

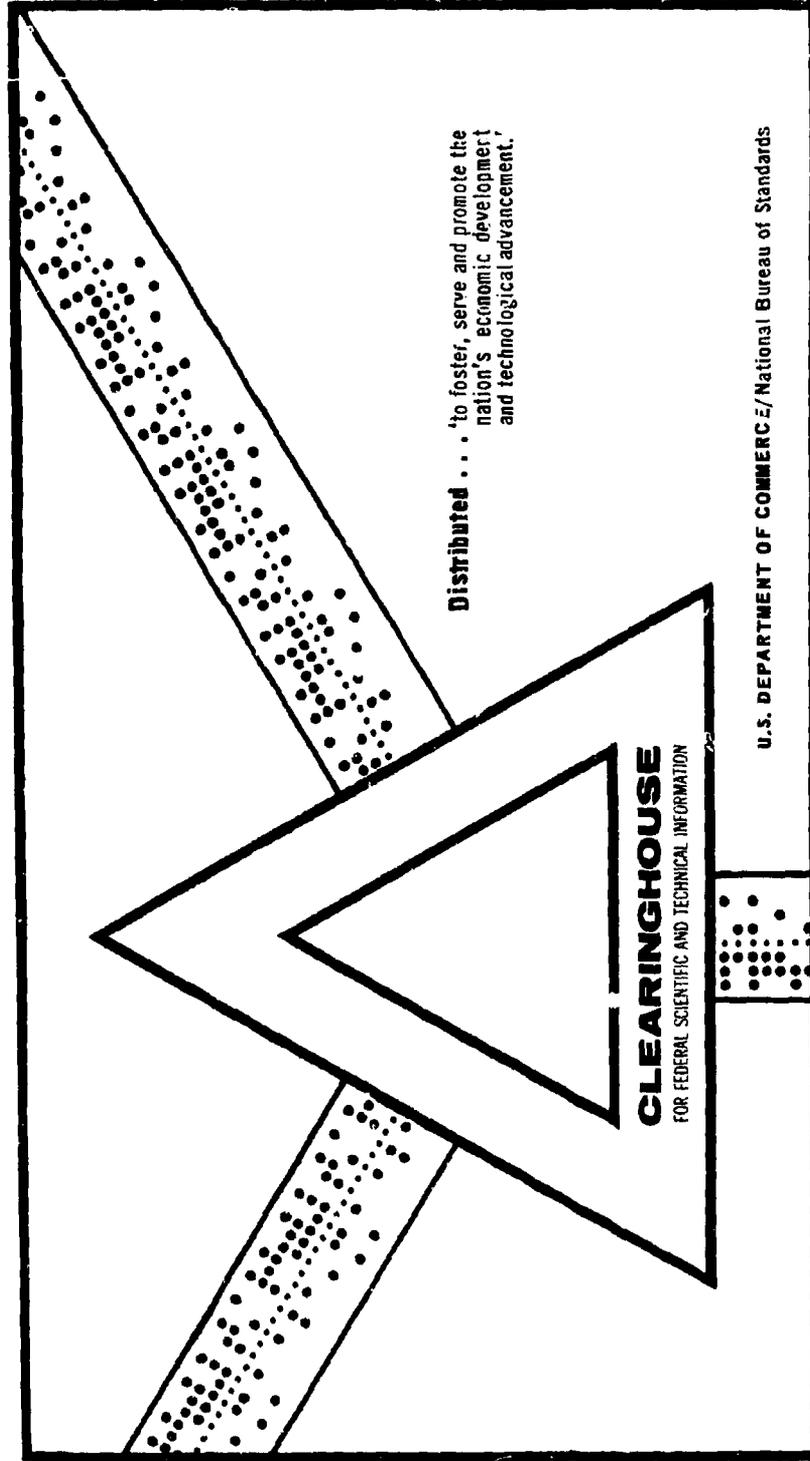
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CONFERENCE STUDY OF ROTATION OF ARTIFICIAL EARTH SATELLITES
BASED ON PHOTOMETRIC DATA (SELECTED ARTICLES)

B. E. Melnika, et al

Foreign Technology Division
Wright-Patterson Air Force Base, Ohio

19 September 1969



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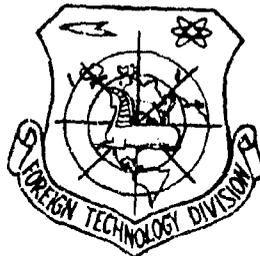
FOREIGN TECHNOLOGY DIVISION



CONFERENCE

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BASED ON PHOTOMETRIC DATA"

(SELECTED ARTICLES)



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BASED ON PHOTOMETRIC DATA" (SELECTED ARTICLES)

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PREPARED BY:

TRANSLATION DIVISION
FOREIGN TECHNOLOGY DIVISION
WP-APB, OHIO.

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А	<i>А</i>	A, а	Р	<i>Р</i>	R, r
Б	<i>Б</i>	B, b	С	<i>С</i>	S, s
В	<i>В</i>	V, v	Т	<i>Т</i>	T, t
Г	<i>Г</i>	G, g	У	<i>У</i>	U, u
Д	<i>Д</i>	D, d	Ф	<i>Ф</i>	F, f
Е	<i>Е</i>	Ye, ye; E, e*	Х	<i>Х</i>	Kh, kh
Ж	<i>Ж</i>	Zh, zh	Ц	<i>Ц</i>	Ts, ts
З	<i>З</i>	Z, z	Ч	<i>Ч</i>	Ch, ch
И	<i>И</i>	I, i	Ш	<i>Ш</i>	Sh, sh
Й	<i>Й</i>	Y, y	Щ	<i>Щ</i>	Shch, shch
К	<i>К</i>	K, k	Ъ	<i>Ъ</i>	"
Л	<i>Л</i>	L, l	Ы	<i>Ы</i>	Y, y
М	<i>М</i>	M, m	Ь	<i>Ь</i>	'
Н	<i>Н</i>	N, n	Э	<i>Э</i>	E, e
О	<i>О</i>	O, o	Ю	<i>Ю</i>	Yu, yu
П	<i>П</i>	P, p	Я	<i>Я</i>	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere.
 When written as ѣ in Russian, transliterate as yě or ě.
 The use of diacritical marks is preferred, but such marks
 may be omitted when expediency dictates.

OPENING ADDRESS

B. Ye. Mel'nika

Pro-Rector of Kishinev State University

Dear comrades! On behalf of the management and members of Kishinev University permit me to welcome you within the precincts of the university.

We welcome you, distinguished specialists, researchers in the field of artificial earth satellites and chiefs of satellite tracking stations, covering our entire country from Komsomol'skon the Amur and Blagoveshchensk to the western boundaries.

At the same time, in your person we greet advanced Soviet science, achieving increasingly newer and newer outstanding achievements in mastering the cosmos. You gathered here in days, when the whole world applauds the new outstanding victory of Soviet science - the flight and landing of automatic interplanetary station "Zond-5," and this makes your reception especially significant.

The fact that the Kishinev State University is selected as the place of conducting this conference is very significant for another reason. Kishinev State University in Moldavia, for all its history, is a university founded relatively recently, in 1951. And if today you conduct your conference with us, if our station is entrusted with coordination of the international cooperation of photometric

operation of SPIN, we regard this as evidence of the overall growth of the level of science in our republic, growth which is a direct result of the wise Leninist policy of our party.

I will not deny that by sending an invitation to conduct the conference with us, we were influenced, so to speak, by mercenary motives. We calculate that carrying out the conference in the Kishinev University, personal contacts of our colleagues with scientists, representing so many leading organizations of our country in the field of investigations of satellites, will have the further result of expansion and advance of works in our university.

