angle; Xn, Yn, Zn – components of the normal vector to the reflective surface.

A possible cause of the non-standard operating mode. Most likely the stabilization of the GSS failed, which led to its rotation around the Z-axis **[1].**

Fig.3. "DSP" model features

It is known that a "DSP" revolves at about 6 rpm, which allows the satellite to monitor the same area of the Earth's surface after ~ 50-52 s. Each satellite of this series has 4 SP (**Fig.3**).
Based on own photometric observations and similar received by Didenko **[2]** it has been found that the DSP's optical system revolves around the optical axis with period P1 = 10.44 s and it performs a conical rotation around the zenith-nadir axis with a period of P2= 62.64 s.

Fig.4 shows a fragment of the light curve of "DSP-18", transmitted in 2009 year from λ = 145°E on λ≈20°E.

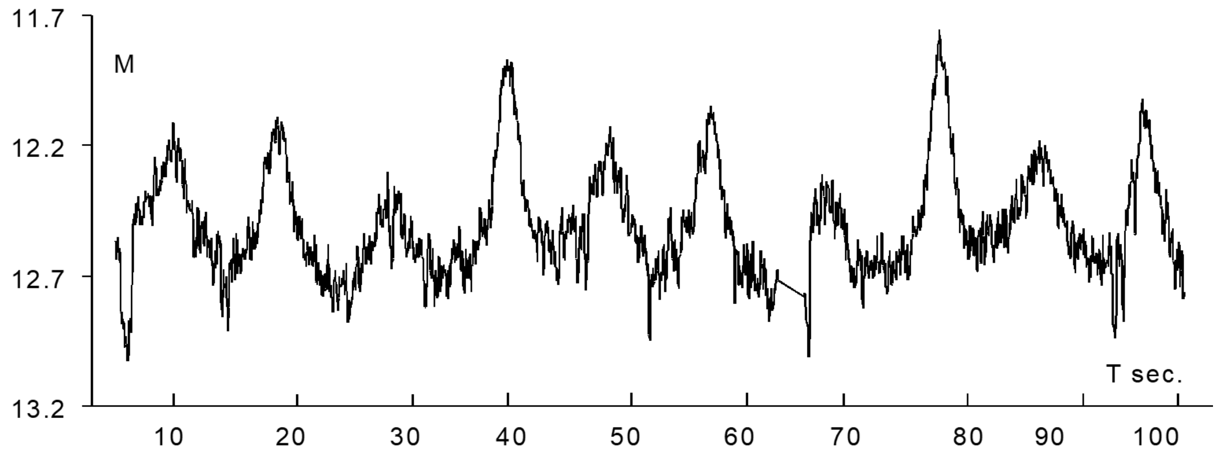

Fig.4. A fragment of the light curve of "DSP-18", V-band, 29 Sep 2014. T_{exp} = 0.2 sec.

Studying the behavior of the satellite "SBIRS-Geo 2" in orbit

The GSS "SBIRS"-system uses a different principle of scanning the Earth. Two telescopes are located inside the moving satellite. The scanning is performed by two mirrors rotating around two coordinates. Mirrors are located in the windows on one side of the platform body. The shape of the object is shown in **Fig.5 [3].**

In addition to the two SP there is yet another one, bent at the end at an angle of 90°. It is also designed to calibrate IR receivers.

For studying of the behavior of the "SBIRS-Geo 2" was used a high-speed photometer based on the FEU-79, operating in pulse counting mode. The photometer is placed in the focus of the 50-cm Cassegrain telescope to test the light receiver and electronics used by the stabilized current and temperature of the LED on the AL-102 **[4].**

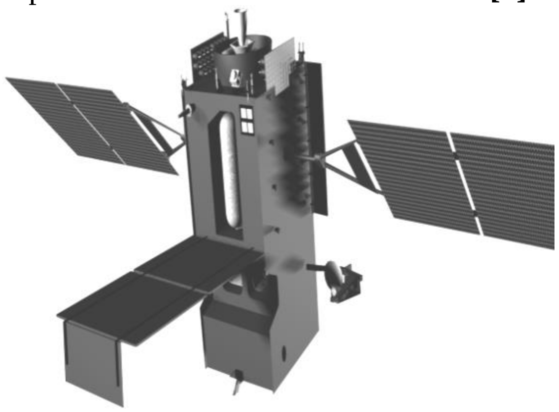

Fig.5. "SBIRS-Geo 2" model features.

