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SOLAR WIND OBSERVATIONS WITH THE AID OF THE INTERPLANETARY STATION VENERA-3

by

K. I. Gringauz
V. V. Bezrukikh
L. S. Musatov

(USSR)

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by K. I. Gringauz
V. V. Bezrukikh
L. S. Mustatov

SUMMARY

These are the preliminary results of measurements of energy spectra of ion fluxes of solar wind beyond the Earth's magnetosphere with the help of spacecraft "Venera-3" during the period from 16 November 1965 to 7 January 1966. Several conclusions are derived relative to physical characteristics of the solar wind and their connection with geomagnetic disturbances.

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* *

Several charged particle traps were installed aboard Venera-3, launched on 16 November 1965, of which one was of a modulation type. They were designed for the measurement of charged particle fluxes over the portion of the trajectory passing in the Earth's magnetosphere, and for the measurements of fluxes of positive ions and their energy spectra in interplanetary space.

Preliminary data are brought up in this paper, relative to the results of measurements of energy spectra of positive ions in solar plasma fluxes, conducted between 16 November 1965 and 7 January 1966 with the aid of the modulation trap.

The modulation trap was of the same type as the one installed aboard the space probe "ZOND-2" [1]. The magnitude and the sequence of direct and alternate voltages fed to traps' electrodes, also corresponded to the description of ref. [1]. Let us recall some of the characteristics of the device: when orienting the normal to the trap along the ion fluxes, the applied modulation trap allows the measurement of positive ions of solar plasma in eight mutually-adjacent energy intervals, of which each has a width of ~ 450 ev. Therefore, the maximum possible registered energy constitutes 3600 ev. It takes 4 minutes

(*) [NABLYUDENIYA SOLNECHNOGO VETRA S POMOSHCH'YU MEZHPLANETNOY STANTSII "VENERA - 3"] [Or VENUS-3].

to obtain one energy spectrum. The sensitivity by flux (in each energy interval) constitutes 10^7 $cm^{-2} \cdot sec^{-1}$. As was shown by measurements on various spacecrafts, in particular by measurements of Wolfe et al on IMP-1 [2], ions with energy $E > 3600$ ev are observed rather seldom.

The total flux of positive ions with energies $E < 3600$ ev is about equal to the sum of the fluxes registered in all energy intervals.

The circuit and the epures of voltages in trap's modulation grid are reproduced in Fig.1 [1].

Measurements with the help of the modulation trap were conducted only during comparatively rare radiocommunication sessions of short duration; this is why the total number of solar plasma spectra obtained for the period considered is only of a few hundred. All measurements were conducted in conditions when the normal to the trap constituted with the direction Sun-spacecraft an angle not exceeding 10°; the angular diagram of the trap is such that there is practically no need to introduce correction to the value of measured fluxes.

