ACADEMY OF SCIENCES OF THE USSR

RADIOTECHNICAL INSTITUTE

INSTITUTE OF THE PHYSICS OF THE EARTH

Preprint

VARIATIONS OF SOLAR WIND FLUXES OBSERVED ON BOARD SEVERAL SPACE-CRAFTS AND PULSATIONS OF THE EARTH'S ELECTROMAGNETIC FIELD CONNECTED WITH THEM

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To be presented at the International Symposium on Solar - Terrestrial Physics, Leningrad, May, 1970

MOSCOW

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Variations of Solar Wind Fluxes Observed on Board Several Spacecrafts and Pulsations of the Earth's Electromagnetic Field Connected with Them

The aim of this paper is the comparison of parameters of solar wind fluxes affecting the magnetosphere measured in the interplanetary space with characteristics of pulsations of the Earth's electromagnetic field recorded on a number of geophysical observatories. The data for different phases of solar activity obtained during the flights of Venera-2 (1965), Venera-4 (1967) [1], Venera-5 and Venera-6 (1969) [2] and the records of the geophysical observatories Borok (Φ =52°53', Λ =123°20'), Petropavlovsk (Φ =44°24', Λ =218°14'), Soroa (Φ =33°, Λ =345°) were used for this comparison. Results of the solar wind measurements on board IMP-1 (1963) [3] were used to verificate and to detalize the obtained conclusions.

I. The connection between the intensity of micropulsations and short-period disturbances of Earth's electromagnetic field and values of solar wind fluxes

At the first stage of the comparison we were interested in a general disturbance of the electromagnetic field determined by its micropulsations and short-period disturbances. The telluric currents data records were used for the estimation of these pulsations and disturbances since the devices for recording of telluric currents on the above-mentioned observatories have much broader amplitude frequency characteristics than those used to record the magnetic field. The equivalent sensitivity of these devices exceeds the sensitivity of the standard magnetograph network by more than an order of magnitude.

In fig.1 an example of telluric current data records from the observatory Borok is presented. It corresponds to the sudden commencement of a geomagnetic storm (the transition from quiet to disturbed state at $1^h\ 58^m$ UT 2.26.1969).

In fig.2 the fragment of telluric currents data record with continuous pulsations is also presented. Such records were later used to determine periods of pulsations.

To characterize the intensity of pulsations the hour E-indice was used (the dimensionless indice E was defined as the ratio of the maximum amplitude of the pulsations of horizontal component of the electric field during one hour to its values averaged over a year).

In this paper universal time is used in all cases.

On the spacecrafts Venera-4, Venera-5, Venera-6 flat integral traps were installed which made it possible to determine variations of ion fluxes of the solar wind $N_i = n_i v$ [1,2]. It should be noted that the initial level was evaluated as $10^8 cm^{-2} sec^{-1}$ in [2] from which variations ΔN_i were counted out. The comparison of N_i-values measured on board Venera-6 2.26.1969 with $n_i v$-values measured at the same time on board HEO S-I [4] confirmed the correctness of the mentioned evaluation.

Comparisons of E-indices values with N_i variations showed that rises of solar wind fluxes affecting the magnetosphere as a rule were accompanied by an increase of the intensity of the electromagnetic field pulsations. In all cases when ΔN_i values reached maximum ones equal to or more than $3\cdot10^{8}cm^{-2}sec^{-1}$, the intensity of pulsations increased (E-indices >1). First of all, the cases of increasing of N_i and rising of the intensity of pulsations were compared during the two-months period of the flights of Venera-5 and Venera-6 from 1.21.1969 to 3.21.1969 [2].

In fig.3 the fragment of this graph corresponding to the period from 1.21.69 to 2.10.1969 is presented. In the upper part of the graph ΔN_i-values are shown with respect to $\sim 10^{8}cm^{-2}sec^{-1}$ level; the time intervals corresponding to N_i increases during which ΔN_i reached a maximum value ($\Delta N_{i\,макс} \geq 3\cdot10^{8}cm^{-2}sec^{-1}$) are marked lower; the time intervals during which E-indice was more than 1 are shown at the bottom of the graph. During the mentioned two-months time interval each case when ΔN_i reached the value equal to or more than $3\cdot10^{8}cm^{-2}sec^{-1}$ corresponded to the case of the increase of the intensity of pulsations with E-indice more than 1. It gave a ground to suggest in [2] a causality between these phenomena.