Calibration of the observations was done by the stars of spectral type G2-G8 wide-band WBVR GAISH catalog **[5].** It is of high precision and evenly covers the equatorial zone. For operational records the instantaneous value of the extinction coefficient was used through "the method of couples of different heights of the stars".

The processing of the photometric results was carried out in the order: determination of satellite instrumental brightness and bringing it to the standard photometric Johnson system → calculation of the satellite's light at the distance 36000 km → calculation of the phase angles ψ for the moments of observation and construction of the phase light curve → the calculation of the effective reflection area for the phase angles → calculation of the magnitude, and thus, effectively reflecting area and other characteristics at the ψ=0° and ψ= 25°.

From 22 Aug 2014 until Oct 2017 the authors received more than 40 light curves in the B, V, R bands. **Fig.6** and **Fig.7** show the light curves for "SBIRS-Geo 2", obtained at small phase angles ψ.

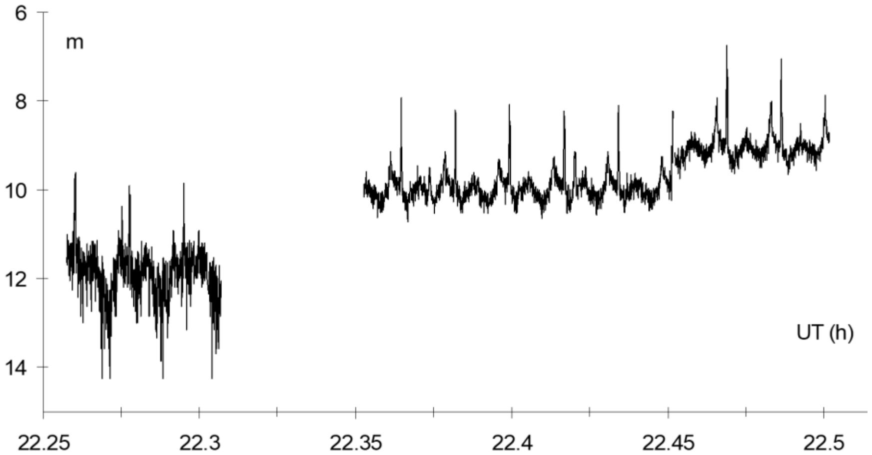

Fig.6. The light curve of "SBIRS-Geo 2" in B, V, R filters. 29 Aug 2014. B (UT = 22.25 – 22.30), V (UT = 22.35 – 22.45), R (UT = 22.45 - 22.50). T_{exp} = 0.1 sec. ψ = 7°.

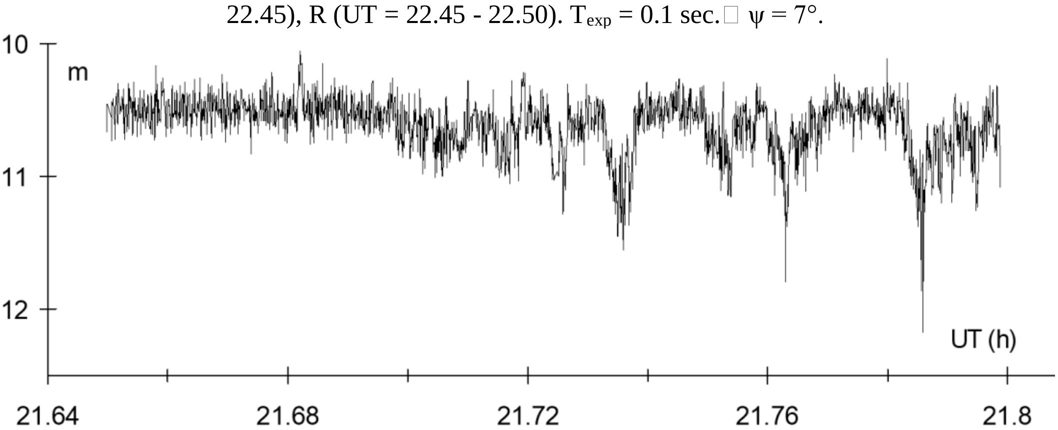

Fig.7. The light curve of "SBIRS-Geo 2" in V-filter, T_{exp} = 0.2 sec, Ψ =15°. 01 Oct 2014.

The most informative B, V, R light curves were the ones obtained on 29 Aug 2014. This night there was a series of specular glints, with the brightest in R. However, the most prominent changes in the brightness of the amplitude were in B filter (**Fig.6**). When the Sun was to the west from the object no changes in R were observed. The presence of specular glints in the light curves allows to determine the position of "SBIRS-Geo 2" in orbit, the direction "satellite-center of the Earth", and the normal vector for the time of the glare.

