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Preliminary Analysis of INTEROBS Programme Observations

By

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Abstract. The authors give a short survey of the material obtained within the INTEROBS—programme and they discuss in some detail the analysis made in Hungary. The determination of changes in the period of a satellite, using approximately known orbital elements, is in progress. The preliminary analysis of the data proved that reliable dP/dn values can be obtained from simultaneous visual observations even during one-week intervals of cooperative work.

Résumé. Les auteurs décrivent sommairement les observations obtenues dans le cadre du programme INTEROBS et discutent en détail l'analyse effectuée en Hongrie. Des déterminations de variation de période d'un satellite utilisant des éléments orbitaux approchés sont en cours. L'analyse préliminaire des données montre que des valeurs dignes de confiance de dP/dn peuvent être obtenues à partir d'observations visuelles simultanées même pendant un intervalle de temps d'une semaine correspondant à la durée d'une campagne de coopération.

The INTEROBS programme (the name comes from the words INTERnational OBServation) is a cooperative programme of observation, the aim of which is to determine the orbital elements of the observed satellites by simultaneous visual observations, or rather the variations in the air density from the variations of the orbital elements.

The first measurements used to test the method within the INTEROBS programme were made by the stations No. 1113 (Baja, Hungary) and No 1120 (Bautzen, Germany) in 1961. Further measurements were made to gather experience with the participation of stations No 1111 (Budapest, Hungary) and No 1185 (Rodewisch, Germany) in 1962. The authors gave an account of these experiences on the conference of observers (1962, Leningrad). It was suggested by the conference to the observers of satellites to participate in the INTEROBS programme and the conference intrusted the coordination of the programme to the station No 1113 (Baja). Since that time, 23 stations from the following countries: Bulgaria, Germany, Hungary, Poland, Rumania, Soviet Union took part in the programme. Later, stations from Finland and Italy joined the programme.

The observations of the INTEROBS programme are taking place within the so-called cooperation weeks. The participating stations endeavour—during the cooperations weeks—to make as many measurements as possible on the basis of the predictions of the computing centre COSMOS (Moscow). The results of observations are sent to the cooperation centre (Station No 1113, Baja), where they are summarized, and those suitable to further elaboration are selected (observations suitable for further elaboration are those which are simultaneously observed by another station). The material suitable for elaboration is published, and placed at the disposal of the participating stations. The material obtained within the INTEROBS programme between August 1963 and October 1964, is administered as a common propriety, and is used to test the method chosen by every station. So, an opportunity is given to compare the results obtained by different methods. The aim of this work is to choose the adequate methods. The comparison of the results obtained will be made in October 1965 at a conference in Budapest. It will be discussed then, on the basis of the experience obtained, whether it is worth to go ahead with the cooperation, and in what form.

So far, cooperation weeks of the INTEROBS programme were held in the following months: August 1963, February, March, April, May, June, July, August, September, October 1964. These measurements were published in [*1*] and [*2*].

7024 position measurements were sent in the coordinating centre. These data were obtained from the observations of 328 transits of 10 different satellites. From this material, 143 simultaneous transits could be chosen with 4103 positions, i.e. 143 such transits, where the same satellite was observed simultaneously by at least two observing stations, independently of the length of the simultaneously observed arc of trajectory.

30% of the observing material apply to 1960-ε 3.
13% of the observing material apply to 1963-17A.
45% of the observing material apply to 1963-47A.
So, 88% apply to three satellites.

The experiences on the first year showed that the number of simultaneously observed transits depends considerably on the meteorological factors, and, in this respect, the computing center (the task of which is to supply uniformly all the participating stations with predictions of proper quality and quantity during the cooperation-weeks) is also an important factor.

The mass treatment of the data was started in Hungary only in 1964. The first step was to determine the coordinates of the satellite at a given moment (within the observed time interval) measured simultaneously from at least two stations. This we made graphicaly: we draw the values α, δ or A, h observed from two or more stations in function of time (on a large scale) and from each curve, smoothing the observed values, we can read the coordinates referring to a selected moment. The coordinates obtained by this graphical interpolation are the so-called "simultaneous points".

