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K.I. Gringauz, M.I. Verigin, T.K. Breus,
L.A. Shvachunova

ON THE PREVAILING IONIZATION SOURCE IN THE MAIN IONIZATION PEAK OF VENUS NIGHT-SIDE IONOSPHERE

117810 Москва, ГСП-7, Профсоюзная 84/32

Телетайп: 111325 ПАРСЕК

Москва

Introduction

The problem of the nature of ionization sources maintaining the Venus night-side ionosphere, that has been recently actively discussed [1-5], rather clear up now, the relative contribution of various sources is still under consideration. This occurred as a result of analysis of charged particle measurements on-board the Venera-9, Venera-10 and Pioneer-Venus Orbiter (PVO). The authors of plasma experiment on Venera-9,10 paying their attention on the fact that the electron fluxes with the energy of several tens of electronvolts were reliably recorded deep in the planet optical umbra at 1500 to 2000 km altitude, have suggested that these fluxes do create the main ionization peak of the ionosphere in planetary night-side [6, 7]. The calculations of electron impact ionization of Venus atmosphere by Gringauz et al., 1976 [8, 9] and revealed the correlation between ionizing electron fluxes j_e and electron peak density $n_{e\,max}$ of nightside ionosphere electron density profile $n_e(h)$, allowed Gringauz et al. [10, 11] to conclude that the electron fluxes with the energy of several tens ev are responsible for the formation of the main (upper) ionization peak.

As it was shown in [12, 13] the assumption of [8-11] that the ionizing electrons penetrate up to the altitude of main ionization peak at $h_{max} \approx 140$ km and the conclusion of [10, 11] that the real value of neutral particles density n_n at this altitude is $\approx 2 \cdot 10^9$ cm^{-3}, i.e. ≈ 30 times less than n_n value according to the Venus nightside upper atmosphere models existed at that time [14, 15], were confirmed by the PVO direct measurements of ionizing electron fluxes [16] and neutral gas [17] in the nightside ionosphere.

The measurements of ionospheric plasma with the aid of PVO Ion Mass Spectrometer [18] led to a suggestion of one more ionization source in the Venus nightside atmosphere. According to this suggestion the O^+ ions transport from the planetary dayside ionosphere and their subsequent downward diffusion to the lower nightsight atmosphere are responsible for the formation of O_2^+ ions (prevailing in the main (upper) peak of ionization) as a result of the following ion-molecular reaction: $O^+ + CO_2 \rightarrow O_2^+ + CO$ [18]. Therefore in a number of papers [12, 13, 18-24] was discussed the question - which of the abovementioned ionization sources is responsible for the upper night ionospheric peak formation. It should be born in mind that in the extremely variable Venus nightside ionosphere [19, 25] other ionization sources should also exist and for explanation of a sporadic lower ionization peak ($h \approx 120$ km) can be used for example the energetic ion fluxes from the plasma sheet [12, 13] revealed by Venera-9, 10 in the Venus magnetic tail, or may be, the energetic electron fluxes [19] and so on.

A straightforward unumbigous solution of the problem of main ionization source in the Venus nightside ionosphere, based on the existing experimental data only, does not seem to be possible despite of the large amount and apparent completeness of the PVO measurements. The considerations of results of charged and neutral particle measurements on-board PVO and on-board Venera-9,10 published till 1980 allowed to Gringauz et al. [12, 13] and **Shunk** and Nagy [24] to conclude that main

$n_e(h)$-peak in the Venus nightside ionosphere can be formed by electron impact ionization and that the contribution of O^+-ions transported from the dayside ionosphere may be essential only in the formation of upper part of the $n_e(h)$-profile (higher than altitude of main peak).

On the other side, Spenner, Knudsen et al. [26] using new results of ion and electron ionosphere measurements by the PVO Retarding Potential Analyzer (ORPA) [23, 26] concluded that ionization and its variability near h_{max} is mainly responsible the O^+-ions transported from the dayside, whereas superthermal electrons provide only relatively stable ionization "background" at these altitudes.

Since, in Spenner et al. paper [26] the description of properties of ionizing electron fluxes is not correct, and conclusions made from comparison of results of the thermal ion density measurements and of the superthermal electron measurements also seem to be not correct, let us return again to the problem of the origin of main ionization peak in the night ionosphere at Venus.