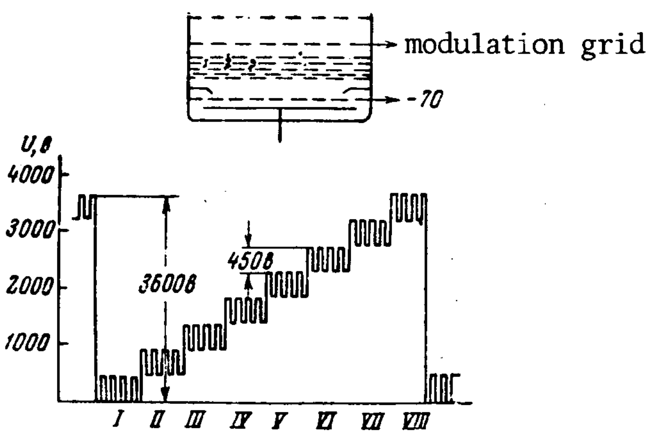

Fig.1

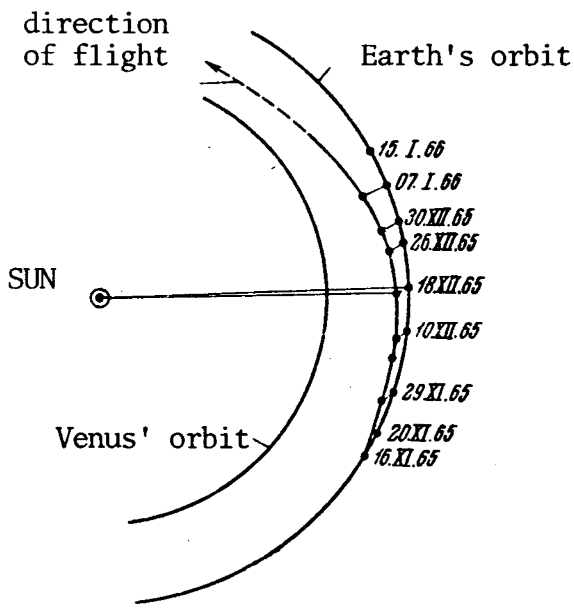

Fig.2

The projection of a portion of Venus-3 trajectory on the ecliptic plane and a portion of the Earth's orbit are shown in Fig.2. Solar plasma fluxes were registered with all apparatus' switches on. The study of the obtained energy spectra of positive ions has shown the following. Though spectra, in which the total flux of solar plasma (or, in any case, its greater part) is concentrated in a certain energy interval (for example, Fig.3), were not too seldom observed, the spectra in which significant ion fluxes of close magnitude were registered in different energy intervals are not scarcer (for example, Fig.4).

As a rule, the greatest ("main") components of spectra were observed in the intervals corresponding to velocities not exceeding 510 km/sec. Rather frequent were the cases of solar plasma flux registrations in which the velocities of the main components of ion fluxes did not exceed 300 km/sec (of the type corresponding to spectra a and ж in Fig.3). For the indicated device's threshold response the simultaneous presence of components of ion fluxes of solar plasma were observed extremely seldom in all energy intervals (see spectra г, д and e). The spectra obtained in sequence (each in the course of 4 minutes, as pointed out above) were often (though no always) departing from one another by details (see, for example, the spectra г, д, e in Fig.4 and the spectrum component variations in the course of two radiocommunication sessions of 18 December 1965, brought out below in Fig.5). The values of the total flux N_Σ, registered during the time of measurements, varied within the limits $1.5 \cdot 10^8$ cm^{-2} sec^{-1} < N_Σ < $2 \cdot 10^9$ cm^{-2} sec^{-1}. If we determine the concentration of ions n_i in the solar wind near the spacecraft as the sum of "partial concentrations", determined for each energy interval of the spectrum as $N_{E_1-E_2}/v_{av}$, where $v_{av} = (v_{min} + v_{max})/2$, the thus determined values of n lie within the limits 2.4 cm^{-3} < n_i < 55 cm^{-3} (the cases when the main component of the flux was in the first interval, when the velocities are $v_{min} = 0$ and $v_{max} = 300$ km/sec, were excluded from consideration since the value of v_{av} is then too uncertain). Note that the results of determinations of fluxes and solar wind velocities with the aid of the ion trap of the type described apparently agrees not too badly with the results of measurements conducted on American spacecrafts with the aid of devices based upon the same principle. Thus, in 1964 several spectra were published [1], that were obtained on the Soviet probe "Zond-2" in an exceptionally magnetoquiet day of 5 December 1964 (the sum of K_p-indices for one day $\Sigma K_p = 3$ [3]); the spectra contained components with velocities v < 300 km'sec and v < 415 km/sec; the total flux of ions N_Σ fluctuated from $3 \cdot 10^7$ to $6 \cdot 10^7$ cm$^{-2}\cdot$sec^{-1}.

Lazarus, Bridge et al [4] announced some results of observations of solar wind on Mariner-4, including the results referred to the day preceding 5 Dec. 1964 (339th day of 1964, i. e. 4 December, see Fig.3 in [4]). This day was also magnetoquiet with $\Sigma K_p = 7$ [3]. According to ref.[4], on 4 December 196e the flux N_Σ constituted $3 \cdot 10^7$ cm$^{-2}\cdot$sec^{-1}, and the mean velocity of ions was ∿ 400 km/sec.