Because of the large number of simultaneous points we had to choose a programme which is suitable for computer reduction. Such a method was suggested by I. ALMÁR and E. ILLÉS [3]. The aim of the authors was the elaboration of a procedure which provides directly from the simultaneous points at each transit the orbital elements, together with the errors. For the computing of the space positions, a very simple range of formulae of "cosmical triangulation" is used in the system of coordinates fixed relatively to the stars, starting from the simultaneous positions. After this, from the obtained XYZ coordinates, we compute with the method of least squares the components of the normal vector of the plan which contains the center of the Earth and which lies at best between these points. We obtain also the errors of the determined components. Then, projecting the space positions on this determined plan, we reduce the question to a two dimensional problem. If the observations have a sufficient accuracy and if the observed arc of the orbit is long enough, then it is possible to determine the parameters of the ellipse which passes at best through the points, and one of the focuses of which coincides with the zero-point (the center of the Earth). The method gives us also the errors of the orbital elements.

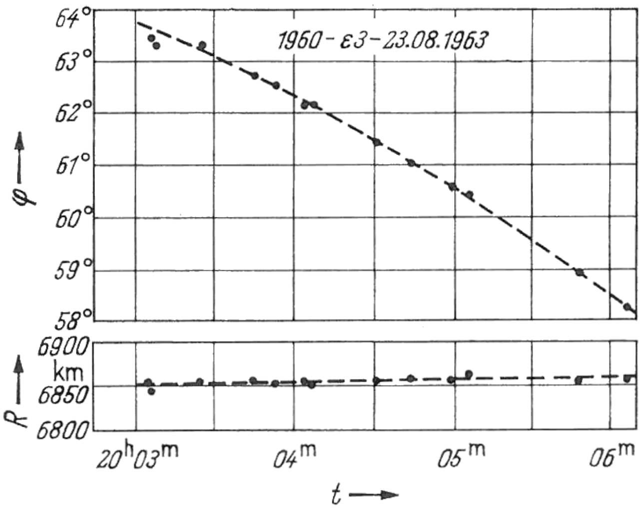


Fig. 1

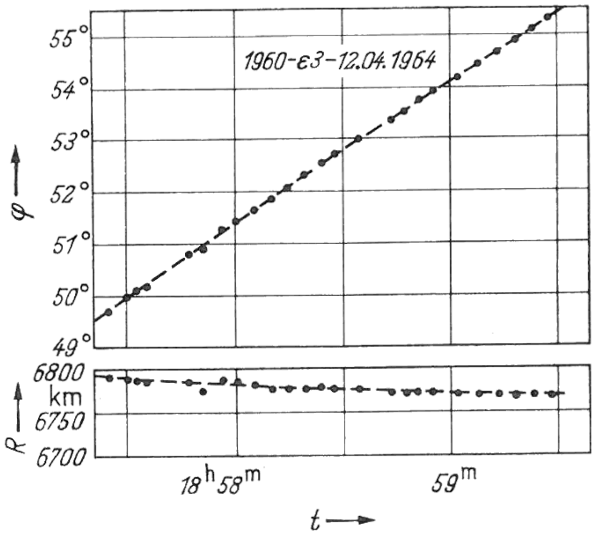


Fig. 2

In the first phase of the treatment, the data referring to 1960-ε3 and 1963-43A (the data published in [*1*]) were elaborated jointly by the Baja and Budapest stations, with an Elliott-803 electronic computer. As a first step, we determined the space coordinates (XYZ) and radius-vectors (R) of the satellites and the geographical latitudes of the subsatellite points (φ). The radius-vectors being drawn in function of time, we can estimate their quality from the spreading of the data. On the basis of the curves obtained, we established that many of the measurements show such a great scattering, that orbital elements cannot be possibly computed from them. The transits for which the single measurements were scattered in time, have been considered the worst, because the fixing of the simultaneous points by graphical interpolation raised difficulties in such cases. Good results were given generally by transits whose positions were separated only by a few seconds of time. The $R(t)$ curves from such better transits show scattering of the order of a few kilometres (Figs. 1—5).