However, the following comparison of similar data corresponding to the period of the flight of Venera-4 (June--July, 1967) did not reveal so clear results. Separate cases were noted when increases of N_i were not accompanied by the considerable rise of the intensity of pulsations and the increase of the intensity of pulsations was observed without the substantial rise of N_i. That is why the problem of the connection with the intensity of pulsations of the Earth's electromagnetic field requires the subsequent consideration with the using of data over a long period of time to obtain statistically grounded conclusions.

It is worth noting that in the majority of cases the increase of solar wind fluxes affecting the magnetosphere is likely to be related to the rise of the pressure on the magnetosphere and the decreases of its cross-section.

Apparently in such cases the periods of the magnetosphere proper oscillations which can be identified with pulsations observed on the Earth's surface must diminish. However, it does not explain why the increasing pressure on the magnetosphere causes the occurence of micropulsations or the rise of its intensity. It is possible that the increase of solar wind fluxes causes the rise of the magnetized plasma turbulence in the transition region between the front of a shock wave and the boundary of the magnetosphere and this in turn causes the surface waves generating magnetogidrodynamic waves inside the magnetosphere.

2. The connection between periods of continuous micropulsations and the parameters of the solar wind

At the next stage of this work the comparison of continuous pulsations of the Earth's electromagnetic field determined from the telluric currents data records of three abovementioned geophysical observatories with N_i-values measured on board Venera-2, Venera-4, Venera-5, Venera-6 was made.

In fig.4 the results of this comparison are shown. For all four spacecrafts the dependences of T on $N_i = n_i v$ were identical although the flights were carried out during different phases of the solar activity. At the same time fig.4 shows that for two ranges of values of T ($T \leq 40$ sec and $T \geq 40$ sec) these dependences are different. For the first range the value of T diminishes with the rise of N_i , but for the second range the value of T increases. For the additional verification of such a dependence observed during the different phases of solar activity and in order to clear out separately the influence of the density n and of the bulk velocity v in solar wind on the period T the results of measurements of solar wind parameters on board IMP-1 (December, 1963 - March, 1964) [3] were analysed (see fig.5). In this analysis the value of T was taken from records of the observatories Borok and Petropavlovsk.

Fig.5a fully confirms the existence of different dependences of T on nv for periods $T \leq 40$ sec and $T \geq 40$ sec which are shown in fig.4.

Dependences T (v) and T (n) obtained from IMP-1 data [3] shown in fig.5b and 5c. The influence of simultaneous variations of n and v was not excluded when plotting fig. 5b and 5c. In fig.5b and 5c one can see that the clear dependence of T on v does not exist and the value of T practically depends on the density of charged particles in the solar wind.

Subsequently similar graphs for fixed values of n (5-10 cm^{-3}) and v (300-350 km sec^{-1}) were plotted. These graphs are shown in fig.6a and 6b; as one can see they are absolutely similar.

The absence of the dependence of T on the solar wind bulk velocity is to some degree unexpected because dependences of different geophysical phenomena on the solar wind bulk velocity were often considered in scientific papers (beginning from [5]). Up to date very little attention was paid to the influence of the solar wind ion density n on phenomena in the circumterrestrial space (although for instance in [6] the strong geomagnetic storm was described which has been caused by the increase of n but not v). These variations of the solar wind pressure $p = \frac{nv^2}{2}$ were supposed to be basically determined by variations of v for the dependence of P on n is linear while the dependence of P on v has a square law character. In this case it was not taken into account that near the Earth's orbit the bulk velocity usually varies not more than by a factor of three (from ~ 250 km sec^{-1} to ~ 750 km sec^{-1}), while n variations can exeed two orders of magnitude (from some fractions to ~ 100 particles in cm^{-3}).

Dependences showed in fig.6 indicate that it is necessary to continue the analysis of the influence of variations of n values on phenomena inside the magnetosphere. Besides they allow to suggest that micropulsations with periods $T \leqslant 40$ sec and $T \geqslant 40$ sec are likely to be generated in different regions of the magnetosphere.