It is necessary to point out that the determination of velocity of the directed motion of solar plasma flux is simple in the presence of one of spectrum's main components, but it is difficult in the case of spectra similar to those brought out in Fig.4. It is possible that for higher resolutions by energies the difficulty will decrease (there may exist within one of the energy intervals a clear narrow spectral line, and the second interval may be found to be filled uniformly).

However, the possibility is not excluded that spectra, similar to those of Fig.4 reflect the penetration of a fast plasma flux into the flux moving more slowly.

The events that may arise in similar cases are considered by Hirchberg [5] in connection with the proposed explanation of sudden commencements of recurrent magnetic storms.

Note that although spectra similar to those of Fig.4 are not too seldom correlating with geomagnetic disturbances, the latter are not recurrent magnetic storms with SC according to our data. Bear in mind, however, that measurements were conducted with great interruptions.

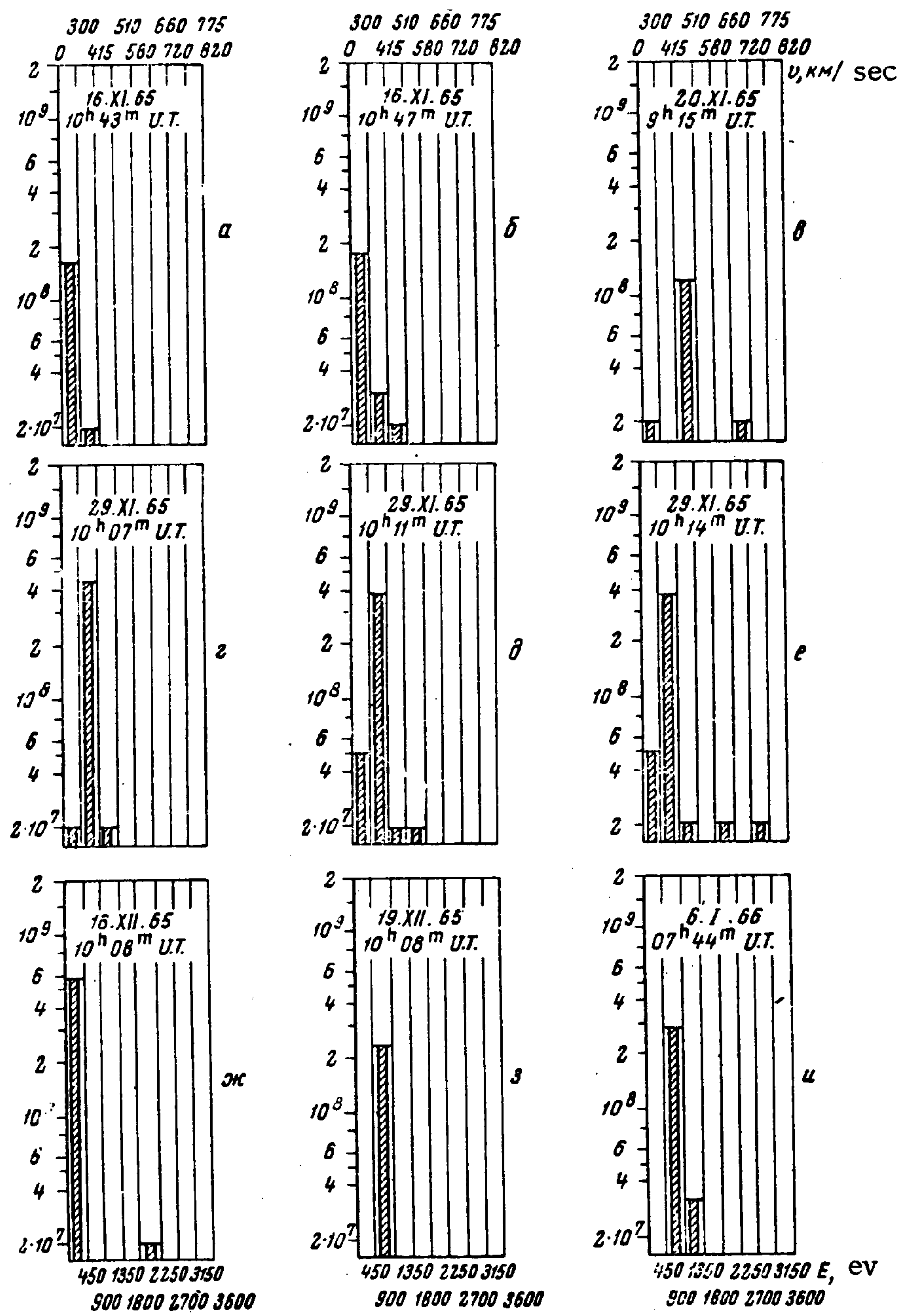
300 510 660 775
0 415 580 720 820
v, км/ sec
16.XI.65
10h 43m U.T.
16.XI.65
10h 47m U.T.
20.XI.65
9h 15m U.T.
29.XI.65
10h 07m U.T.
29.XI.65
10h 11m U.T.
29.XI.65
10h 14m U.T.
16.XII.65
10h 08m U.T.
19.XII.65
10h 08m U.T.
6.I.66
07h 44m U.T.
а
б
в
г
д
е
ж
з
и
450 1350 2250 3150
900 1800 2700 3600
E, ev

