Reports of the Academy of Sciences of the USSR

1961

SovietRxiv

Abstract

Full Text

Reports of the Academy of Sciences of the USSR

1961. Volume 137, No. 3

GEOPHYSICS

V. M. GRIGOREVSKII

ON RAPID CHANGES IN THE PERIOD OF ROTATION ABOUT THE TRANSVERSE AXIS OF THE SECOND SOVIET ARTIFICIAL EARTH SATELLITE

(Presented by Academician L. I. Sedov on 23 IX 1960)

Soviet stations for observing artificial Earth satellites obtained an extensive series of photometric observations of the second artificial satellite. These observations were transferred by the Astronomical Council of the Academy of Sciences of the USSR to the Odessa Astronomical Observatory for processing.

Table 1

No.	JD 2436 ...	Date (world time) 1958	$^1/_4\,P$	σ	n	W	$^1/_4\,P'$
1	278.586	III. 16.086	47.5	$\pm 11^s.5$	2	165	$24^s.5$
2	281.580	19.080	42.8	4.3	12	204	19.5
3	282.435	19.935	52.2	4.3	12	172	28.8
4	283.208	20.708	32.7	2.4	7	178	9.3
5	284.136	21.636	40.1	5.2	8	170	16.6
6	285.221	22.721	55.8	5.9	13	186	32.2
7	286.075	23.575	40.9	1.9	8	148	17.3
8	287.230	24.730	47.5	2.5	2	172	23.8
9	288.240	25.740	47.5	2.5	2	242	23.7
10	289.247	26.747	50.4	8.8	5	212	26.5
11	291.258	28.758	63.3	15.8	3	232	39.2
12	296.291	IV. 2.791	55.0	1.0	2	320	30.5
13	297.252	3.752	52.0	8.0	2	283	27.4

No.	JD 2436 ...	Date (world time) 1958	$^1/_4\,P$	σ	n	W	$^1/_4\,P'$
14	301.265	7.765	70.0	–	1	310	45.1
15	302.255	8.755	70.2	19.0	6	310	45.2
16	303.284	9.784	59.0	–	1	289	33.9
17	304.225	10.725	70.5	8.5	2	335	45.3
18	305.256	11.756	70.7	9.7	3	255	45.5
19	306.219	12.719	49.0	–	1	251	23.7
20	307.267	13.767	38.0	–	1	160	12.6

Table 1 gives data on the period of rotation of AES-2 about the transverse axis for March–April 1958, obtained by the author from these observations. The values of $^1/_4P$ were determined as time differences between neighboring extrema of the brightness curves (for details see ([11])) and correspond to the synodic period ([5]) of rotation of the satellite about the transverse axis. (Rotation about the longitudinal axis, owing to the longitudinal symmetry of AES-2, does not cause changes in brightness.) The values of $^1/_4$ of the period in the table are the means of n observed individual values (averaging of data from different observers was performed in order to reduce observational errors and the influence of the "parallactic" ([5]) shift of the moments of the brightness extrema); σ is the root-mean-square error of the corresponding mean.

A comparison of the second and third columns of the table shows that the smooth increase with time of the rotation period of AES-2 relative to the transverse axis is accompanied by comparatively rapid oscillations lying outside the limits of observational error. The cause of these oscillations is unclear.

L. I. Sedov pointed out ([1]) the possibility of braking of the satellite' s rotation about its center of mass through interaction with the Earth' s magnetic field. Theoretical calculations by Yu. V. Zonov ([2]) confirmed that the occurrence of eddy currents in the metallic shell of a rotating satellite leads to a noticeable secular decrease in its angular velocity of proper rotation. It was therefore natural to try to find the cause of the rapid changes in the satellite' s rotation period in changes of the Earth' s magnetic field or of the state of the terrestrial atmosphere under the influence of some external factors. To this end we compared the course of $^1/_4P$ with the change in certain characteristics of solar activity.

Fig. 1. Change in Wolf numbers and in the rotation period of the second Soviet satellite with time. The cross marks the value $^1/_4P = 44^{\mathrm{s}}.2$, obtained by the author from Moor' s photoelectric observations ([11]).

It turned out that the features of the curve of change in solar activity are repeated, with some delay, on the curve of change in the satellite' s proper rotation period (Fig. 1). The correlation is most clearly manifested between

Fig. 1. Change in Wolf numbers and in the rotation period of the second Soviet satellite with time. The cross marks the value $^1/_4P = 44^{\mathrm{s}}.2$, obtained by the author from Moor' s photoelectric observations ([11]).

Figure 1: Fig. 1. Change in Wolf numbers and in the rotation period of the second Soviet satellite with time. The cross marks the value $^1/_4P = 44^{\mathrm{s}}.2$, obtained by the author from Moor' s photoelectric observations ([11]).

Fig. 2. Dependence $^1/_4P - W$. The cross marks the value $^1/_4P = 44^{\mathrm{s}}.2$.

Figure 2: Fig. 2. Dependence $^1/_4P - W$. The cross marks the value $^1/_4P = 44^{\mathrm{s}}.2$.

the period and the Wolf numbers. The lag of the period changes in this case is 2.55 days.

The numbers W in Table 1 were taken from the Wolf-number curve—the data ([3]), shifted to the right by 2.55 days. The dependence $^1/_4P - W$ is shown in Fig. 2 and is expressed by the formula obtained by the method of least squares:

$$^1/_4P = +20^{\mathrm{s}}.03 + 0^{\mathrm{s}}.14246\,W.$$

Fig. 2. Dependence $^1/_4P - W$. The cross marks the value $^1/_4P = 44^{\mathrm{s}}.2$.