One-hundred and seventy-two years ago Napoleon in a letter to the outstanding astronomer-mechanical engineer Laplace wrote: "Of all the sciences astronomy is the one which was the most useful for intelligence and commerce; at the same time it needs further relations and the existence of scientific intercourse the most." Now, when circumterrestrial outer space is furrowed with hundreds of celestial bodies, created by the hands of man, when cosmonauts accomplish walks in outer space, when prospects of landing on the moon become increasingly closer, our huge planet becomes progressively smaller and smaller. While in our time the character of any science becomes increasingly collective, your field of science simply cannot be developed without the closest contacts. This is why we undertook everything in our power, so that your conference would be held at a high level, corresponding to the branch of science, which you represent.

We wish you fruitful and successful work, and also a pleasant stay in Moldavia.

OPENING ADDRESS

A. G. Masevich

Chairman of the Commission for Multilateral Collaboration
of Academies of Sciences of Socialist Countries on the
Problem "Scientific Studies Based on Observations
of Artificial Earth Satellites"

Dear comrades! We are gathered here, in Kishinev, in order to discuss results of the international cooperative work of SPIN, a program which was proposed by colleagues of satellite tracking stations at the Kishinev State University. By decree of the Commission of Multilateral Collaboration of Academies of Sciences of Socialist Countries, the coordinator of work on this program is designated the chief of the Kishinev station docent V. M. Grigorevskiy.

As a result of three years of work there has already been obtained interesting observation material for investigation of the connection between manifestations of solar activity and changes of the period of rotation of satellites, and also for investigation of satellite orientation. Theoretical studies of aerodynamic, electromagnetic and other forms of braking of rotation of satellites are expanded increasing wider.

Some time ago there was compared braking of rotation and braking of the motion in orbit of the same satellite. Now there have even been conducted the first specially set parallel investigations of periods of rotation and handling of satellite 65114 on the basis of

results of observations obtained in accordance with international SPIN and INTEROBS programs. We hear about results of the enumerated investigations in reports.

It is necessary to note the especially good work in the field of photometry of satellites by the collective of Kishinev artificial earth satellite tracking station and the work of the station chief V. M. Grigorevskiy. The Kishinev station not only heads the international work on the SPIN program and directs its execution, but also does much itself for its fulfillment. It is sufficient to say that more than half of all the observations in 1965-1968 on the SPIN program were carried out in Kishinev.

Colleagues of the station published dozens of theoretical and experimental works on this topic. There is published a volume, containing results of the international SPIN program for 1965-1966 and in the near future there will be published a volume with results of work on the SPIN program for 1967.¹

On behalf of the Commission of Multilateral Collaboration of Academies of Sciences of Socialist Countries, I wish the collective of the station future success in the work.

We hope that our conference will serve the further expansion and mutual enrichment of photometric and other works associated with them.

¹Bulletin "Results of observations of Soviet artificial earth satellites," issue 114, Moscow, 1968.

RESULTS AND AIMS OF INTERNATIONAL SPIN PROGRAM

V. M. Grigorevskiy

A list of basic problems, which can be solved with satellite photometry, and some results obtained by this method are presented.

Even during observation of the launching rocket of the first artificial earth satellite many Soviet [1, 2] and foreign [3, 4, 5] observers paid attention to oscillation of its brightness with amplitude on the order of 5-6 stellar magnitudes. Regular purposeful photometric observations were started on the initiative of V. P. Tsesevich at the Odessa Astronomic Observatory in December 1957 [6, 7].

In March 1958 in these observations of the second Soviet satellite there were included other Soviet satellite tracking stations (see summary in [8]), and change of brightness of the launching rocket of the third Soviet satellite was even observed literally throughout the world - in USSR, the United States, Poland, Australia, Bulgaria, German Democratic Republic and others (a list of these observations is presented in [9]).

The many observations led to the appearance of many theoretical works, which in the first years were dedicated exclusively to the question of determination of satellite orientation based on photometric data [10-15] and others. (Possibly, in this fact there was

manifested the influence of [10], written even before launching of the satellites).

Subsequently there appeared works, in which rotation of the satellite relative to the center of masses was examined from the viewpoint of mechanics, and also electrodynamics.

The monograph by V. V. Beletskiy [16] summed up the 8-year theoretical research of motion of an artificial earth satellite relative to center of masses. V. V. Beleskiy examined all the factors affecting the character of dynamic motion of a satellite, evaluated the contribution of each of them, constructed in general form the theory of dynamic motion of an axisymmetrical artificial earth satellite under the influence of all the basic factors and successfully applied this theory for determination of orientation of particular satellites.

It is necessary to say, however, that determination of orientation far from exhausts all the information which can be obtained on the basis of photometric studies of satellites. Therefore, it seems of some use to present a list of the basic problems, solution of which can be obtained (and in many cases is already obtained) by photometry of artificial earth satellites.

1. Determination of satellite orientation: in case of diffusion of light by its surface; in case of mirror reflection; in a mixed case (nonpherical indicatrix of scattering); with the aid of specially installed mirrors or transducers. Such determinations would be well combined for checking with some independent determination, for example, according to radar observations.

Determination of orientation by photometric data is the basic method for inactive satellites (for example, carrier rockets). However, for active artificial earth satellite photometry can permit releasing part of the telemetering channels from transmission of corresponding information.

2. Study of the shape of satellite surface. By using the dependence of radius of the sun's image on a given element of the satellite surface on the radius of curvature of this element and by passing from point to point during rotation of the artificial earth satellite, it is possible to control the change of shape of the satellite.

3. Study of reflective properties of the satellite surface and their changes with the passage of time based on colorimetric and polarimetric observations.

4. Astrophysical problems. For example, the proposal by I. Almar [17] about determination of absolute distribution of energy in stellar spectra based on absolute distribution of energy in the solar spectrum - with the use of isotropically dispersing light of the satellite.

5. Study of vertical distribution of ozone in the terrestrial atmosphere, and also detection of aerosols of terrestrial and space origin at different altitudes in the atmosphere - by photometric observations of satellites during their entry into the earth's shadow.

6. Obtaining of photometric data on deceleration of the rotation of satellites by the terrestrial atmosphere and the earth's magnetic field; study of changes of this deceleration in connection with changes of solar activity; determination of density of the atmosphere based on deceleration of satellite rotation.

A more particular problem, connected with the study of atmospheric density, is photometric observations of inflation of satellites-balloons at the moment of their placement into orbit.

The presented list is not absolutely comprehensive. However, even in such a form it quite well illustrates the capacity of photometric methods of investigation of artificial earth satellites.

The international cooperative of the SPIN program is basically aimed at investigation of the last of the above-mentioned problems.

Conditions of dynamic motion of oblong satellites of type 1957 β and 1958 δ , turned out to be close to end over end [18], that is, the axis of rotation is almost exactly perpendicular to the longitudinal axis.

In reference to this, different authors worked out a number of methods [11-15] for determination of orientation of oblong satellites with direct use of photometric data.

In this case the problem is broken up into two parts:

a) determination of orientation of the axis of rotation of the satellite, that is, the plane of its rotation;

b) study of the period of rotation, that is, in essence the position of the satellite in the plane of its rotation.

Even the first determinations of the period of rotation of the second Soviet satellite permitted determining its rapid increase [7, 19]. Further investigations [20] showed that in separate cases the satellite changed the period of rotation almost twice in two days! (All calculations of orientation are performed with some average constant period). In this case such changes do not carry a periodic character, but turned out to be very closely correlated with changes of solar activity.

The similar connection of period of rotation with solar and geomagnetic factors was established for a number of satellites [9, 20-23]. There were revealed synchronous changes of the period of rotation and period of revolution of the satellite under the influence of variable solar activity [21, 9, 24].

There is established the fact of manifestation of considerably thinner "solar" effects on the period of rotation than on the period

of revolution [21], which is easily explained by the smallness of kinetic energy of rotation as compared to kinetic energy of revolution along the orbit.

At present the treatment of photometric observations, obtained by stations of countries-participants of SPIN work, is performed along the following two principal directions:

1. From 7-8 solar and geomagnetic factors, forming peculiarities of the curve "period of rotation-date" we try to statistically select those 2-3 factors, which introduce the greatest contribution and explain the main characteristics of the curve. Exposure of such a limited number of factors facilitates the creation of theory of phenomenon.