Fig.3

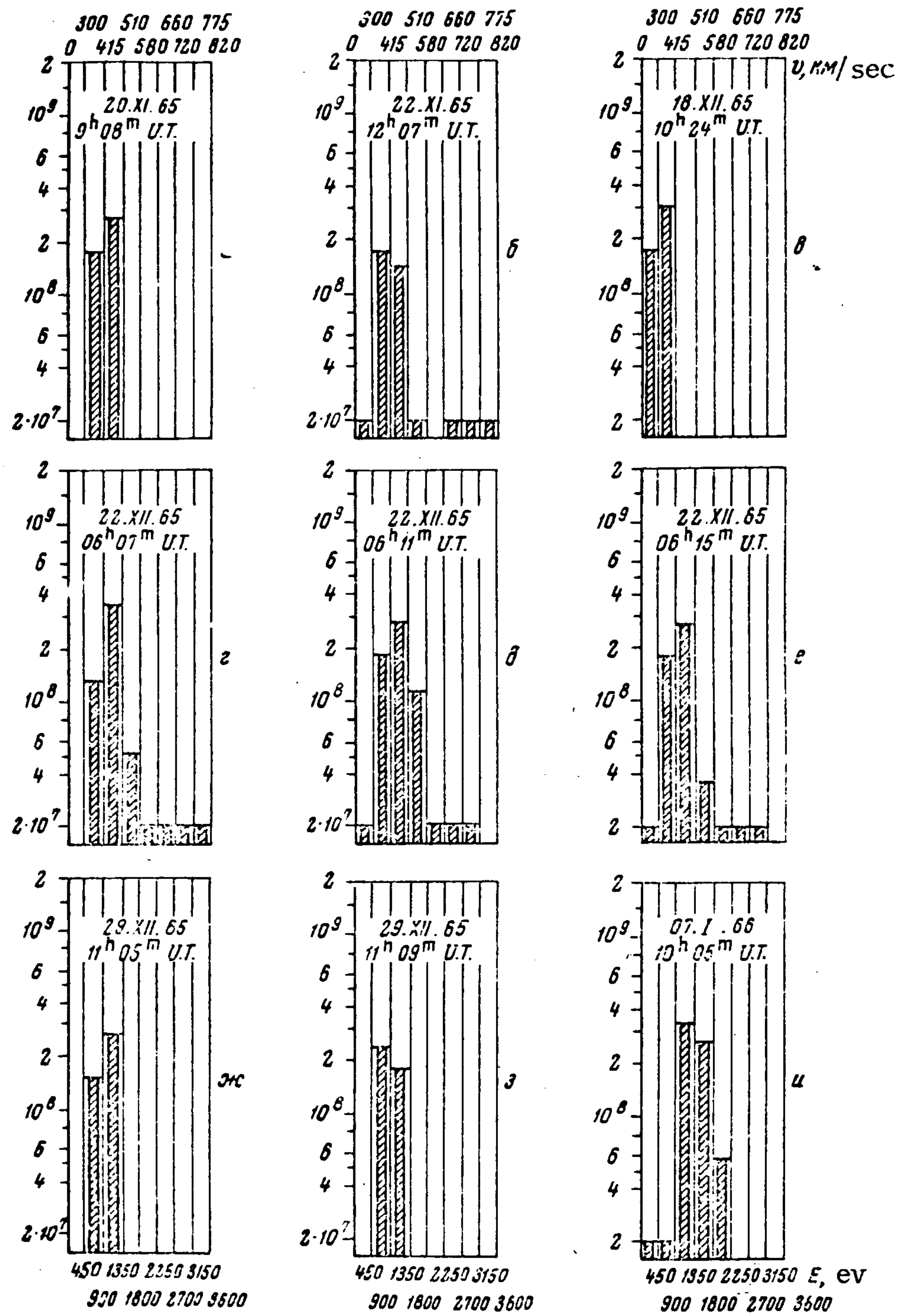
300 510 660 775
0 415 580 720 820
v, км/sec
20.XI.65
9h 08m U.T.
22.XI.65
12h 07m U.T.
18.XII.65
10h 24m U.T.
22.XII.65
06h 07m U.T.
22.XII.65
06h 11m U.T.
22.XII.65
06h 15m U.T.
29.XII.65
11h 05m U.T.
29.XII.65
11h 09m U.T.
07.I.66
10h 05m U.T.
450 1350 2250 3150
900 1800 2700 3600
E, ev