The diminishing of T with the rise of N_i for pulsations with $T < 40$ sec is in a good agreement with the conceptions of the generation of micropulsations of this group (Pc 2-3) inside the Earth's cold plasma envelope (plasmosphere) since its boundary (plasmopause) approaches the Earth during the increase of geomagnetic activity while the magnetosphere is compressed and moves away from the Earth during the decrease of the pressure on the magnetosphere. The diminishing of the dimension of the resonator for which plasmopause and the lower boundary of the ionosphere serve respectively as the outer and inner walles naturally decreases the period of oscillations generating in this resonator. Arguments in favour of the generating of pulsations Pc-2 and Pc-3 type (with the period $T < 40$ sec) in plasmosphere were discussed previously in [9]. However, the possibility of the generation of these pulsations in the whole volume of the magnetosphere changing under the influence of the solar wind is not excluded.

It is more difficult to explain the increase of T with the rise of $n_i v$ for pulsations with $T > 40$ sec which correspond to the Pc-4 type of pulsations. In consequence with existing conceptions these pulsations can be generated in a relatively narrow field line tube which is projected on the auroral zone [10]. These pulsations are identified with Alfven waves propagating in this tube. In such a case the period of pulsations is connected with the plasma density n at the top of the field line by the following relation: $T \sim \frac{\sqrt{n}}{\cos^2\Phi_0}$, where Φ_0 is the geomagnetic latitude corresponding to the latitude of the tube projection.

In fig.5c one can see that periods of pulsations with $T > 40$ sec increase with the rise of n in the interplanetary space. Assuming that the rise of the plasma density in the solar wind can lead to the increase of plasma density in the outermost region of the subsolar part of the magnetosphere (for instance due to the large-scale convective motion of the magnetosphere plasma or due to the penetration of the solar wind into magnetosphere by means of some mechanism) then using the relation $T \sim \frac{\sqrt{n}}{\cos^2\Phi_0}$ one can qualitatively explain the upper part of graphs in fig.4, 5a and 5b (for $T > 40$ sec). It must be noted that the analysis of the data obtained on board the satellite ATS-1 showed that the value of n had varied from $n = 1.8\ cm^{-3}$ to $14.8\ cm^{-3}$ in the same region of the magnetosphere (at $R = 6.6\, R_E$ near local noon) during the compression of the magnetosphere 1.13.1967 [12].

Summarizing, it can be said the obtained results show that the basic solar wind parameter which determines the character of electromagnetic field pulsations generated on the Earth's surface is the density of the proton component of solar wind fluxes.

It must be stressed that from one hand the changes of the particle density of the solar wind determine the changes of the volume of the resonator in the magnetosphere where Pc-2-3 pulsations are formed. From the other hand the character of Pc-4 period dependence (which are formed in the outer regions of the magnetosphere) on N_i can be an indication of the rise of the plasma density in the subsolar part of the magnetosphere.

From fig.4, 5a and 5c one can conclude that continuous micropulsations with two different periods corresponding to two branches of the graph may simultaneously exist. However, these periods must be in relations determined by the mentioned graphs.

Brief conclusions

1. During the flights of the spacecrafts Venera-5 and Venera-6 (1969) the clear dependence of the general intensity of micropulsations and short period disturbances of the Earth's electromagnetic field on the solar wind fluxes affecting the

magnetosphere is observed.

2. During the flight of the spacecraft Venera-4 (1967) this dependence was not so clear.

The analysis of the connection between the intensity of these disturbances and values of solar wind fluxes needs to be continued; data over longer periods of time should be considered in order to obtain statistically grounded conclusions.

3. The period of continuous micropulsations of the Earth's electromagnetic field depends on values of the solar wind fluxes. It does not practically depend on the solar wind velocity but it is determined by the density of the solar wind.

4. A character of dependences of T on solar wind ion fluxes and on the ion density allows to make conclusions about the possibility of the simultaneous existence of two types of pulsations with steady periods determined by graphs shown on fig.4 and 5c.

The authors thank to B.A.Tverskoy and A.V.Gulelmi for the helpful discussions.