2. Attempts are undertaken to construct the theory of change of period of rotation and orientation for satellites of particular form taking into account such "regular" factors as, for example, aerodynamic or electromagnetic braking [25-27].

This, in turn, will permit:

a) excluding regular braking, left in pure form for investigation of that part of it, which is connected directly or indirectly with variations of solar activity;

b) obtaining exact values of the density of terrestrial atmosphere at flight altitudes of the satellite by braking of rotation. It is difficult to reevaluate the value of such a result: not to mention that the "coefficient of scientific use" of passive satellites is increased (for example, carrier rockets), we will obtain, absolutely independent of orbital data, determinations which "are absolutely comparable" with orbital: having calculated, for example, the density of the atmosphere by the satellite's deceleration in orbit and by braking of its rotation, we will have two perfectly independent determinations for which the shape of the satellite, flight altitude, conditions in the terrestrial atmosphere and geomagnetic field etc. are all identical.

The first attempts of parallel study of the period of rotation and period of revolution of the same satellite have been undertaken [9, 21, 24], however, the main work in this direction is still ahead.

The main directions of work on the SPIN program are the same. However, the course itself of the ever expanding works not only permits, but, it is possible to say, also dictates new directions. Thus, for example, the inclusion of Egyptian astronomers in the number of participants of SPIN (Helwân Soviet-Egyptian satellite tracking station, UAR) permits obtaining photometric observations during the winter months.

Up to now (according to annual conditions) European stations for all practical purposes have not obtained such observations. Winter observations in the UAR (in combination with available summer) will permit the investigation of seasonal effects in deceleration of the rotation of satellites.

Another example of the problem, placed by the course of work itself, is the necessity to explain the sharp decrease period of rotation of satellite 1965-11-4, observed during the winter of 1967-1968. However, this unusual fact still needs detailed check and it is still too early to discuss it in detail.

In conclusion I would like to urge all the participants of this conference (in particular, observers-photometric measurers) to wide collaboration and joint active work in the field of photometric investigations of satellites.

We are convinced that from photometric observations at the present time there is obtained in the best case 30% of the information, which they can give. Only by the joint efforts of many researchers and collectives can the entire 100% be obtained.

A DEVICE FOR ELECTROPHOTOMETRIC OBSERVATIONS OF
ARTIFICIAL EARTH SATELLITES ENTERING THE
EARTH'S SHADOW

P. N. Boyko and V. S. Matyagin

In the astrophysics Institute of the Academy of Sciences of Kazakh Soviet Socialist Republic there is made a photoelectric instrument, equipped with three axes of rotation, designed for photometric observations of artificial earth satellites entering the earth's shadow.

One of the axes of the instrument to be directed to the pole of apparent path of the satellite. Tracking the satellite along its trajectory is carried out by a synchronous electric motor. Angular velocity of tracking can be changed both discretely and smoothly over a wide range (from 0.01 to 1 deg/s).

Before the cathode of the photomultiplier there is placed a disk, revolved by an electric motor, with four round cutouts, in which light filters and luminophor can be placed. The brightness of satellite is recorded on the photographic paper tape of a loop oscillograph. One of the loops is also set aside for recording time marks from the chronometer or from quartz clock.

Tests of the instrument conducted by us on stars and the satellite Pageos showed that all subassemblies of the instrument work well, the instrument is convenient to handle. With an outlet round shutter 1 in diameter the electrometer permits confidently recording

stars up to 7^m through blue and orange light filters. In the period from 16 to 22 September 1968 with two light filters there were obtained several oscillograms of the satellite Pageos, tracking of which was carried out almost through the whole sky, from horizon to horizon. However, in the shown period of time during observations at Alma Ata Observatory Pageos did not approach the earth's shadow. Observations will continue, and we hope that we will manage to obtain high-quality observation material, which will permit determining the content of ozone and distribution of aerosols in the earth's atmosphere by the method developed by V. G. Fesenkov.

Alma Ata, station No. 1067

DATA ON DECELERATION OF SATELLITE 1965-11-4 OBTAINED FROM
SIMULTANEOUS OBSERVATIONS BASED ON INTEROBS AND
SPIN PROGRAMS

V. M. Grigorevskiy, T. V. Kasimenko, I. M. Panich,
and V. A. Vorob'yeva

1. Observations of satellite 1965-11-4, carried out in September 1966 simultaneously based on international cooperative INTEROBS and SPIN programs, present a unique possibility for the parallel study of changes of orbital and rotational speeds of the same object and for comparison of these changes both among themselves, and with changes of solar activity and different geomagnetic characteristics.

2. Period of rotation was determined by photometric observations within the limits of the SPIN program for 1966. Method of treatment of data is described in [1]. Period of revolution was determined by INTEROBS data for the same interval of time by the method of I. D. Zhongolovich [2].

3. Investigation of periods of revolution and rotation has shown that in both cases there is observed good agreement of changes of periods with different characteristics of solar activity, in particular, agreement not only with usually used index - solar noise in the decimeter range, but also with Wolf numbers is remarkable. In this case the overall course of changes of period of rotation and period of revolution is completely analogous and the changes themselves exceed errors of determination of periods.

4. Comparison of accelerations of rotation and revolution also showed a sufficient similarity of change of these characteristics and reconfirm the necessity of more frequent observations for production of more short-term variations both by the SPIN program, and in terms of INTEROBS program.

5. This work is the first experiment of detailed parallel investigation and comparison of the period of rotation and period of revolution of the same satellite.

Results of comparison turned out to be rather interesting and confirmed the fruitfulness of such parallel investigations, which will be continued.

6. The work is published completely in [3].

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Kishinev, station No. 1024
Astronomical council of Academy of Sciences USSR

INFLUENCE OF THE EARTH'S MAGNETIC FIELD ON THE
CHARACTER OF MOTION OF SATELLITES

G. M. Shmelëv, V. M. Grigorevskiy, and N. S. Shmelëva

The influence of the earth's magnetic field on the character of motion of satellites is examined for hypothesis $\vec{H} = \text{const}$ and with different initial angles between \vec{H} and vector of angular velocity of spin of satellite $\vec{\omega}$.

As it is known, in massive conductors (satellites), moving in an external magnetic field, the latter causes the appearance of eddy currents (Foucault currents). Due to the appearance of these currents, the moving satellite acquires magnetic moment, interaction of which with the magnetic field of the earth causes the influence of this field on the character of motion of the conductor. This question was investigated earlier in sufficient detail.

V. V. Beletskiy [1] examined it in general form for an arbitrary symmetric satellite. Yu. V. Zonov [2] obtained an expression for relaxation time of deceleration of spin of a spherical satellite. The authors examined deceleration of a cylindrical satellite in the magnetic field of the earth [3]. (Let us note that in [2] and [3] it was assumed that the angular spin velocity of the satellite $\vec{\omega}$ comprises angle $\pi/2$ with the magnetic field strength of the earth \vec{H}).

Nonetheless, it is of interest to examine this question more specifically.

In the cited works the induced magnetic moment was determined as $M = k\omega H$, where k - coefficient, depending on the shape and dimensions of satellite, and also on its orientation in external field.

In this case the dependence of ω on time has the form

$$\omega = \omega_0 e^{-\gamma t} \quad (1)$$

where γ^{-1} - relaxation time.

Generally speaking, components of the vector of induced magnetic moment [4]

$$M_i = V \sum_{k=1}^3 \alpha_{ik} H_k \quad (2)$$

$i = 1, 2, 3$. (Everywhere $\mu = 1$).

Here $V \alpha_{ik}$ constitutes the so-called tensor of magnetic polarizability of the body as integer. Dimensionless coefficients $\alpha_{ik}(\omega)$ depend on the shape of the satellite and its orientation in the external field (but not on its volume V).