Fig.4

The greatest flux of solar plasma was registered in described measurements on 18 December 1965 ($N_\Sigma > 10^9$ $cm^{-2}\cdot sec^{-1}$) during two radiocommunication sessions lasting from 0905 to 0940 hours and 1010 to 1057 hours UT.

The results of measurements of spectra of ion fluxes performed during these sessions are plotted in Fig.5. The upper curve shows how the total flux N_Σ of ions with energies $E < 3600$ ev and velocities $v < 820$ km/sec varied in the indicated time interval, and the lower curves show the variations of ion flux components with velocities lying in the intervals of corresponding curves.

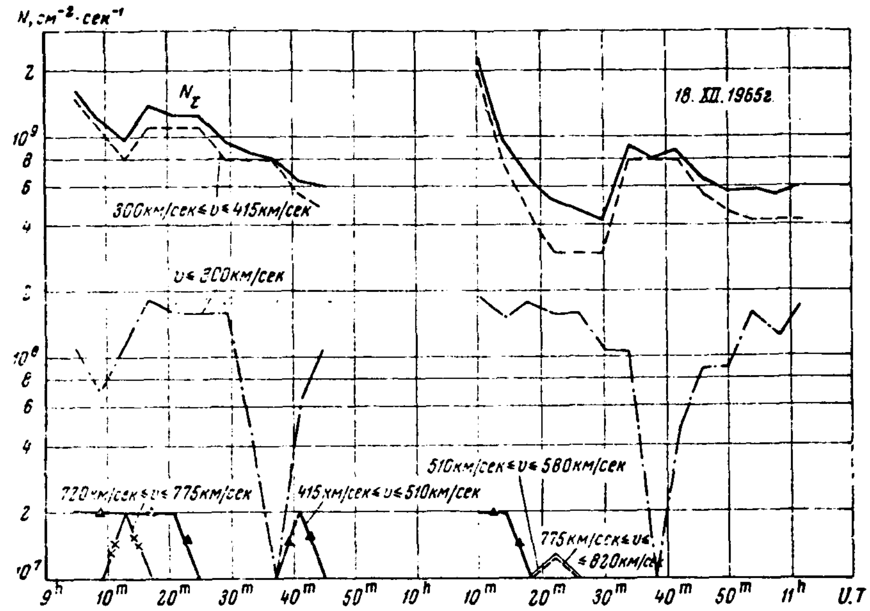

Fig.5

As may be seen from Fig.5, the main component of the flux has velocities in the range from 300 to 415 km/sec. Spacecraft Venera-3 was then located at the distance $R \approx 10 \cdot 10^6$ km from the Earth. The difference in the distances from Sun to Earth and from Sun to spacecraft constituted $\sim 9 \cdot 10^6$ km. Consequently, assuming the radial flow velocity of solar wind as being $v_{av} = 360$ km/s (and also that the solar wind parameters do not vary within the comparatively small central angle spacecraft-Sun-Earth, see Fig.2), we may consider that the solar wind fluxes, characterized by the measured spectra, reached the Earth's magnetosphere approximately ~ 7 hours after encountering the spacecraft (i. e., in a period $\sim$ 1600 $\div$ 1800 hours UT).

