THE ANALYSIS OF A SMALL-AMPLITUDE STRUCTURE FOR COSMIC OBJECTS LIGHT CURVES

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ABSTRACT In the given work a small-amplitude structure for stabilized cosmic objects (CO) light curves is considered by an example of orbital complex "Salyut-7" light curves in various versions of the "bundle". Coefficients s and κ are determined of noise and "determined" components the velocity of ratio variation of which $\frac{s}{\kappa}$ may serve as a sign of undocking (docking) of the objects at their optical unresolvability.

Key words: Artificial satellites

Results.

Active artificial CO are, as a rule, stabilized. So are called CO, observational time of which $\Delta\ T$ is small relative to the period of their rotation round their own mass centre P i.e.$\Delta\ T < P$. Light curve data are characteristic of: greater degree of smoothness due to small values of a numerical derivative which implies a pronounced light curve behaviour level above the background, minimum value of a composite factor, explicit or latent periodic component. However, after primary reduction of analyzed light curves according to the due procedure (Beletsky, 1985), a structure was found inherent to all the orbital complex light curves and showing small light variations with amplitude up to 0.6 units of standard brightness close to the integral light variation within all the observation time. As light curves of stabilized CO are the least informative pertaining the light curve correlation with the form of respective objects, such light variations can be of interest for finding the character of their changes when observing CO during the undocking.

A small-amplitude structure for stabilized CO light curves is likely to be due to the angle change between the object symmetry axis and the orbiting object towards the observer, the former having details slightly different from reflective properties or due to marked condition variation in optical radiation scatter by the object. In some cases, certain symmetry present in outer CO design, that is in the arrangement of the above details as well, may provide an appreciable periodic component in the corresponding light curve. To ground the correspondence of small-amplitude light variations with real properties of objects observed, it is necessary to show that these variations be sufficiently determined not only by random processes occurring while the object passes the scattered optical radiation through the atmosphere. The given processes imply real CO noise component as quite necessery in all the light curves; it can be defined by the expression

$$S = \frac{1}{N} \sum_{k=1}^{N} \frac{\sigma(I_k)}{I_k} \qquad (1)$$

where for each point of the light curve $(I_k) = (I_1, I_2, ..., I_n)$ the empiric function magnitude obtained from observed stars, determines an interval of assumed I_k values. To find a small-amplitude component value of I let us make up auxilliary series

$$I_1^{min}; I_1^{max}; I_2^{min}; I_2^{max}; ...; \ I_r^{min}; I_r^{max}; ...; I_n^{min}; I_n^{max}$$

and

$$I_1^{max} - I_1^{min}; \ I_1^{max} - I_2^{min}; ...; \ I_r^{max} - I_r^{min};$$

$$I_r^{max} - I_{r+1}^{min}; ...; \ I_{n-1}^{max} - I_{n-1}^{min}; \ I_{n-1}^{max} - I_n^{min}$$

Then, the unknown is

$$\kappa = \frac{1}{2\,(n-1)} \sum_{r=1}^{n-1} (I_k) \frac{1}{\sum_{k=m_r}^{m_r+1}}$$

$$(m_{r+1} - m_r + 1)(2I_r^{max} - I_r^{min} - I_{r+1}^{min}) \quad (2)$$

Here $k = m_1, .., m_r, ..., m_n$ are coordinates of series terms, locally minimum values of I_k. And the relation

$$\frac{S}{\kappa} = \frac{2(n-1)}{N} \sum_{k=1}^{N} \frac{\sigma(I_k)}{I_k} (\sum_{r=1}^{n-1} (m_{r+1} - m_r + 1)$$

$$(2I_r^{max} - I_r^{min} - I_{r+1}^{min})(\sum_{k=m_r}^{m_{r+1}} I_k)^{-1})^{-1} \quad (3)$$

will determine an index of correspondence of some found light variations with real determined processes.

If we give a wanted initial value to index k, take $N' < N$ and substitute them to the expression obtained for $\frac{s}{\kappa}$, then an arbitrary part of the studied light curve consisting of N' values can be evaluated in terms of the given index. It is evident that determinancy degree of light curve structure is the more, the less is $\frac{s}{\kappa}$ index, and its total determination by random processes occurs at $\frac{s}{\kappa} \rightarrow 1$. For light curves of stabilized objects, the $\frac{s}{\kappa}$ index is likely to change in passing from some parts of the curve to the other. So, it is reasonable to study such a light curve by dividing the whole curve (I_k) into parts, the definite constant step being not too small $\Delta\ k\ >\ n \cdot max(m_{r+1} - m_r)$, ($n$ is the number of variations per curve part in $\Delta\ k$, $n_{min} > 1$) $(I_k)_1$, $(I_k)_2$, ..., $(I_k)_i$, ...,$(I_k)_{\frac{k}{\frac{N}{\Delta\ k}}}$ and by obtaining discrete function $(\frac{s}{\kappa})$ showing reliability of small-amplitude light variation determinancy within all the observation time of CO.