Formula (2) occurs in the system of coordinates, rigidly connected with the body, in which the stationary satellite is in a prescribed variable external field $\vec{H}(t)$. All values in (2) are assumed written in complex form.

Generally speaking, M_i are composite functions of ω , in this case two limiting cases are distinguished (high and low) frequencies. "Depth of penetration" of field into conductor is determined as

$$\delta = \frac{c}{\sqrt{2\pi\sigma\omega}} \quad (3)$$

and condition of smallness of frequencies is $\delta \gg l$, where l - either dimensions of "solid" satellite, or thickness of shell of a hollow satellite.

In this case $M \sim \omega$, and formula (1) is valid. Case of high frequencies is determined by inequality $\delta \ll \ell$.

In this work there is examined the behavior of a spherical satellite in the earth's magnetic field, which is considered uniform and constant (motion along geomagnetic equator) for large and small ω .

Let us select axis Z of fixed system of coordinates (rigidly connected with \vec{H}) along the vector of intrinsic kinematic moment of satellite, and plane XZ in such a manner that vector \vec{H} would lay in this plane. Changing to system of coordinates, revolving together with the satellite, we obtain that in this system the stationary satellite is in two variable mutually perpendicular external fields of type $H_x e^{-i\omega t}$, phase shifted to $\pi/2$.

By using formula (2) in this case, L. D. Landau and Ye. M. Lifshits [4] find that the moment of forces affecting the sphere is

$$K_x = V\alpha'' H_x H_z; \quad K_y = -V\alpha' H_x H_z; \quad K_z = -V\alpha'' H_x^2. \quad (4)$$

Tensor α_{ik} in this case degenerates into scalar $\alpha = \alpha' + i\alpha''$. (Expression for α is obtained in [4]).

Let us note that if angle θ between \vec{H} and $\vec{\omega}$, counted from predetermined fixed vector \vec{H} , is equal to 0 or π , then $\vec{K} = 0$, and the field has no effect on the satellite. In cases $\theta = \frac{\pi}{2}; \frac{3\pi}{2}$ we have: $K_x = K_y = 0$ and all the action of the field on the satellite is reduced to damping of angular velocity ω . With arbitrary θ the action of field on the satellite is still reduced to change of angle θ and to precession of vector $\vec{\omega}$ around \vec{H} . Let us note that apparently it is doubtful whether the system of equations of motion, formulated with the aid of (4), can be solved exactly.

Let us examine particular cases.

A. Case of low frequencies ($\delta \gg \ell$).

In this case $\alpha'' \approx 5 \frac{\delta^2}{a^2} \alpha'$ (a - radius of sphere) and $|K_x| \gg |K_y|$. Considering the satellite as a gyroscope and using Resal theorem [1] we obtain the equation for $\theta(t)$:

$$\frac{d\theta}{dt} = - \frac{V a^2 \delta H^2}{10 c^2 \mathcal{J}_1} \cdot \sin 2\theta ,$$

where \mathcal{J}_1 - moment of inertia of sphere.

From (5) we find that

$$t_{ij} \theta = e^{-\gamma t} \operatorname{tg} \theta_0 ; \quad (6)$$

$$\gamma = \frac{V a^2 \delta H^2}{10 c^2 \mathcal{J}_1} . \quad (7)$$

Coefficients α_{ik} , with the help of which the problem on hand is solved and, in particular, formulas (6) and (7) are found, are determined in the final analysis as a result of solution of Maxwell equations for a conductor of particular form in quasi-stationary electromagnetic field $\sim e^{-i\omega t}$. It is obvious that in the examined case, when $\delta \gg \ell$, Maxwell equations should be solved based on the same boundary conditions both in the case of a solid sphere, and in case of a hollow. Therefore, for a hollow sphere K_x , K_y and K_z are found from (4) by means of differentiation (4) with respect to a . In this case

$$\gamma = \frac{V a h \delta H^2}{2 c^2 \mathcal{J}_2} \quad (8)$$

Here h - thickness, and \mathcal{J}_2 - moment of inertia of hollow satellite.

From (6) it follows that with the passage of time the vector of kinematic moment tends to be set parallel or antiparallel to vector \vec{H} . From (6) it also follows that when $\theta_0 = 0$, \mathcal{K} angle $\theta = 0$, \mathcal{K} does not change with the passage of time. The same occurs in case

$$\theta = \frac{\pi}{2} , \frac{3\pi}{2}$$

Let us note that in the examined approximation γ' does not depend on ω .

Natural frequency of rotation of the satellite ω as a function of time is determined from equation

$$\frac{d\omega}{dt} = -\omega \gamma' \sin^2 \theta \quad (9)$$

By substituting here θ from (6), we find

$$\omega = \omega_0 \frac{\cos \theta_0}{\cos \theta} \quad (10)$$

Here $\omega_0 = \omega(t=0)$. As one would expect, when $\theta_0 = 0$; \mathcal{N} . frequency does not change ($\omega = \omega_0$), and when $\theta_0 = \frac{\pi}{2}$; (10) changes into (1). With the passage of time $\omega \rightarrow \omega_0 \cos \theta_0$. Let us note that projection $\vec{\omega}$ to \vec{H} is an integral of motion.

Calculation of moment K_y leads to slow precession of $\vec{\omega}$ around \vec{H} with constant angular velocity

$$\Omega = \frac{4\pi V a^4 b^2 \omega_0 \cos \theta_0 H^2}{105 c^4 J_1} \quad (11)$$

in case of a solid sphere and

$$\Omega = \frac{4\pi V a^3 h b^2 \omega_0 \cos \theta_0 H^2}{15 c^4 J_2} \quad (12)$$

- a hollow.

Thus, in the examined case vector $\vec{\omega}$ slowly precesses around the direction of magnetic field \vec{H} , where angle of precession θ asymptotically approaches zero, and projection $\vec{\omega}$ to \vec{H} is a constant.

B. Case of high frequencies ($\delta \ll \ell$).

In this case $\alpha' \cong \frac{a}{\delta} \alpha''$; $|K_y| \gg |K_x|$ and speed of precession

$$\Omega = \frac{3V \cos \theta \cdot H^2}{8\pi J_{1,2} \omega} \left[1 - \frac{3c}{a\sqrt{2\pi\theta\omega}} \right] \quad (13)$$

turns out to be much greater than $\frac{d\theta}{dt}$, in contrast to case A.

θ as a function of t has form (6), during which

$$\gamma = \frac{9cVH^2}{16\pi a\omega J_{1,2}\sqrt{2\pi\theta\omega}} = \frac{\xi}{\omega^{3/2}} \quad (14)$$

grows with decrease of frequency ω , and curve $\Omega = \Omega(\omega)$ has maximum.

Equations (13) and (14) are again obtained in approximation $\omega = \text{const}$.

In the examined case ($\delta \ll \ell$), naturally the obtained results are equally valid both for a solid and for a hollow satellite. ($J_{1,2}$ - moment of inertia of solid or hollow satellite respectively).

In approximation $\theta = \theta_0$ we find the dependence of frequency ω on time:

$$\omega^{3/2} = \omega_0^{3/2} - \frac{3}{2} \xi t. \quad (15)$$

Formulas obtained in B with growth of t , that is, with decrease of ω should obviously change into corresponding formulas in the case of low frequencies A. In conclusion let us once again note that found formulas are obtained approximately and actual formulation of the problem ($\vec{H} = \text{const}$) carries an idealized character.

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4. L. D. Landau, Ye. M. Lifshits. Elektrodinamika sploshnykh sred (Electrodynamics of continuous medium). M., 1957.

5. N. N. Bukhgol'ts. Osnovnoy kurs teoreticheskoy mekhaniki (Basic course of theoretical mechanics). M., 1966.

Kishinev, station No. 1024

Questions and Discussion of the Report

A. G. Masevich:

Is it possible to apply this method to satellites of another shape?

G. M. Shmelëv:

Of course. In particular, now by the same method we solve the problem in reference to cylindrical artificial earth satellites.