Positional observations determine the phase angle, the change in longitude and latitude of the satellite's sub-point and other angles in the equatorial satellite coordinate system.

Normal vector was determined using the method described in **[6]**

$$\vec{n} = \vec{v}_{\Theta} + \vec{v}_s$$

where $\vec{v}_{\Theta} = \begin{bmatrix} \cos\alpha_{\Theta} \cos\delta_{\Theta} \\ \sin\alpha_{\Theta} \cos\delta_{\Theta} \\ \sin\delta_{\Theta} \end{bmatrix}$,

and $\vec{v}_s = \begin{bmatrix} \cos\alpha \cos\delta \\ \sin\alpha \cos\delta \\ \sin\delta \end{bmatrix}$

are the equatorial coordinates of the directions "satellite-Sun" (ΘS) and "satellite-observer" (SO), respectively. The equatorial coordinates of the normal direction are

$$\vec{n} = \begin{bmatrix} X_n \\ Y_n \\ Z_n \end{bmatrix}; \ \alpha_n = arctg\left[\frac{Y_n}{X_n}\right], \delta_n = \arcsin Z_n .$$

Calculation of the phase angle of the satellite at the time of observation $\{T_i\}_{i=1,N}$:

$$\cos\psi_i = \frac{(\vec{v}^{\,i}_{\Theta S} \cdot \vec{v}^{\,i}_{SO})}{d \cdot \left|\vec{v}^{\,i}_{\Theta S}\right|},$$

$$\vec{v}^{\,i}_{SO} = -d \cdot \begin{Bmatrix} \cos\alpha_i \cdot \cos\delta_i \\ \sin\alpha_i \cdot \cos\delta_i \\ \sin\delta_i \end{Bmatrix} - \text{vector SO}, \quad (1)$$

where $\vec{v}^{\,i}_{\Theta S} = \vec{v}_{\Theta O} + \vec{v}^{\,i}_{OS}$ – vector "satellite-Sun", (α_i,δ_i) in **(1)** – the equatorial coordinates of SO and d – the topocentric distance SO at the moments of observation T_i.

$$\vec{v}_{\Theta O} = R_{AE} \begin{Bmatrix} \cos\alpha_{\Theta} \cdot \cos\delta_{\Theta} \\ \sin\alpha_{\Theta} \cdot \cos\delta_{\Theta} \\ \sin\delta_{\Theta} \end{Bmatrix} \text{ –"Sun-observer”},$$

R_{AE} –the average distance from Earth to the Sun,

$(\alpha_{\Theta},\delta_{\Theta})$ – Right ascension and Declination of the Sun at the time of observation;

$\vec{v}^{\,i}_{OS} = -\vec{v}^{\,i}_{SO}$ is a vector OS at time T_i.

The effective reflection area $S\gamma_\lambda$ of the satellite can be estimated as:

$$S\gamma_\lambda = d^2 \cdot 10^{\frac{m^{\Theta}_\lambda - m_\lambda}{2.512}} \cdot \sec\psi , \qquad (2)$$

where m_λ - the observed magnitude, γ_λ – the object's surface color reflection coefficient.

All input quantities in **(2)** can be reliably measured or calculated on the basis of the observations. Parameter $S\gamma_\lambda$ depends on the spatial orientation of the object, the longitude of the satellite's sub-point and the coordinates of the observer.

Rows in the **Table 2**: 1 - observing GSS interval in UT; 2 and 3 - the equatorial coordinates of the Sun; 4 and 5 - the equatorial coordinates of the observer at the observation interval; 6 and 7 - the geocentric equatorial coordinates of the position of the satellite in orbit; 8 and 9 - the equatorial coordinates of the direction normal to the details of the glare of the object; 10 and 11 - the equatorial coordinates of the direction vector of the satellite in its orbit; 12 - the angle between the directions of the SO to the Center of the Earth and the normal to the details of glare; 13 - the value of the phase angle of the SO; 14 and 15 - longitude and latitude position of the object in orbit on the observation interval; 16 and 17 – the speed of the satellite on the latitude and longitude at the time of observation; 18 - the geographical longitude and latitude of the observation point.

The analysis shows that the shape of the light curves for "SBIRS-Geo 2" essentially depends on the relative position of the Sun to the object (west or east) and the relative position of the satellite to the local meridian. The satellite not only revolves around the Earth with the diurnal period, but also performs librational movement along the equator in the range of ~ 9° - 10°. For example, during the observations 29 Aug

2014 the average value of its longitude $\lambda \approx 28°.5$, as of 3 May 2016 $\lambda \approx 20°.6$.