As is seen from the index $\frac{s}{\kappa}$ calculated for all the light curves of the orbital complex (the list is given below), not all the curves obtained during the object transit show small-amplitude variations due to random processes. Over half of all the curves have small-amplitude structure with a noise component being less than 60i.e. $\frac{s}{\kappa}$ index varics from 0.40 to 0.64. It should be noted that 3 days transits up to "Progress-24" separation from 11.07.1985 have $\frac{s}{\kappa} \approx 1$, i.e. without any determined component present. But on 11.07.1985 two orserved light curves of undocked objects showed a determined small-amplitude component present with $\frac{s}{\kappa} = 0.510$ for "Progress-24" and $\frac{s}{\kappa} = 0.644$ for the complex "Salyut-7" - "Soyus-T-B". It is probable that such a great $\frac{s}{\kappa}$ change should be manifested while observing the docking and undocking objects per transit. Certain rate variation function of $(\frac{s}{\kappa})_i$ for some part of the corresponding light curve could be a sign of undocking or docking in this case even at optical unresolvability of the objects. Other parameters of small-amplitude structure of the light curve may change as well in this case.

A list of light curves of the orbital copmlex (CO 82-33-1)

1. 8.07.85, 20 02.290, "Salyut-7"-"Soyus T -13"-"Progress-24";
2. 8.07.85, 21 38.425, "Salyut-7"-"Soyus T -13"-"Progress-24";
3. 8.07.85, 23 15.221, "Salyut-7"-"Soyus T -13"-"Progress-24";
4. 11.07.85, 19 51.197, "Salyut-7"-"Soyus T -13"-"Progress-24";
5. 11.07.85, 21 27.227, "Salyut-7"-"Soyus T -13"-"Progress-24";
6. 13.07.85, 19 11.961, "Salyut-7"-"Soyus T -13"-"Progress-24";
7. 13.07.85, 20 47.562, "Salyut-7"-"Soyus T -13"-"Progress-24";
8. 15.07.85, 20 08.182, "Salyut-7"-"Soyus T -13" and separately "Progress-24" (undocking of "Progress-24");
9. 17.07.85, 19 28.003, "Salyut-7"-"Soyus T -13";
10. 18.09.85, 17 16.096, "x";
11. 18.09.85, 17 22.066, "Salyut-7"-"Soyus T -13"-"Soyus T-14";

It is probable for the objects passing their own mass centres with large periods during their detachment to have marked rotational motion round the axes, particularly for those whose activity is not suggested, as direction coincidence of detaching force vector-pulse with the common objects symmetry axis is unlikely. The resulting momentum depends on detaching force vector-pulse, the angle between its direction and a common symmetry axis of objects and mass distribution about the volume of the detached object. It depends on the ratio of momentum formed at the undocking and of constaut resulting forces of different nature acting on the orbiting object whether the object will have a constant angular velocity of rotation round the axis passing through its mass centre or whether it will oscillate about some steady equilibrium position with rather a small period not to be found in analyzing the light curve per transit. Such oscillations may be only with slight amplitudes and will be shown in small-amplitude structure of light curves only at small values of S provided the atmosphere is most favourable during observations, radiation recording of sufficient frequency, and the least level of dark current noise. To check up the supposition on the object oscilation after undocking, an analysis was made on the periodicity by the method (Beletsky, 1985). The structure was found inherent to all the light curves of two parts of the spaceship "Progress-24" light curves. For the curve $\frac{s}{\kappa} = 0.510$, and for the curve part with maximum amplitude $\frac{s}{\kappa} = 0.339$, i.e. the determined component value is about 50%.

Similarly, an analysis of orbital complex light curves was made for which $\frac{s}{\kappa} < 0.5$. In small-amplitude structure of light curves obtained before and after undocking, no periodic component has been found.

For the most efficient revealing of a reliable determined small-amplitude component, it stands to reason to carry ont complementary CO observations by the above method by determining a multidimensional vector field preset in the celestial sphere at the observation moment. It implies that each point of the celestial sphere should fit a multidimensional vector with components

$$S_\nu = \frac{1}{N_\nu} \sum_{k=1}^{N} \frac{\sigma(I'_k)_\nu}{(I'_k)_\nu} \tag{3}$$

$(I'_k)_\nu$ is the set of extended in time photoregistrations of extraatmospheric radiation sources with different light values. The given problem can be solved by using the theory of electromagnetic radiation distribution in the turbulent atmosphere for the optical range to determine digital filter parameters for small-amplitude structure of light curves.

Reference

Beletsky V.V.: 1985, *Artificial Earth Satellite motion relative to the mass centre,* Moscow, Nauka.