V. V. Beletskiy:

Formulation of the problem, expounded in the report, deserves attention. Detailed investigation of cases with arbitrary ω and θ is of absolute interest. However, in the final analysis, the problem is reduced to solution of Maxwell equations.

G. M. Shmelev:

Certainly. After all, finding coefficients α_{ik} is exactly reduced to solution of Maxwell equations.

DETERMINATION OF PARAMETERS OF THE ATMOSPHERE BASED ON
DECELERATION OF A SATELLITE TAKING ITS ORIENTATION
INTO ACCOUNT

V. V. Beletskiy, G. I. Zmiyevskaya,
and M. Ya. Marov

Tracing the change of orbital motion of an artificial earth satellite or the character of change of motion moments of a satellite relative to center of masses on a predetermined orbit permits independently determining the atmospheric density in the region of perigee (when $e \geq 0.02$) for a specific scheme of interaction of the satellite with incoming flow. Knowledge of artificial earth satellite orientation in orbit gives the possibility of accurately calculating the density and in principle to reveal short-period variations of atmospheric parameters.

In the work are listed results of calculation of coefficient C_x of aerodynamic drag for a satellite of complex configuration taking into account data on its orientation. For undisturbed motion of the "Proton" satellite near the center of masses there was accepted a model of regular precession and obtained average coefficient \bar{C}_x , not depending on fast periods of rotation of the satellite. As initial we used data determining the position of kinetic moment vector, obtained by statistical treatment of readings of magnetometers installed on "Proton-2" satellite.

There is examined a series of models of interaction of flow with the satellite surface in the assumption of freely molecular airflow

at Maxwellian velocity distribution of incoming molecules. According to data on orbital deceleration of the satellite, there are evaluated coefficients of accommodation of normal and tangential pulse components, values of which correspond to a model of diffused reflection of flow of molecules at a temperature differing from the wall temperature. The developed method of calculation of \bar{C}_x will permit determination of the change of aerodynamic drag coefficient with change of height of perigee of the satellite and to follow the transition from conditions of freely-molecular airflow to flow with slip for heavy "Proton" type satellites.

Based on the assumptions made, we evaluated the possible change of atmospheric density at altitudes of around 200 km.

RESULTS OF TREATMENT OF OBSERVATIONS BASED ON THE SPIN
PROGRAM AND SOME QUESTIONS OF TECHNOLOGY
OF OBSERVATIONS¹

I. M. Panich, V. A. Vorob'yeva,
and V. M. Grigorevskiy

Results of observations based on the SPIN program in 1967 and partially for 1968, and also some results of investigation of 1967 material are presented. A method of visual photometric observations is described, making it possible to increase the accuracy of determination of values of the period of satellite brightness variation.

Collective photometric observations based on the SPIN program began in 1966. According to the program satellites 1965-11-4 and 1965-53-6 were observed. (Photometric observations of these objects, and also satellite 1965-06-V, were obtained at the Kishinev station in 1965 also [1, 2]).

In the 1966 observations there participated stations of the People's Republic of Bulgaria (No. 1102 - Stara Zagora), the Socialist Republic of Rumania (No. 1132 - Kluzh) and the Soviet Union (No. 1023 - Kiev, No. 1024 - Kishinev, No. 1027 - Krasnodar). In all during 1965-66 for the above-named two objects there were obtained photometric observations of 94 passes - 3938 moments of maximum of brightness [2].

¹Compiled according to material reported by the authors at the conference and at the seminar of observers.

In 1967 the complement of participants of the work was expanded by stations No. 1145 - Prague, ChSSR, No. 1185 - Rodewisch, German Democratic Republic, No. 1040 - Riga and No. 1092 - Kirov, USSR. Results: 143 passes, 4101 moments of maximum. These did not include observations carried out at the Kluzh station - they, unfortunately, up to now are not a coordinator of SPIN work.

In 1968 in the photometric observations there were included 6 more stations from Hungary, German Democratic Republic, Polish People's Republic, USSR and the UAR.

On 10 October 1968 at the disposal of the coordinator there were data on 66 passes (1644 moments), which were observed photometrically. However, most of these observations are obtained at the Kishinev station and therefore the above-mentioned data for 1968 are undoubtedly incomplete and considerably increase after the obtaining of results from stations-participants of the work. (All observations of 1968 pertain to satellite 1965-11-4. For satellite 1965-53-6 - see below).

Thus, for 1965-1968 based on incomplete data within the limits of the SPIN program there have already been obtained photometric observations encompassing 303 passes, 9683 moments.

We already cited evaluations of the accuracy of these observations (Figs. 1-3 in [3]). Figure 1 permits affirming that observations of one station can be at the same level: on this figure we plotted quadratic error of the period of rotation as a function of the number of observed maxima based on observations of satellite 1965-11-4 in 1967 at only the Kishinev station alone.

As a result of the work we obtained a large number of observations. As an example in Fig. 2 there is presented a graph of dependence of the period of rotation of satellite 1965-53-6 on time. The satellite was observed from the moment of launch right up to the present (interruptions on the graph - the absence of visibility or absence of ephemerides).

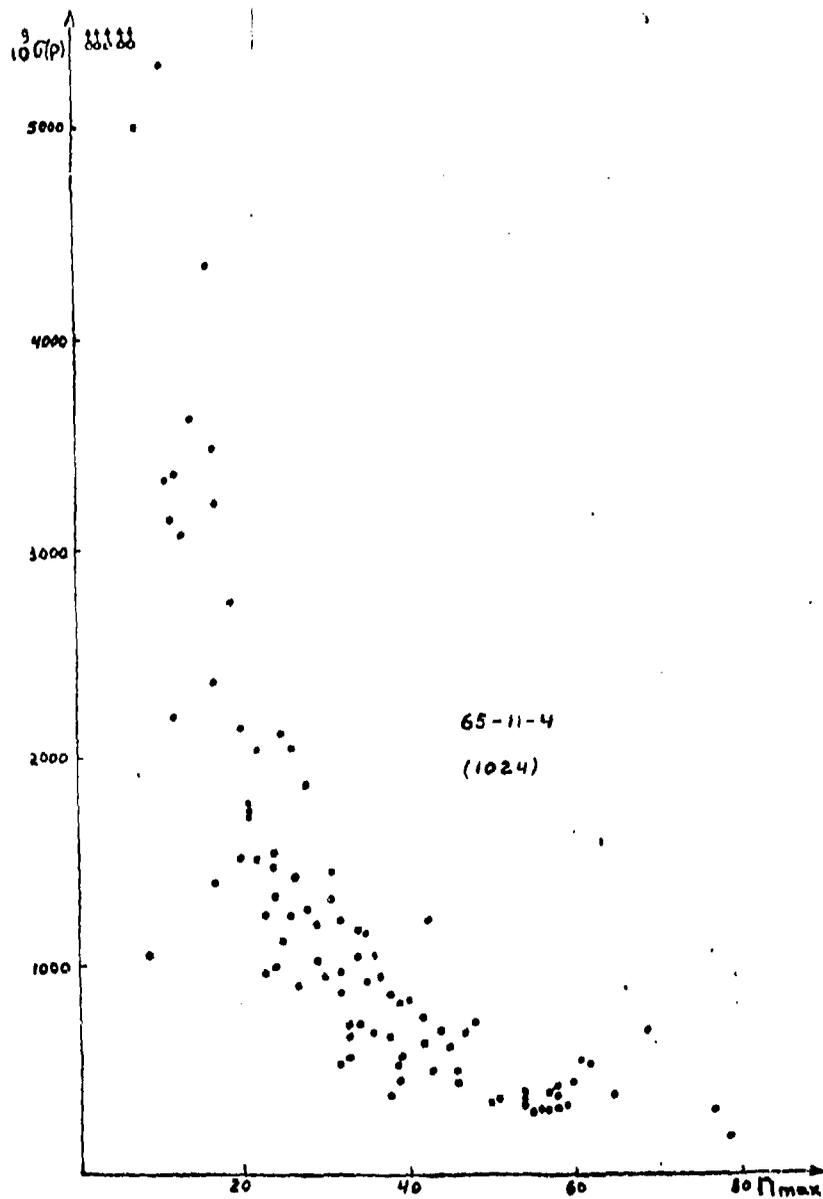


Fig. 1.