A significant change in illumination in all three color channels occurs when the satellite is near the observer's meridian, and the Sun illuminates the satellite from the east side. If the Sun is to the west from the satellite, the change in its brightness, including deep dips (**Fig. 5**) occurs mainly in blue and yellow filters. This is caused by the periodic shading of the solar panel with the IR sensor. A weak periodicity of brightness variation occurs when the object is shifted at some angular distance from the meridian of the observer to the west.

Table 2. Results of calculation of dynamic characteristics of GSS "Sbirs-Geo 2".

№	Parameters	22 Aug 2014	29 Aug 2014
1	UT (h m s)	22 34 30 – 22 40 50	22 15 00 – 22 29 40
2	$\alpha_{\odot}$ (°)	151.85	158.25
3	$\delta_{\odot}$ (°)	11.56	9.13
4	α_o (°)	158.95 – 160.54	160.78 – 164.27
5	δ_o(°)	8.37 – 8.23	8.21 – 7.87
6	α_g (°)	159.07 – 160.65	160.93 – 164.43
7	δ_g(°)	1.31 – 1.17	1.16 – 0.85
8	α_n (°)	–	159.51 – 161.27
9	δ_n (°)	–	8.67 – 8.51
10	α_x (°)	249.12 – 250.64	250.48 – 253.98
11	δ_x (°)	2.01 – 2.02	2.06 – 2.08
12	ν (°)	9.41 – 9.80	7.65 – 8.28
13	ψ (°)	7.68 – 9.17	2.67 – 6.08
14	λ (°)	28.95 – 28.94	28.52 – 28.49
15	φ (°)	-1.31 – -1.17	-1.16 – -0.86
16	ω_λ (°/min)	0.0016	0.0017
17	ω_φ (°/min)	0.0233	0.0205
18	λ, φ (°)	30.27; 46.40	30.27; 46.40

The satellite is located in orbit so that its longitudinal axis coincides with the direction of its orbital motion in the east direction. The side of the platform, on which windows with mirrors and an infrared calibration panel are located, face the Earth. The light from the satellite to the observer is reflected from the SP, infrared panel and the body ribs. This indicates that there is an oscillatory motion of the GSS and SP around the longitudinal axis of the satellite with a period of P = 62.64 s. There is no information about oscillation motions of the GSS body publicly available.

When the GSS is near the local meridian and the Sun in the lower culmination crosses the local meridian, the observer can see the specular glints from one of the mirrors, deployed at an angle to the northern parts of the hemisphere. In Aug 29, 2014 such glares were recorded. They can be observed only at the moment when the GSS is near the local meridian at a $\psi \leq 6°.0$- $6°.5$.

A direction from the satellite to the Sun and the observer coordinate δ must match within 1°.5 for the glints to be observable. This is due to the deep placement of mirrors in the windows of satellite body and their rapid rotation. The rotation of the mirror occurs with the period P_1=15.66 s. Thus, for one full period of oscillations, P_2 = 62.64 s, the satellites manage to control the strip 4 times the width of ~ 9000 km from north to south poles of the Earth.

The specular glints on the peaks of several gloss maxima in the R-band observed on the 29 August 2014 were not created by rotating mirrors. They were created by the calibration panel, as a result of satellite's oscillations as it reaches the maximum deviation to the north.

Again on 29 Aug 2014, the reflections in the R-band were not created by rotating mirrors. These flashes were created by the calibration panel as a result of oscillation of the satellite platform.

This allowed to estimate the magnitude of the oscillation angle of the satellite's body around its longitudinal axis. Its value (ν - δ_g), at the time of observation, was close to 7°. That is, the satellite makes oscillations with an angle of 7°.0-7°.5, one and the other side. Thus, it increases the controlled area by the Earth's surface, with the capture of two poles. And the previous generation DSP satellites scan the Earth's surface up to 83° north and south latitude.

Table 3 shows some of the date of the photometric characteristics this GSS at the time of observation. Reflective effective area ($S\gamma_\lambda$) was calculated from the **Eq.(2).**

Table 3. Photometrical characteristics of "SBIRS-Geo 2" at the time of observation.