It is interesting that the deviations of the observed values of $^1/_4P$ from those calculated by this formula are of the same order as the corresponding σ, and in half the cases they are smaller than σ. In accordance with this, the correlation between the magnitude of the period and the Wolf numbers proved to be significant: $r = +0.76$.

To check the significance of the correlation obtained, we used the table given in ([9]), which gives the probability of the occurrence of such a correlation in a random sample from an uncorrelated population. Since this probability turned out to be very small ($P \ll 0.01$), the correlation we found is definitely significant.

The values of the satellite' s rotation period published by V. P. Tsesevich ([4]) for 1958 δ_1 also correlate with the Wolf numbers; however, their small number does not permit a reliable determination of the degree of correlation.

Thus, variations of solar activity, affecting the state of the Earth' s magnetic field and also of the terrestrial atmosphere ([6–8]), are apparently the cause of the comparatively rapid changes in the period of rotation of satellites relative to the transverse axis.

However, the question arises: why do variations of the Earth' s magnetic field and of the state of the terrestrial atmosphere under the influence of changes in solar activieffects have a direct impact on the satellite' s rotation period? It is obvious that these variations should cause only oscillations in the angular acceleration of the satellite' s rotation, without disturbing the monotonic character of the change in the period: the period will increase smoothly even with constant Wolf numbers, while its acceleration, being quasi-constant at constant W, should vary as W varies.

To clarify this question, from the data of Table 1 the following formula was obtained by the method of least squares:

$$^{1}/_{4}P = -138^{\mathrm{s}}.15 + 0^{\mathrm{s}}.65150\,(JD - 2436000.0) \tag{1}$$

If the smooth increase of the period given by this formula were entirely due to the "ordinary" braking in the Earth' s atmosphere, then the correlation obtained above should have applied not to the satellite' s rotation period, but to the differences between the observed values of the period and those computed from formula (1). However, these differences showed no correlation whatsoever with the Wolf numbers. At the same time, the correlation between the differences of the observed and computed, according to formula (1), values of the period and the differences of the observed and computed, with respect to the formula

$$W = -1015^{\mathrm{s}}.75 + 4^{\mathrm{s}}.250305\,(JD - 2436000.0), \tag{2}$$

obtained analogously to formula (1), turned out also to be significant: $r = +0.63$.

These results make it possible to conclude that the smooth increase of the period over the time interval under consideration during the existence of IES-2 was to a significant extent due to the general increase in solar activity.

It was possible to estimate the share contributed to the overall braking of the satellite' s rotation by effects associated with variations in solar activity. For this purpose, from the data of Table 1 the formula was obtained:

$$P = -8^{\mathrm{s}}.84 + 0^{\mathrm{s}}.33064\,(JD - 2436000.0) + 0^{\mathrm{s}}.53535\,W, \tag{3}$$

which takes into account both the smooth increase of the period and its variation with changes in W.

For a comparative estimate of the influence of solar activity and of the "ordinary" braking, in this formula one should pass from W to the daily change in the Wolf numbers W_{JD}, which, as formula (2) shows, is on average equal to $W : 4.25$ over the time interval considered. Correspondingly, the coefficient of W_{JD} becomes equal to $2^{\mathrm{s}}.27540$.

Thus, on average, 87.3% of the change in the rotation period of satellite 1957 β in March–April 1958 is associated with the change in solar activity.

It is now clear why the correlation appears in the case $P{-}W$, and not $\Delta P{-}W$: according to formula (3), from 16 III to 13 IV 1958 the smooth change in the period amounted to only $2^{s}.37$. Consequently, within the errors with which the satellite' s rotation period is determined from photometric data (see Table 1), it may be considered that the entire change in the period is associated with variations in solar activity.

Reasoning more rigorously, we may assert that if the second term in formula (3) correctly separates that part of the change in the satellite' s rotation period which is not connected with variations of solar activity, then the difference

$$P - 0^{s}.33064\,(JD - 2436000.0) = P'$$

gives, to within an additive constant, the acceleration of rotation due only to varia-

···with variations in solar activity. In this case one may expect that the correlation ${}^{1}/_{4}P' - W$ will be almost the same as in the case ${}^{1}/_{4}P - W$. The calculations confirmed this fact: $r' = +0.74$.

Thus, in the last month of the existence of ISZ-2, the braking of its rotation was due mainly to the sharply increased solar activity.

Astronomical Observatory
of Odessa State University
named after I. I. Mechnikov

Received
4 VI 1960

REFERENCES

1. L. I. **Sedov**, *Artificial Earth Satellites*, vol. 2, Publishing House of the Academy of Sciences of the USSR, 1958, p. 6.

2. Yu. V. **Zonov**, *Artificial Earth Satellites*, vol. 3, Publishing House of the Academy of Sciences of the USSR, 1959, p. 120.

3. *Solar Data*, Bull. Acad. Sci. USSR, Nos. 3-4 (1958).

4. V. P. **Tsesevich**, Bull. of Optical-Observation Stations of ISZ, No. 7, 12 (1959).

5. V. M. **Grigorevskii**, Bull. of ISZ Stations, No. 10, 6 (1959).

6. T. R. **Noweller**, *Nature*, 182, 468 (1958).

7. R. **Jastrow**, *Sci. Am.*, 201, No. 2, 37 (1959).

8. P. E. **Elyasberg**, V. D. **Yatskov**, *Artificial Earth Satellites*, vol. 4, Publishing House of the Academy of Sciences of the USSR, 1960, p. 18.

9. R. A. **Fisher**, *Statistical Methods for Researchers*, Table V A, Moscow, 1958.

10. J. G. **Moore**, *Publ. Astron. Soc. Pasif.*, 71, No. 419, 163 (1959).

11. V. M. **Grigorevskii**, Bull. of ISZ Stations, No. 8 (18), 14 (1960).

Note: Figure translations are in progress. See original paper for figures.