Subsequently these data will undoubtedly prove useful for determination of density of the atmosphere, and also its variations, connected with change of solar activity. In Fig. 3 there are shown almost synchronous changes of the period of rotation of satellite 1965-53-6 and decimeter solar noise in May 1967.

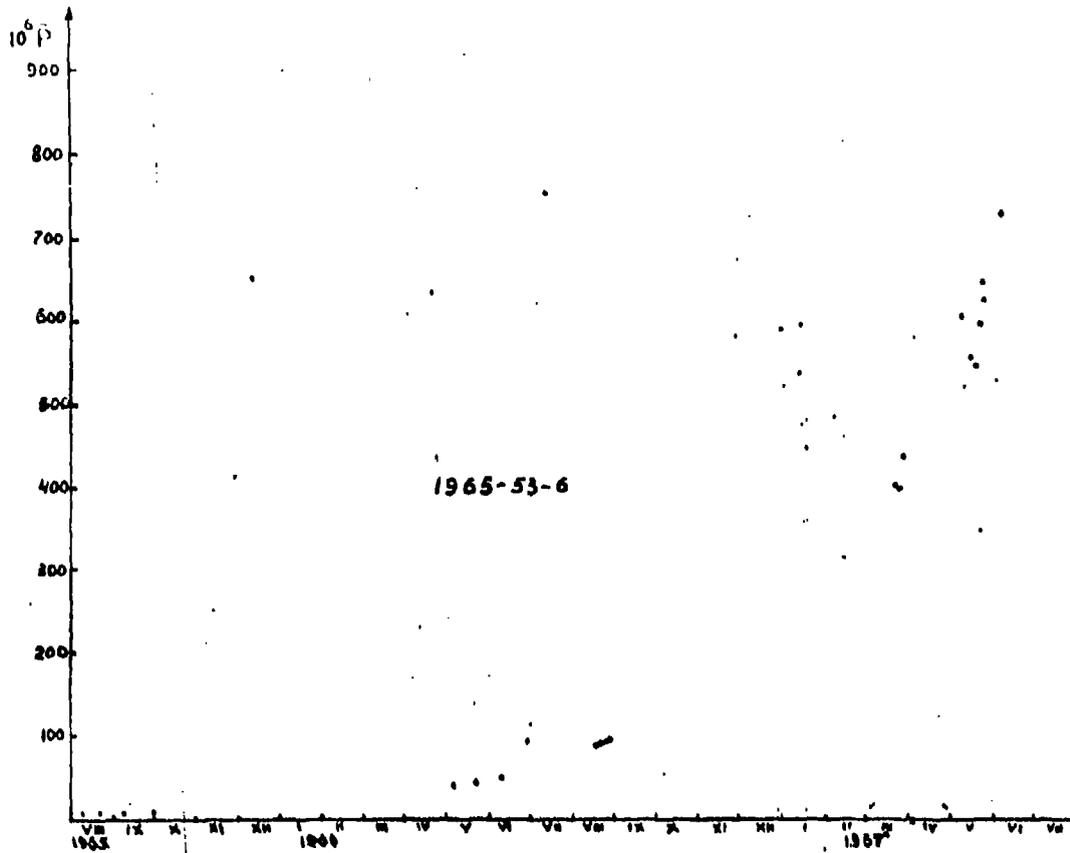


Fig. 2.

Other results of treatment of photometric observations were already listed in reports of V. M. Grigorevskiy and T. V. Kasimenko.

At present the period of rotation of satellite 1965-53-6 has considerably increased and became greater by far than the time of its observation at the given station during one pass. Many observers noted this fact. However, in order to be certain of this, it was necessary to conduct many observations, which although they did not lead to obtaining concrete data about the period of rotation, nonetheless they were extremely necessary and useful.

Period of rotation of satellite 1965-11-4 was also noticeably increased. Direct fixing of moments of maximum becomes difficult.

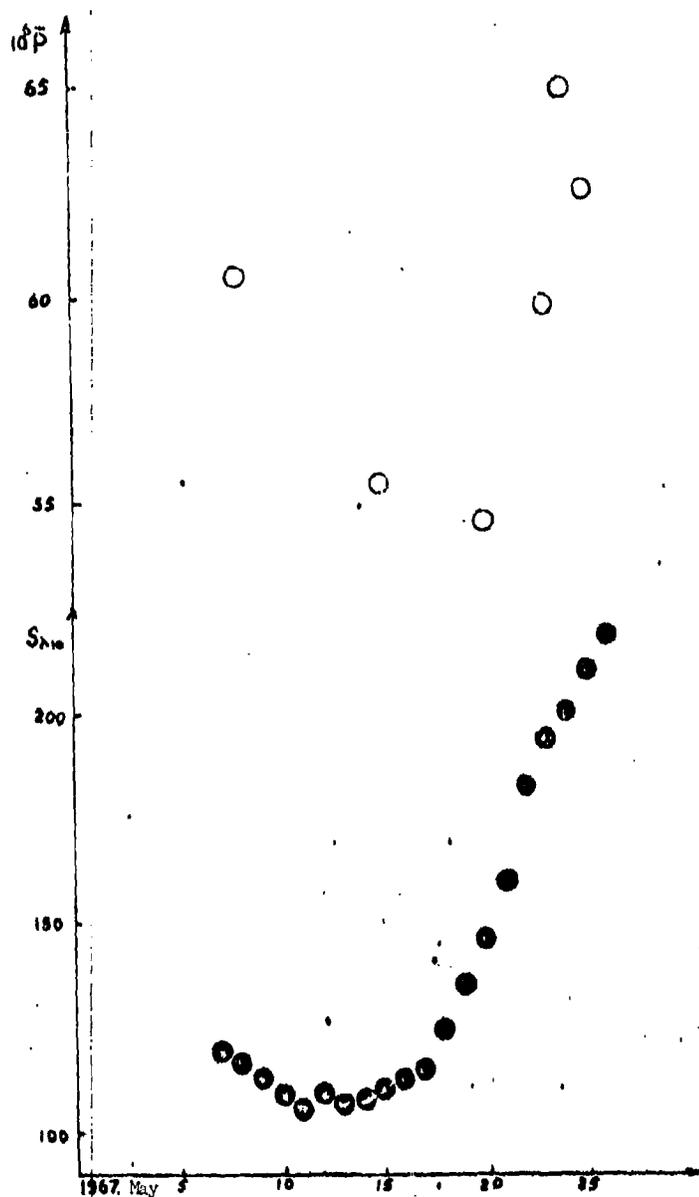


Fig. 3.

For this satellite at the Stara Zagora (Bulgaria) and Kishinev stations there was used a somewhat different method of observations, making it possible to noticeably increase the accuracy of results.

There were noted not simply maxima of brightness, but a number of characteristic points on the brightness curve, for example,

moments of beginnings "H" and ends "K" of maximum.

For all practical purposes this looks so: if the curve has a large period and a small amplitude (we represented it schematically in Fig. 4), then there are noted either moments of its passage through some stellar magnitude m_0 (for example, fifth-sixth), or moments of disappearance and appearance of the satellite in minimum, if the satellite is not visible in minimum.