Date, δ☉	Sp	m (± 0.05) ψ = 0°	m ψ = 25°	γ_λ ± 0.02	$S\gamma_\lambda$, m² ψ = 0° ± 0.05	ε°
29 Aug 14 δ☉ = +09°07'	B	14.23	14.33	0.003	0.128	1
	V	12.41	12.52	0.180	0.377	1
	R	10.40	10.50	0.035	1.49	1
30 Aug 14 δ☉ = +08°46'	B	13.398	13.505	0.006	0.274	1
	V	9.465	9.573	0.132	5.611	1
	R	10.172	10.28	0.021	1.823	1
01 Oct 14 δ☉ = -03°11'	V	12.36	12.47	0.009	0.396	1

In the table columns: the first - the date of observation, exposure and the declination of the Sun; Second - color channels B,V, R; third - a standardized magnitude of the satellites on the phase angle ψ = 0°; fourth - a standardized magnitude on the phase angle ψ = 25°; fifth - spectral reflection coefficient; sixth - the value of the effective reflective area – ($S\gamma_\lambda$); seventh - an approximate estimate of the angle of inclination of the solar panels to the observer.

In the case of the appearance of specular glints, the smoothing was done using the phase function for a flat plate with Lambert scattering. The procedure of the interpretation section of the diffuse component proposed in **[7]** was used at zero phase angle, as it is possible to calculate the corresponding value ($S\gamma_\lambda$) for ψ = 0°.

The color index data and the magnitude m in different filters confirmed that the "red" component predominates in the reflected light from the satellite. But periodic oscillations of the satellite and shading of the solar panels is brighter in the blue component.

Conclusions

A thorough analysis of the light curves and coordinate information provides a good opportunity to study the orbital behavior of the GEO satellites. This is shown in the examples of three GEO satellites.

Photometry of "Cosmos 2397" showed that the satellite's SP is oriented to the Sun. The object rotates around the Z axis with 18 minutes period, describing the cone with angle close to 5°. This possible attribute (but not the reason) for the abnormal operation "Cosmos 2397".

Offered the following model of functioning "SBIRS-Geo 2" in comparison with the "DSP"- system. The satellite of the "DSP"-system rotates with P1 ~ 10.44 s about its longitudinal axis, and makes a conical rotation with P2 = 62.64 s. This allows the GSS to scan the same surface in about 50 seconds at a range of up to 83° south and north latitudes. To control the whole of the Earth's surface in orbit should work with up to 8 satellites.

Satellites of the "SBIRS GEO" have improved technical characteristics of infrared sensors. The satellite platform does not rotate but oscillates to the south and north with an angle of 7°-7°.5 with P2 = 62.64 s. The satellite platform comprises two telescopes and two scanning mirrors. The mirrors are located at an angle to the plane of the equator and are deployed respectively to the south and north. Both mirrors make a conical rotation with P1 = 15.66 s. Each of the mirrors during the period P2 scans the same surface area four times with P1 ~ 15.7 sec. The satellite "SBIRS", swaying around the longitudinal axis, controls near the Polar Regions of the Earth.

"SBIRS", have the inclination of the orbit i = 4°.9, and do a librational movement for a day. As a result, the controlled area of the Earth's surface expands. It is enough to have four GSS of the SBIRS series placed along the equator through 90° to scan the entire surface of the Earth every 15-16 sec.

REFERENCES

1. Sukhov, P.P., Karpenko, G.F., Sukhov, K.P., Epishev, V.P., Motrunich, I.I., Kudzej, I., Dubovsky, P.A. (2014), “On the advantages of photometric observations of the geostationary satellites at small phase angles”. Odessa Astronomical Publications, vol. 27/2, pp. 149-153.
2. Didenko, A.V., Usol'tseva, L.A. (2010), “Analysis of ground-based information about a geostationary satellite “DSP F23” in distress” [“Analiz nazemnoy informatsii ob avariynom geostatsionarnom sputnike “DSP F23””]. Izvestiya NAN RK. No 4, pp. 81-84.
3. http://spaceflightnow.com/atlas/av037/geofactsheet.pdf.
4. Sukhov, P.P., Chaychuk, R.A. (1984), “Light-emitting diode standard of brightness” [“Svetodiodniy etalon yarkosti”]. Novaya tekhnika v astronomii, AN USSR, pp. 20-23.
5. Kornilov, V.G., Volkov, I.M. i dr. (1991), “Catalog of WBVR-magnitudes of bright stars in the northern sky” [“Katalog WBVR-velichin yarkikh zvezd severnogo neba”]. Trudy GAISH. T. 63, M.,: Izd-vo Moskovskogo un-ta, 400p.
6. Epishev, V.P. (1983), “Determination of the orientation of satellites from their reflection properties” [“Opredeleniye oriyentatsii INT v prostranstve po ikh zerkal'nomu otrazheniyu”]. Astrometriya i astrofizika AN USSR. Vyp.50, pp. 89-93.
7. Severnyi, S.A., Smirnov, M.A., Bagrov, A.V. (1986), “Determination of the shape of a satellite from photo-metric observations” [“Opredeleniye formy iskusstvennogo sputnika Zemli po fotometricheskim nablyudeniyam”]. Nauchniye informatsii.Vyp.58,pp. 103-106.