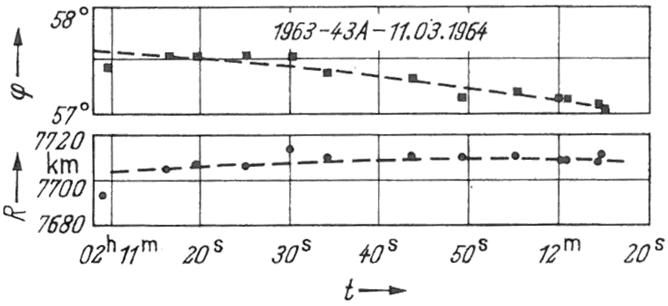


Fig. 3

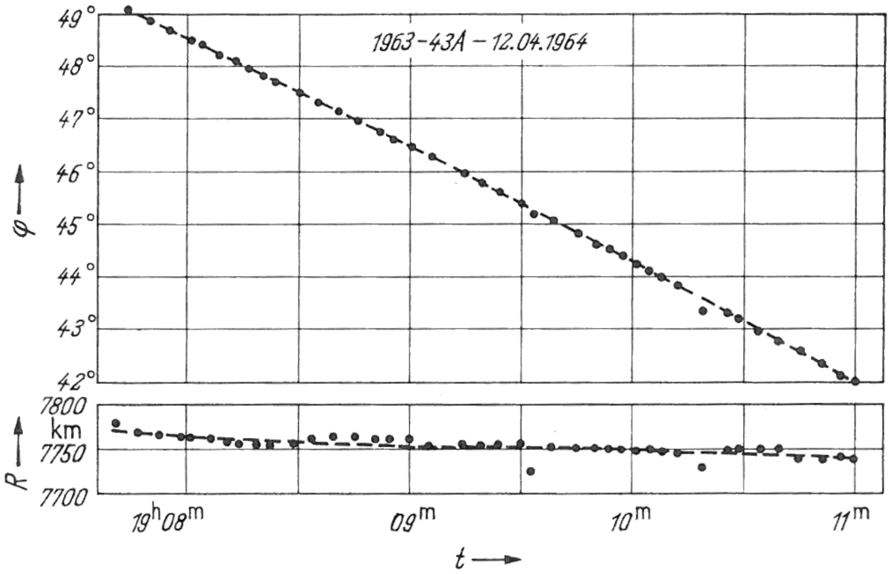


Fig. 4

Looking at the curves, we can establish that the first and last points of the curve may be off compared with the general course of the curve. This can be explained by the undefined character of the graphical interpolation on these points.

Taking in view the scattering of the radius-vectors, it becomes clear, even on the curves showing the best results, that in case of methods, where the orbital elements are computed from radius-vectors, the actually computed radius-vectors can often give rise to unreliable orbital elements because of the scattering (mainly on short arcs of orbit). It is practical in these cases to draw the curve radius-vectors in function of time, and further, to perform the calculations omitting the deficient points.

The $\varphi(t)$ curves have the same aspect as the $R(t)$ curves, but the scattering is generally considerably less. This encouraged us to apply the procedure proposed by Zhongolovich [4]. He suggested to establish the use of approximate orbital elements and to determine by this the period of the satellite. This can be made for instance by the use of the coordinates of the subsatellite points, and then we obtain the nodal period. The period can be established with a relatively great accuracy, even on the basis of serial observations which contain a comparatively short arc of the orbit.