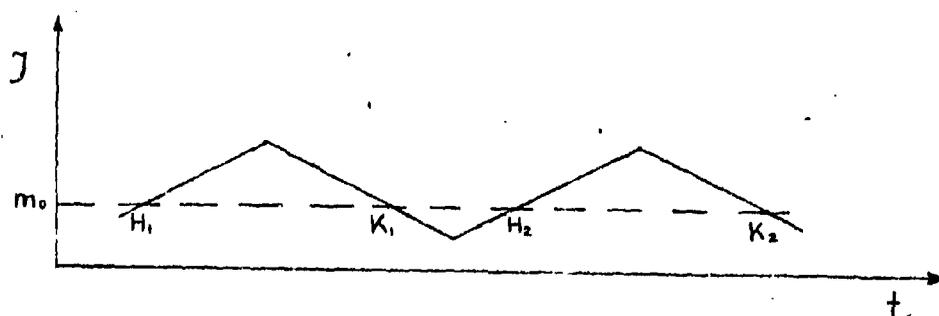


Fig. 4.

As was shown [4], such observations permit obtaining the period of rotation sufficiently accurately even for satellites with curve of brightness variation "inconvenient" for photometry.

As an example let us list observations of satellite 1965-53-6, carried out by I. M. Panich by this method 23 March 1967.

H_1	47 ^m 55 ^s .1	$\Delta t = 29.3$
K_1	48 24.4	6.8
H_2	48 31.3	27.2
K_2	48 58.5	7.9
H_3	49 06.4	28.5
K_3	49 34.9	4.8
H_4	49 39.7	30.0
K_4	50 09.7	7.4
H_5	50 17.1	

These data show how confidently the period is determined: intervals, encompassing maxima and minima agree with each other quite well.

Needless to say, this method is fully appropriate for satellites with "good" curve of brightness variation. In this case it is possible to recommend noting not only moments H and K, but, where this is possible - also moments of maxima and (or) minima.

Experience of the Stara Zagara and Kishinev stations shows that this is fully in the power of a trained observer.

In conclusion let us present curves of variation of the period of rotation of satellite 1965-11-4 in 1967 based on data of all the participants of SPIN work (Fig. 5) and according to the data of the Kishinev station along (Fig. 6). It is obvious that continuous and thorough observations of even one station can give good results.

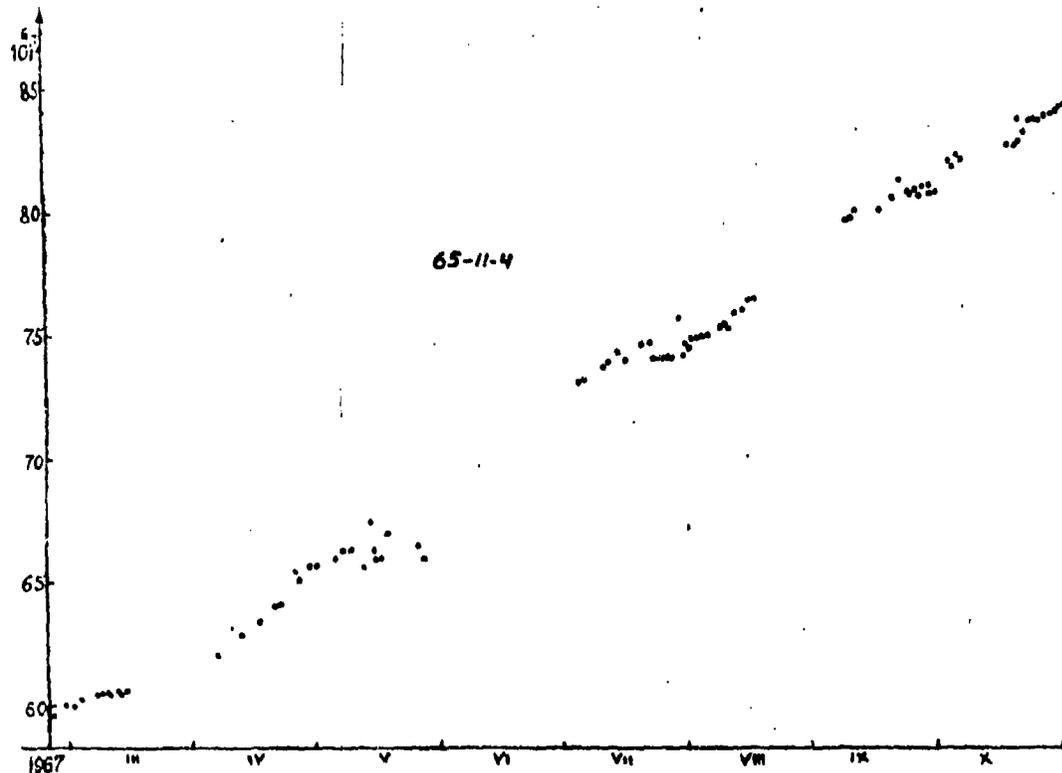


Fig. 5.

CONCLUDING REMARKS

A. G. Masevich

Comrades! Our conference has come to an end. Now we can say that our work during these days was especially fruitful. We are convinced that a result of the conference will be further expansion and qualitative development of works on the SPIN program.

Here contacts were established and opinions were exchanged between scientists, leading the investigations in associated regions of science. It is possible to say with confidence that this fact will undoubtedly promote both the development of investigations in associated regions of science, and also the appearance of new complex works, similar to the joint work reported here on SPIN and INTEROBS programs.

Participants of the conference express deep gratitude to the management of Kishinev University, showing us generous hospitality. Special gratitude to the comrades whose attention and much trouble made our stay on Moldavian soil so pleasant and bright, that even the continuous rain could not darken our best impressions.

We warmly thank the pro-rector of the university, docent B. Ye. Mel'nika, the chairman of the organizational committee docent V. M. Grigorevskiy, head post graduate G. A. Lancha and member of the organizational committee V. A. Vorob'yeva, having done especially

much for the successful work of the conference, and for the fact that we have grown fond of hospitable Moldavia and we resolved to hold another conference here, and maybe even several.

DATA HANDLING PAGE

61-ACCESSION NO. 98-DOCUMENT LOC MT9501360		29-TOPIC TAGS aerospace conference, photometric observation, aerospace personnel, satellite tracking		
69-TITLE RESULTS AND AIMS OF INTERNATIONAL SPIN PROGRAM				
47-SUBJECT AREA 05, 22, 20				
12-AUTHOR/CO-AUTHORS GRIGOREVSKIY, V. M.				16-DATE OF INFO -----68
43-SOURCE SOVESHCHANIYE "ISSLEDOVANIYA VRASHCHENIYA ISKUSSTVENNYKH SPUTNIKOV ZEMLI PO FOTOMETRI-CHESKIM DANNYM" (RUSSIAN) FTD-				48-DOCUMENT NO. MT-24-208-69
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63-SECURITY AND DOWNGRADING INFORMATION UNCL. 0		64-CONTROL MARKINGS NONE	97-HEADER CLASS UNCL	
76-REEL FRAME NO. 1890 0216	77-SUPERSEDES	78-CHANGES	86-GEOGRAPHICAL AREA UR	NO OF PAGES 6
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STEP NO. 02-UR/0000/68/000/000/0007/0007			ACCESSION NO.	
<p>ABSTRACT</p> <p>(U) This paper was presented at a Soviet conference held in Kishinev to discuss international work of SPIN (a program proposed by colleagues of satellite tracking stations at the Kishinev State University). Basic problems of the SPIN program are discussed. The author indicates these problems can be solved with satellite photometry and he gives some of the results obtained by this method.</p>				

DATA HANDLING PAGE

61-ACCESSION NO. 06-DOCUMENT LOC TT9501361		70-TOPIC TAGS aerospace conference, photometer, photo multiplier tube, photometric observation		
69-TITLE A DEVICE FOR ELECTRO- PHOTOMETRIC OBSERVATIONS OF ARTIFICIAL EARTH SATELLITES ENTERING THE EARTH'S SHADOW				
71-SUBJECT AREA 05, 20, 22				
12-AUTHOR/CO-AUTHORS BOYKO, P. N. ; 16-MATYAGIN, V. S.				18-DATE OF INFO -----68
13-SOURCE SOVESHCHANIYE "ISSLEDOVANIYA VRASHCHENIYA ISKUSSTVENNYKH SPUTNIKOV ZEMLI PO FOTOMETRI- CHESKIM DANNYM" (RUSSIAN)			F1D-48-DOCUMENT NO. MT-24-208-69	49-PROJECT NO. 72302-78
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76-REEL FRAME NO. 1890 0217	77-SUPERSIDES	78-CHANGES	46-GEOGRAPHICAL AREA UR	NO OF PAGES 2
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ABSTRACT

(U) This paper was presented at a Soviet conference held in Kishinev to discuss international work of SPIN (a program proposed by colleagues of satellite tracking stations at the Kishinev State University). The authors described a photo-electric instrument designed for photometric observations of artificial earth satellites entering the earth's shadow. Tests of the instrument on stars and the satellite Pageos showed that all subassemblies of the instrument worked well.