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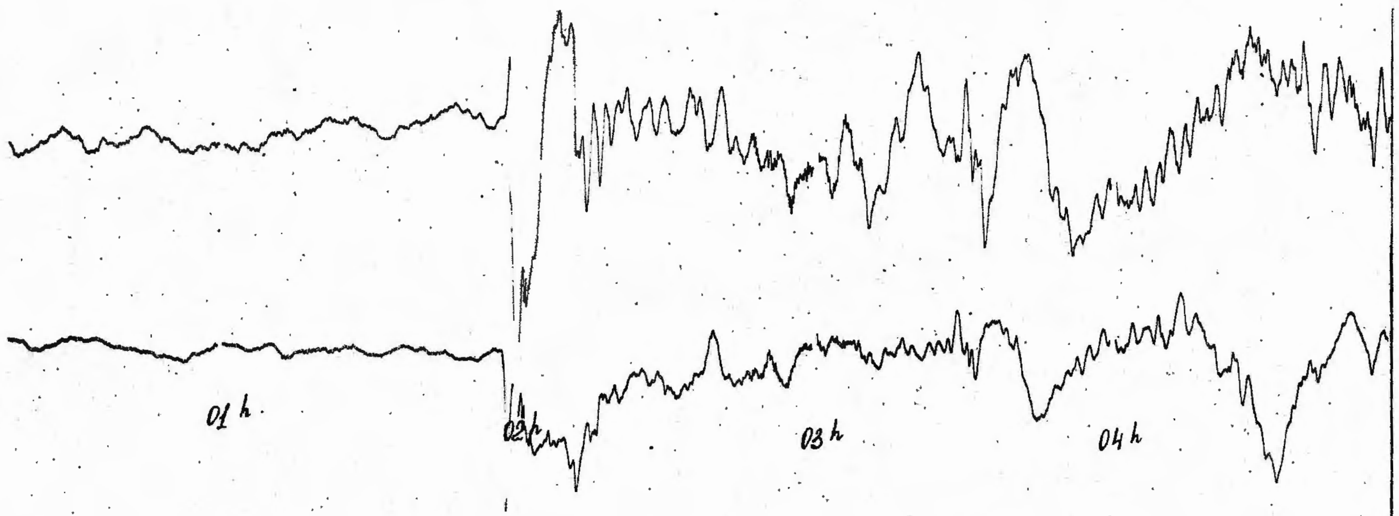


Fig.1. An example of telluric currents data records from the observatory Borok corresponding to a sudden commencement of an electromagnetic storm (the transition from quiet to disturbed state at $1^{h}58^{m}$ UT 2.26.1969)

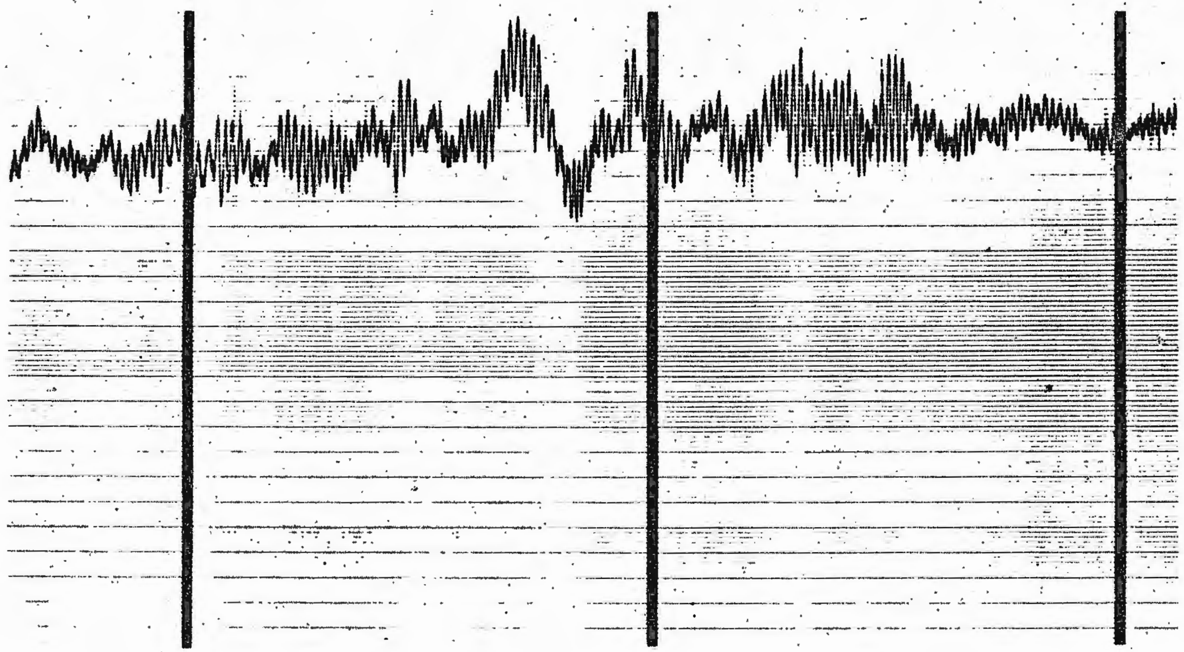
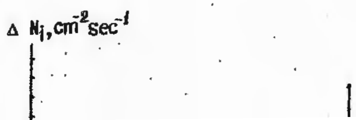