Стаття надійшла до редакції 15.11.2018.

В.П. Епишев[1], И.И. Мотрунич[1], В.М. Периг[1], П.П. Сухов[2], К.П. Сухов[2], Р.К. Павлажек[3]

[1]Лаборатория космических исследований Ужгородского национального университета, ул. Далекая, 2а, 88000, Ужгород, Украина

[2]Астрономическая обсерватория Одесского национального университета им. И. Мечникова, ул. Маразлиевская, 1б, Парк Шевченко, 65014, Одесса, Украина

[3]NCAC of PAS, ул. Бартиска, 18, 00-716, Варшава, Польша, Сибилла Технологии, ул. Торунская, 59/004, 85-023, Бидгощ, Польша, e-mail: pawlaszek@sybillatechnologies.com

О ВОЗМОЖНОСТИ КОНТРОЛЯ ПОВЕДЕНИЯ ГЕОСИНХРОННЫХ ОБЪЕКТОВ ПО РЕЗУЛЬТАТАМ ИХ НАЗЕМНЫХ НАБЛЮДЕНИЙ

Рассмотрены возможности совместного использования фотометрических и позиционных наблюдений геосинхронных спутников (ГСС) для объяснения их поведения на орбите. Приведен пример контроля трех ГСС:

"Космос 2397", "SBIRS-GEO 2" и "DSP-18". Комплексные исследования по "SBIRS-GEO 2" показали, что его поведение на орбите отличается от прогнозированного. Отмечено, что для обзора всей поверхности Земли, включая полярные регионы, с интервалом около 15-16 секунд, достаточно вдоль экватора иметь 4 ГСС серии "SBIRS". Для решения этой же задачи нужно не менее 8 ГСС серии "DSP", которые обозревают поверхность Земли до широты ±83° с периодом 50 секунд.

Ключевые слова: ГСС, кривая блеска, фазовый угол, фотометрия.

В.П. Єпішев[1], І.І. Мотрунич[1], В.М. Періг[1], П.П. Сухов[2], К.П. Сухов[2], Р.К. Павлажек[3]

[1]Лабораторія космічних досліджень Ужгородського національного університету, вул. Далека, 2а, 88000, Ужгород, Україна, e-mail: lkd.uzhgorod@gmail.com

[2]Астрономічна обсерваторія Одеського національного університету ім. І. Мечникова, вул. Маразлієвська, 1б, Парк Шевченко, 65014, Одеса, Україна, e-mail: psukhov@ukr.net

[3]NCAC of PAS, вул. Бартиска, 18, 00-716 Варшава, Польща, Сібілла Технології, вул. Торунська, 59/004, 85-023, Бідгощ, Польща, e-mail: pawlaszek@sybillatechnologies.com

ПРО МОЖЛИВОСТІ КОНТРОЛЮ ПОВЕДІНКИ ГЕОСИНХРОННИХ ОБ'ЄКТІВ ЗА РЕЗУЛЬТАТАМИ ЇХ НАЗЕМНИХ СПОСТЕРЕЖЕНЬ

Запропоновано новий підхід у сумісному використанні даних фотометричних і позиційних спостережень геосинхронних супутників (ГСС) для пояснення їх поведінки на орбіті. Наведено приклад контролю трьох ГСС: "Cosmos 2397", "SBIRS-GEO 2" і "DSP-18". Комплексні дослідження по "SBIRS-GEO 2" показали, що його поведінка на орбіті відрізняється від прогнозованої. Відмічено, що для обзору всієї поверхні Землі, у тому числі полярних областей, з інтервалами приблизно 15-16 секунд, достатньо мати 4 ГСС серії "SBIRS" рівномірно розташованих уздовж екватора. Для розв'язку цієї ж задачі потрібні щонайменше 8 ГСС серії "DSP", які зондують поверхню Землі до широт ±83° з періодом 50 сек.

Ключові слова: ГСС, крива блиску, фазовий кут, фотометрія.