From Fig.6 (next page), where the planetary three-hour K_p-indices are brought out for the period from 15 to 20 December 1965 [6] it may be seen that for the said period the day of 18 December was the most magneto-perturbed. The parts of the magnetograms, taken down on 18 December 1965 on one of the high-latitude observatories (Barroy) and on one of mid-latitudes, are brought out in Fig.7. Here H is the horizontal component of the geomagnetic field, Z is the vertical component and D is the geomagnetic declination. The index 0 denotes the base value of each component, from which the variations of the corresponding field component are counted. When comparing these magnetograms one should bear in mind that the scales of the graphs are different: to the unit of length along the ordinate axis on the Odessa magnetogram correspond significantly smaller values Z, D and H than on Barrow magnetograms (the ratios corresponding to multiplying factors are as follows: $S_{Zb}/S_{Zo} = 19$, $S_{Hb}/S_{Ho} = 19$, $S_{D\,b}/S_{Do} = 27$)*. The magnetograms were obtained in the B-2 World Data Center, Moscow.

* b stands for Barrow; o stands for Odessa.

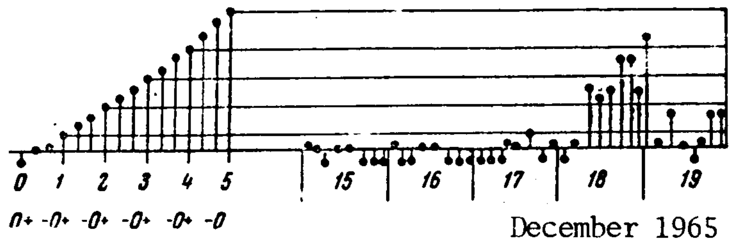

Fig.6

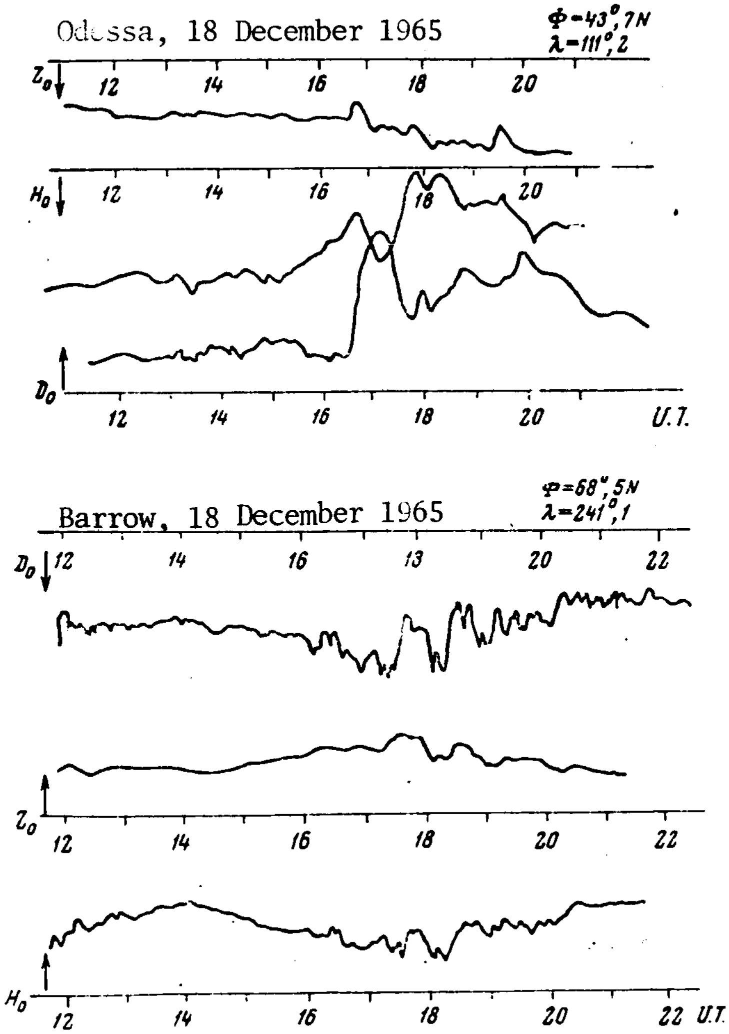

Figure 7

It may be seen from Fig.7 that in the period 1600 — 1800 hours UT, which, as already mentioned, corresponds to about the approach to Earth of solar plasma with characteristics measured on Venera-3 at 1000 — 1200 h.UT, the most intense variations of the geomagnetic field components for 18 Dec. were observed on Earth. We may see from Fig.5 that basic component velocity of solar wind's ion flux was all the time in a single interval

$$300 \text{ km/sec} < v < 415 \text{ km/sec},$$

while the value of the flux N_Σ varied substantially from $2 \cdot 10^9$ to $4 \cdot 10^8 \text{cm}^{-2}\text{s}^{-1}$.

Just as in earlier observations of solar plasma fluxes [1, 7], $K_p \approx 5$ corresponds to a flux of ions $N_\Sigma \simeq 10^9 \text{ cm}^{-2} \cdot \text{sec}^{-1}$.

It may be seen from Fig.6 that the 24-hour periods of 16 and 19 December 1965 were significantly more magnetoquiet than 18 December 1965. Spectra and in Fig.3 constitute specimens of the spectra obtained in these days, and the fluxes N are substantially lesser in these days than on 18 December.