Fig.2. The fragment of telluric currents data record with continuous pulsations from the observatory Borok



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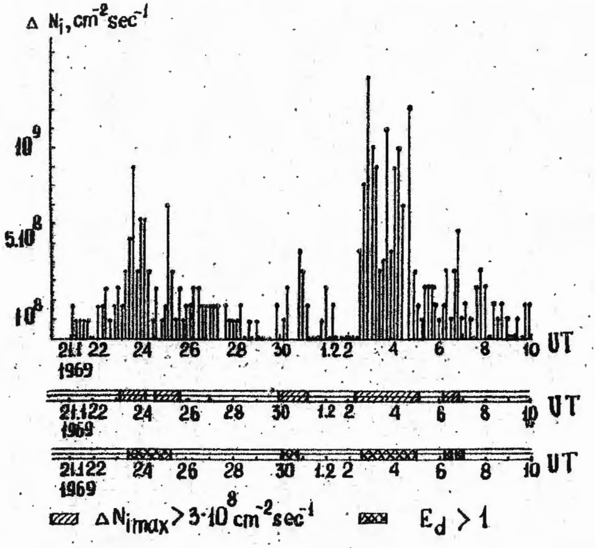

Fig.3. Variations of solar wind ion fluxes measured on board Venera-6 for the period from January 21 to February 10.1969. The time intervals corresponding to ion fluxes increases during which ΔN_i reached maximum value $\Delta N_{i_{max}} \geq 3x10^8 cm^{-2} sec^{-1}$ and the time intervals with indices E > 1 are shown at the bottom of the graph