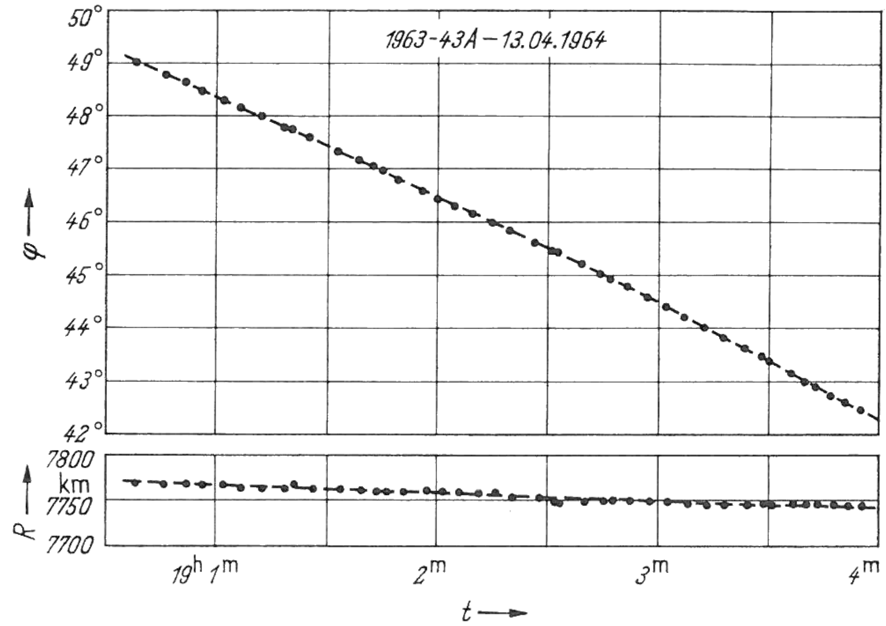


Fig. 5

At this stage of our work, we examined whether the changes of period can be revealed by this method, from the material got from the INTEROBS programme. The treatment has been done in the following way: we chose a reference latitude on the basis of the obtained coordinates of the subsatellite points, and then we calculated, using the approximate orbital elements, for each subsatellite point the time of crossing the reference latitude. The average of this times calculated in this way was named the observed time: O. We determined the change in period per revolution as follows: if the period of the satellite is constant, the time of the n-th crossing of the reference latitude, measured from a time t_0 is:

$$C = t_0 + n\,P\,, \tag{1}$$

where P is the nodal period of the satellite at t_0. But the observed time O differs from this calculated time, because the satellite has a decrease of period and therefore (if we consider that the decrease of the period is constant) the time of the n-th crossing of the reference latitude is:

$$O = t_0 + n\,P - \frac{n\,(n+1)}{2}\,\varDelta \tag{2}$$

where $\varDelta$ is the change of period per revolution ($= dP/dn$).

From (1) and (2), we get,

$$\varDelta = \frac{-2\,(O - C)}{n\,(n+1)} \tag{3}$$

So we obtain for each observed crossing of the reference latitude a value of $\varDelta$. If $\varDelta$ is not constant, but scatters around a constant value, then it is suitable to determine the period belonging to the last observed point and to use the same procedure starting from the last point. In this fashion, so we obtain a new value $\varDelta'$. By weighting the obtained values $\varDelta$ and $\varDelta'$ we obtain:

$$\bar{\varDelta} = \frac{n\,(n+1)\,\varDelta + n'\,(n'+1)\,\varDelta'}{n\,(n+1) + n'\,(n'+1)}\,.$$

The weighting is justified by the fact that the effect of the error in 0 on $\varDelta$ is inversely proportional to $n(n+1)$ and $n'(n'+1)$ respectively.

The $-2(O - C)$ values being drawn in function of $n(n+1)$, we obtain a straight line if $\varDelta$ is constant. If $\varDelta$ is not constant, i. e. it has a systematic deviation starting from a time t_k, we divide the interval into two parts: from $t_0 - t_k$ anf drom $t_k - t_n$. The treatment further on is the same as above. In the last case, we obtain graphically a broken straight line.

In the manner mentioned, I. Almár treated the material concerning to the object 1960-ε 3. He made use of 12 transits in 9 days (20—30 August, 1963). The approximate orbital elements used by him were those published ITA (Institute of Theoretical Astronomy, Leningrad). According to the values obtained the average value of $\varDelta$ in the time between 21—26 August, 1963 was (Fig. 6):

$$dP/dn = -0.0110 \text{ sec/Rev}$$

and between 26—30 August, 1963:

$$dP/dn = -0.0075 \text{ sec/Rev.}$$

(The scattering of is $dP/dn = 0.002$ sec/Rev.)

On the curve, we can see the change of dP/dn as a sudden break. The reality of the break is conspicuous also on the $O - C$ curve (Fig. 7). The obtained result being compared with the different indices of solar activity, it is conspicuous that the decrease of dP/dn happened at the same time when, as a consequence of the disappearence of a large sunspot group, the relative sunspot number and the sunspot areas decreased suddenly (Catanian measurements). There is no correlation with radio-flux.