It should be remarkes, at the same time, that cases were registered, when to comparatively high values of N_Σ ($\sim 4 \cdot 10^8 \text{ cm}^{-2} \text{ sec}^{-1}$) corresponded for the very same velocities of ions as on 18 December 1965, minor geomagnetic disturbances. The date of 29 December 1965 could serve as an example of such a case (spectra г, д and e in Fig.3), when the indexes $K_p \leqslant 1_+$.

Apparently, such examples speak in favor of considerations put forth by Walters [8], who noted that there no physical foundations to expect a direct correlation between any one parameter of the structure of unperturbed solar wind and the geomagnetic disturbances, for prior to acting upon the magnetosphere, solar wind must cross the shock wave front, after which its characteristics change substantially. Apparently, a significant influence on the geoeffectiveness of solar wind flux may be exerted by the orientation of the interplanetary magnetic field vector near the Earth's magnetosphere. As was shown by Ness and Wilcox [9], this orientation may vary periodically.

CONCLUSION. During radiocommunication sessions with spacecraft VENERA-3 measurements took place of energu spectra of ion fluxes of solar wind with energies E < 3600 ev, using the modulation type ion trap.

The fluxes of solar plasma were registered for all switching of the device; the ion fluxes measured between 16 December 1965 and 7 January 1966 lie within the limits

$$1.5 \cdot 10^8 \text{ cm}^{-2} \cdot \text{sec}^{-1} < N_\Sigma \quad 2 \cdot 10^9 \text{ cm}^{2} \cdot \text{sec}^{-1}$$

and the velocities of spectrum's main components usually did not exceed 510 km/sec.

Sugnificant and close in value ion fluxes wree rather often observed in different energy intervals. At the same time, the determination of the magnitude of directed velocity of solar wind is difficult; it is possible that such spectra correspond to penetration of a more rapid plasma flux into one that flows more slowly.

Although very large fluxes of ions ($N_{\Sigma} \sim 10^9$ $cm^{-2} \cdot sec^{-1}$) correspond most often to increased values of K_p-indices (as indicated in earlier publications) a direct correlation between any one parameter of the unperturbed solar wind and the geomagnetic disturbances is apparently absent.

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**** THE END ****

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