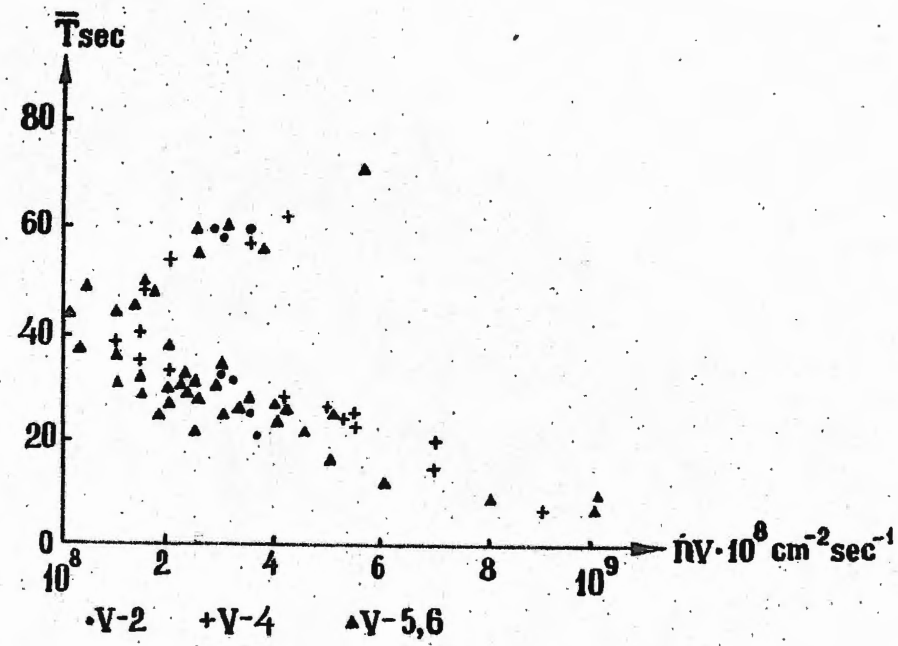

Fig.4. The dependence of periods T of micropulsations determined from data of several geophysical observatories on values of solar wind ion fluxes measured on board Venera-2, Venera-4, Venera-5 and Venera-6 (i.e.during different phases of solar activity)

Fig.4. The dependence of periods T of micropulsations determined from data of several geophysical observatories on values of solar wind ion fluxes measured on board Venera-2, Venera-4, Venera-5 and Venera-6 (i.e.during different phases of solar activity)