DATA HANDLING PAGE

61-ACCESSION NO. 1890 0218		62-DOCUMENT LOC		63-TOPIC TAGS aerospace conference, photometric analysis, satellite motion	
64-TITLE (AREA OF INFORMATION) OBTAINED FROM SIMULTANEOUS OBSERVATIONS BASED ON INTEROPERABLE SPIN PROGRAMS					
67-SUBJECT AREA 01, 02, 03					
68-AUTHOR CO-AUTHORS GRIGOREVSKIY, V. M.; 16-KASIMENKO, T. V.; 16-PANFILI, I. M.; 16-VOROB'YEVA, V. A.		69-DATE OF INFO -----68			
69-SOURCE SOVESHCHANIYE "ISSLEDOVANIYA VRASHCHENIYA ISKUSSTVENNYKH SPUTNIKOV ZEMLI PO FOTOMETRIЧЕСКИМ ДАННЫМ" (RUSSIAN)		70-DOCUMENT NO. MT-24-208-69		71-PROJECT NO. 72302-78	
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80-CONTRACT NO.	81-X REF ACC. NO. 65-	82-PUBLISHING DATE 94-	83-TYPE PRODUCT TRANSLATION	84-REVISION FREQ NONE	
85-STEP NO. 02-UR/0000/68/000/000/0009/0011			86-ACCESSION NO.		

ABSTRACT

(1) This paper was presented at a Soviet conference held in Kishinev to discuss international work of SPIN (a program proposed by colleagues of satellite tracking stations at the Kishinev State University). The authors state that observations of satellite 1965-11-4, carried out in September 1966 simultaneously based on international cooperative INTEROPS and SPIN programs, present a unique possibility for the parallel study of changes of orbital and rotational speeds of the same object and for comparison of these changes both among themselves, and with changes of solar activity and different geomagnetic characteristics. Period of rotation was determined by photometric observations within the limits of the SPIN program for 1966. Investigation of periods of revolution and rotation has shown that in both cases there is observed good agreement of changes of periods with different characteristics of solar activity, in particular, agreement not only with usually used index - solar noise in the decimeter range, but also with Wolf numbers is remarkable. In this case the overall course of changes of period of rotation and period of revolution is completely analogous and the changes themselves exceed errors of determination of periods.

DATA HANDLING PAGE

81-ACCESSION NO. 96-DOCUMENT LOC		82-TOPIC TAGS		
TT9501363		aerospace conference, satellite motion, aerospace personnel, magnetic field effects		
83-TITLE INFLUENCE OF THE EARTH'S MAGNETIC FIELD ON THE CHARACTER OF MOTION OF SATELLITES				
SUBJECT AREA				
05, 20, 20				
87-AUTHOR CO-AUTHORS SHMELEV, G. M; 16-GRIGOREVSKIY, V. M. ; 16-SHMELEV, N. S.				88-DATE OF INFO -----68
89-SOURCE SOVESHCHANIYE "ISSLEDOVANIYA VRASHCHENIYA ISKUSSTVENNYKH SPUTNIKOV ZEMLI PO FOTOMETRI-CHESKIM DANNYM" (RUSSIAN)				84-DOCUMENT NO. FTD-MT-24-208-69
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	65-	94-	TRANSLATION	NONE
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ABSTRACT				
<p>(U) This paper was presented at a Soviet conference held in Kishinev to discuss international work of SPIN (a program proposed by colleagues of satellite tracking stations at the Kishinev State University). The authors examine the influence of the earth's magnetic field on the character of satellite motion through a given hypothesis.</p>				

DATA HANDLING PAGE

61-ACCESSION NO. 02-0000/68/000/000/0030/0030		39-TOPIC TAGS aerospace conference, satellite motion, aerodynamic drag, magnetometer/(U)proton 2 unmanned laboratory		
66-TITLE DETERMINATION OF PARAMETERS OF THE ATMOSPHERE BASED ON DECELERATION OF A SATELLITE TAKING ITS ORIENTATION INTO ACCOUNT				
47-SUBJECT AREA 05, 17, 22, 20				
12-AUTHOR CO-AUTHORS BELITSKIY, V. V.; 16-ZMIYEVSKAYA, G. I.; 16-MAROV, M. YA		18-DATE OF INFO -----63		
43-SOURCE SOVESHCHANIYE "ISSLEDOVANIYA VRASHCHENIYA ISKUSSTVENNYYKH SPUTNIKOV ZEMLI PO POTOMETRI-CHESKIM DANNYM" (RUSSIAN)		FIND-	48-DOCUMENT NO MP-24-208-63	49-PROJECT NO 72302-78
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76-REEL FRAME NO. 1890 0220	77-SUPERSEDES	78-CHANGES	46-GEOGRAPHICAL AREA UR	NO OF PAGES 2
CONTRACT NO.	X REF ACC. NO. 65-	PUBLISHING DATE 94-	TYPE PRODUCT TRANSLATION	REVISION PROC NONE
STEP NO. 02-UR/0000/68/000/000/0030/0030		ACCESSION NO.		
<p>ABSTRACT</p> <p>(U) This paper was presented at a Soviet conference held in Kishinev to discuss international work of SPIN (a program proposed by colleagues of satellite tracking stations at the Kishinev State University). The authors discuss the calculation of the aerodynamic drag coefficient for a satellite of complex configuration allowing for its orientation. Statistical treatment of readings of the magnetometers installed on the Proton-2 satellite was used as the initial data to determine the position of the kinetic moment vector. The developed method of calculation permits the determination of the aerodynamic drag coefficient change with change of height of perigee of the satellite and following the transition from conditions of freely molecular airflow to flow with slip for heavy Proton type satellites. The possible change of atmospheric density was evaluated at altitudes of around 200 km.</p>				

DATA HANDLING PAGE

01-ACCESSION NO. 06-DOCUMENT LOC TT9501365	29-TOPIC TAGS photometric analysis, satellite tracking, satellite motion, spacecraft tracking station, aerospace conference
00-TITLE RESULTS OF TREATMENT OF OBSERVATIONS BASES ON THE SPIN PROGRAM AND SOME QUESTIONS OF TECHNOLOGY OF OBSERVATIONS	
47-SUBJECT AREA 05, 17, 22, 20	

12-AUTHOR/CO-AUTHORS PANICH, I. M.; 16-VOROB'YEVA, V. A.; 16-GRIGORIEVSKIY, V. M.	10-DATE OF INFO -----68
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43-SOURCE SOVESHCANIYE "ISSLEDOVANIYA VRASHCHENIYA ISKUSS'TVENNYKH SPUTNIKOV ZEMLI PO FOTOMETRI-CHESKIM DANNYM" (RUSSIAN)	46-DOCUMENT NO. MT-24-208-69 69-PROJECT NO 72302-78
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63-SECURITY AND DOWNGRADING INFORMATION UNCL. O	64-CONTROL MARKINGS NONE	97-HEADER CLAIM UNCL
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ABSTRACT

(U) Results of observations based on the SPIN program in 1967 and partially for 1968, and also some results of investigation of 1967 material are presented. A method of visual photometric observations is described, making it possible to increase the accuracy of determination of values of the period of satellite brightness variation.