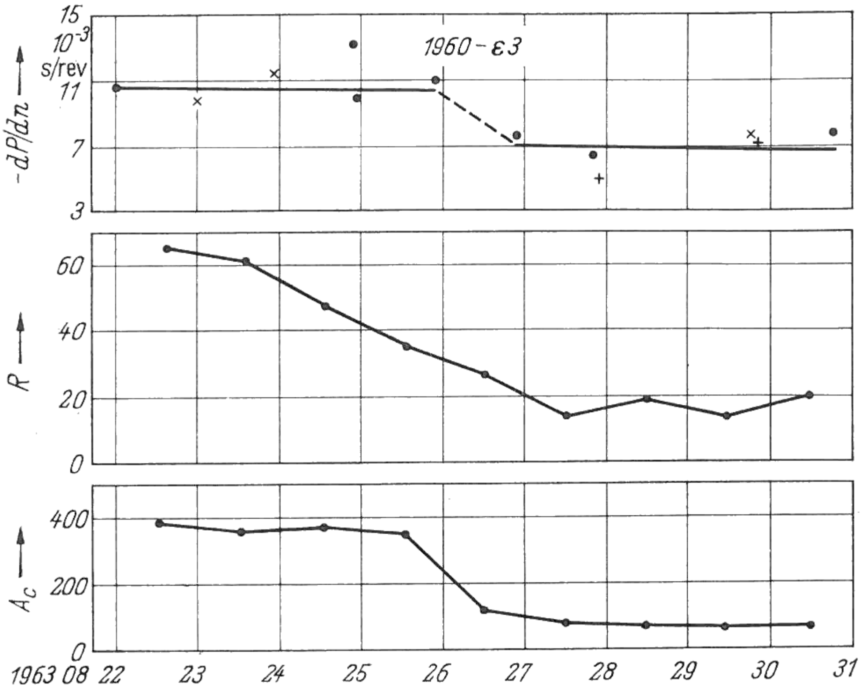


Fig. 6

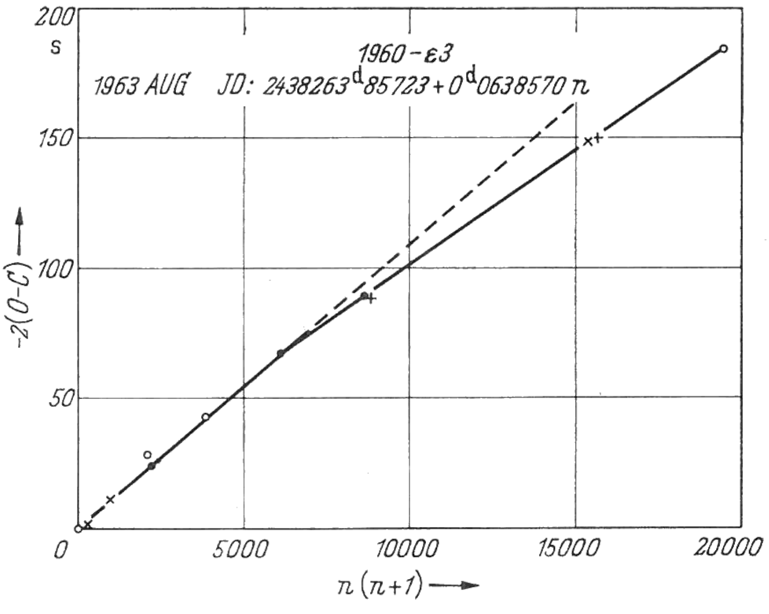


Fig. 7

If we compute the life-cime t_L of the satellite on the basis of the present data and if we compute the theoretical values of Δ with the formula given by KING-HELE, then the results obtained are: —0.0072 sec/Rev, and —0.0084 sec/Rev depending upon the constant used.

The material of the month of April 1964 is considerably smaller. It was not possible to determine an acceleration, but we got a reliable value of Δ:

$$dP/dn = -0.0128 \text{ sec/Rev.}$$

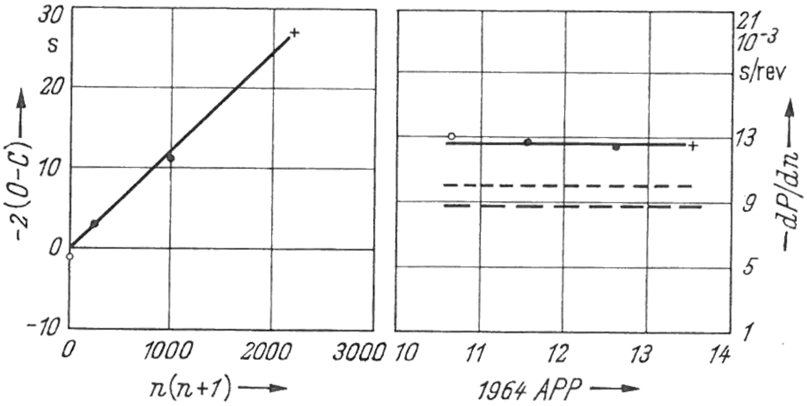
The theoretical value are considerably smaller: —0.0088 sec/Rev and —0.0103 sec/Rev, respectively (Fig. 8).

The material concerning 1963-43A (10—14 March, 1964, 10—15 April, 1964) is not of a good quality. The average standard deviation of the obtained latitude crossing times is about: 0.8 sec. We treated the material in the same manner but it was not possible to determine a reliable value of Δ (at each transit). Therefore we determined only the average nodal period concerning the two cooperation-weeks. These are:

$$P_n = 102.372 \text{ min.} \quad (10\text{—}14 \text{ March}),$$

$$P_n = 102.364 \text{ min.} \quad (10\text{—}15 \text{ April}).$$

From the change of period in this time interval we obtain an average value of 0.010 sec/Rev. The theoretical one computed with the formula given by KING-HELE is: 0.007 sec/Rev.



1960-ε3

1964 APR JD: $2438496^{d}82339 + 0^{d}0634370\, n$

Fig. 8

On the basis of the obtained results one can make the following conclusions: By suitable methods, the values of Δ can be determined with sufficient accuracy from simultaneous visual observations. The time of a possible sudden acceleration can be determined in a fortunate case with an uncertanity of some hours, or at the worst of 1—2 days. We can consider as important the fact that we obtain at each transit the values of Δ separately. There is no need of averaging the observing material collected from a longer time interval. This averaging would cause the sudden changes of air-density to disappear.

The computing of the other elements from the available material can be done only with difficulty, because the lengths of the observed arcs of orbit are too short. Because of this we proposed to observe, if possible, two successive transits of the same satellite during the cooperation-weeks of this year. The observed arcs of orbit are in such cases not quite identical and so they can partly prolongate each other. Another method is to observe satellites with large inclination and, by help of the newly joined stations (Italy, Finland, Sweden), we shall then prolongate considerably the observed length of the orbital arc.

References

[*1*] Ill, M.: Ergebnisse d. im Rahmen d. INTEROBS-Programms abgehaltenen Kooperationswochen (Folge I), Baja, 1964.
[*2*] Ill, M.: Ergebnisse d. im Rahmen d. INTEROBS-Programms abgehaltenen Kooperationswochen (Folge II), Baja, 1965.
[*3*] Illés E., and J. Almár: Zur Berechnung momentaner Bahnelemente künstlicher Erdsatelliten aus Basisbeobachtungen, Beobachtungen künstlicher Erdsatelliten, Nr. 3, 1964, Berlin: NKGG der DDR, 1965.
[*4*] Zhongolovich, I. D.: A Remark on the Treatment of Simultaneous Observations. Conference at Riga, 1—5 Febr. 1965; see also page 1 of the present book.

Discussion[1]

Prof. Herrick remarked that this method is somewhat related to the Gauss-Gibbs method of determination of orbits from positions only, but, in this case, the difference lies essentially in the fact pointed out by Mr. Ill that the period is being determined from observations of several passes.

Prof. Herrick and Dr. Baker considered that a sizeable amount of information is lost by using fixes or space positions rather than the observations themselves, the residuals for each observation reduced as such would certainly improve the precision of the determination of the orbit. Contamination of good data by forcing its use as a fix is possible in the proposed methods. The elimination of non simultaneous observations would also be avoided and more information would be used and precision would be improved. M. Ill and Mrs. Massevitch pointed out that the presented method has the advantage of being much simpler and of requiring a much smaller amount of computing time, permitting anyhow to determine the period of a satellite within a single night of observations. Mr. Merson considered that 16 observations in 3 or 4 passages are sufficient to provide a good orbit.

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[1] This discussion also refers to the following two papers.