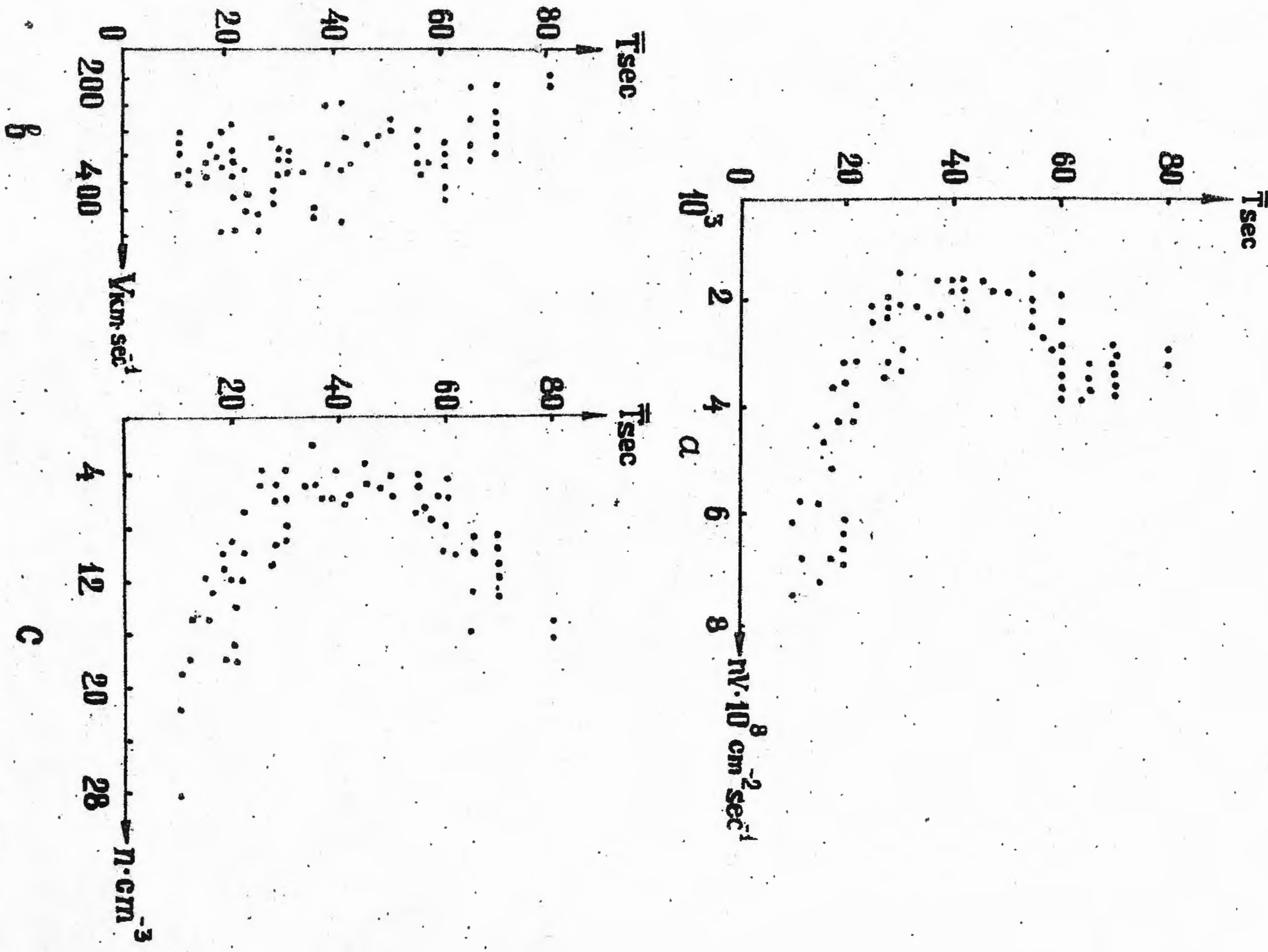

Fig.5. The dependence of the period T of micropulsations on values of solar wind fluxes (fig.5a), velocity (fig.5b) and density (fig.5c) from IMP-1 data

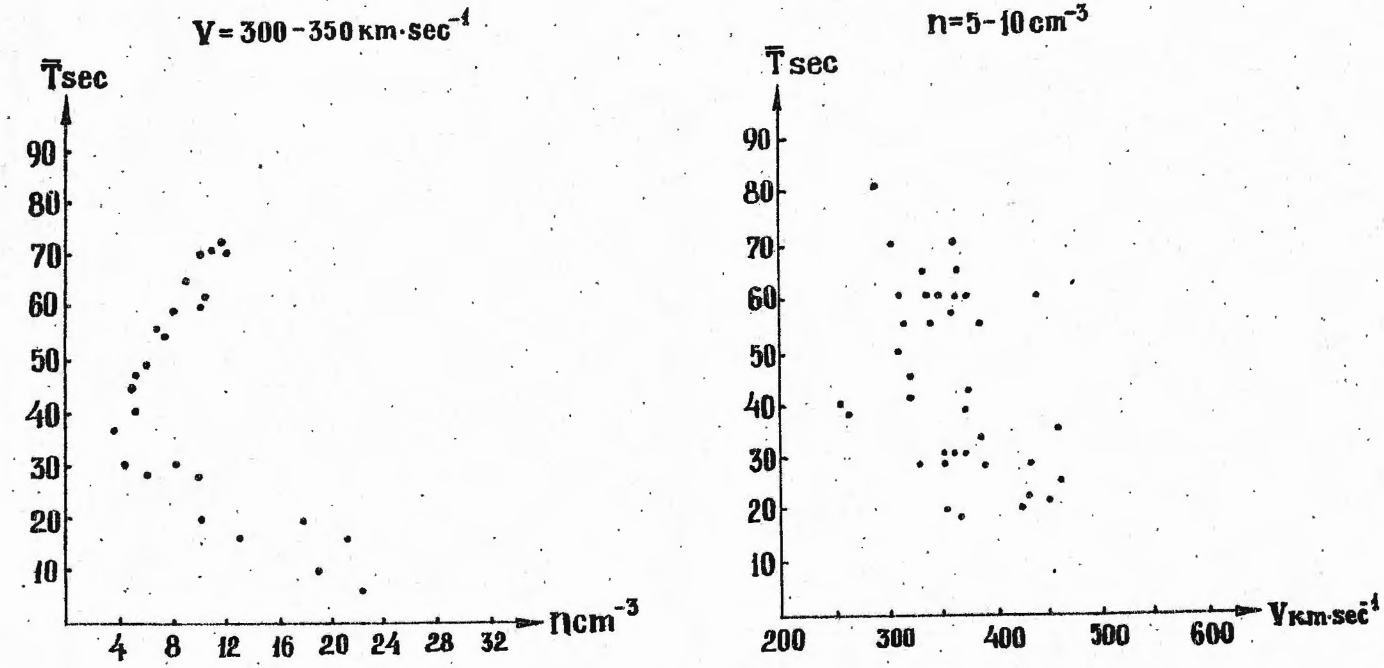

Fig.6. The dependence of the period T of micropulsations on density and velocity of solar wind for fixed values of n (fig.6a) and V in narrow ranges (fig.6b) from IMP-1 data