On the variability of ionizing electron fluxes

Analyzing the variations of superthermal electron fluxes measured by ORPA at altitudes $\gtrsim$ 180 km Spenner et al. [26] claim that they are stable within a factor of 2. This suggests that the superthermal electrons cannot be the main source of the nightside variable upper ionization peak and their role is reduced to the formation of stable "background" of $n_e(h)$-profile [26] . To confirm a relative stability of the ionizing electron fluxes Spenner et al. [26] used partly published in [11] results of electron spectra measurements above the Venus nightside on-board the Venera-9,10 satellites. It is easy to show that actually the measurements of plasma electron component in the Venus optical umbra onboard the Venera-9,10 revealed the opposite i.e. the high variability of the electron fluxes.

The wide-angle ($\pm 40^{\circ}$) retarding potential analyzers (RPA) were used to measure electron energy spectra onboard Venera-9,10.

In the case of Venera-9,10 analyzing grid was of a spherical shape; 16 values of retarding potential were used which were subsequently changed every 10 seconds (with total cycle of measurements 160 sec); the collector current I_e was measured every second; the total range of variation of retarding potential was 0-300 v. By use of I_e values, angular characteristics of RPA and by use of supposition that electron distribution function is isotropic, the values of omnidirectional electron fluxes were determined. One must bear in mind, that the normal to the RPA aperture was oriented in the antisolar direction and measurements under consideration were made in the deep optical umbra of the Venus; so the electron fluxes measured were directed to the planet. On the Fig. 1 all values of I_e for four values of retarding potential U_R (U_R = 20,40,80 and 150 v) averaged by 10 second-intervals are given in the altitude range 1200-2000 km at the distances $\gtrsim$ 1000 km from the boundary of the optical umbra. These measurements were made in October-December 1975, and usually not more than 3-4 retardation curves (electron spectra) could be obtained during each satellite pass (2 days) in the abovementioned region of optical umbra.

As one can see from Fig. 1, for all U_R values spread of measured I_e -values and j_e ($E_e \gtrsim e V_T$) values is $\approx$ 2 orders of magnitude during the whole period of measurements. So, the

Venera-9,10 measurements of plasma electron component do not confirm conclusion of Spenner et al. [26] on the relative stability of electron fluxes behind the Venus. Even among the nine electron spectra presented earlier in [11] (and measured by Venera-9,10 practically simultaneously with the radio occultation $n_e(h)$-profiles) there are two spectra with electron fluxes differing from the mean values by factor more than 2 [26, 28]

The abovementioned variability of electron fluxes behind the Venus (Fig. 1) reflects mainly their pass to pass variation. During one pass through the region of the optical umbra under consideration the electron fluxes as a rule varied essentially less and the increase of I_e by factor 50 was observed once - on November 7, 1975 [28] . The samples of Venera-9, 10 electron spectra, measured on various passes through the optical umbra are shown in Fig. 2. The vertical bars in this Figure are the limits of electron fluxes variations during 10 sec for the fixed value of U_R . These electron spectra are quite similar in shape but different one from another by number fluxes up to two orders of magnitude. Presented on Fig. 2 spectra were measured by Venera-9, 10 in 1300 to 1900 km height interval. In paper of Spenner et al. [26] it was mentioned that according to the ORPA data aboard PVO the shape of electron spectra at lower altitudes (200 to 1000 km) is similar and the electron fluxes value is independent on altitude. The similarity of electron spectra measured from Venera-9, 10 and from PVO is an evidence that the electron fluxes of several tens of electrons volts above the nightside of Venus in the entire altitude range from 200 to 2000 km are of the same origin.

Then the value of ionizing electron fluxes in the Venus nightside ionosphere should also vary in the wide range. This is not in agreement with the conclusion repeatedly emphasized by Spenner et al. [26] that variations of the suprathermal electron fluxes in the nightside ionosphere usually do not exceed a factor 2. The reasons of this difference are not quite clear since in [26] it is not described in what way factor 2 was obtained and there is no information on the extremal values electron fluxes observed in the nightside ionosphere; it is not clear how the data were choson for analyze of the electron fluxes variability. A simple comparison of electron fluxes with $E_e > 45$ ev in the vicinity of $h \approx 300$ km measured in the nightside ionosphere at 60 and 56 PVO orbits presented at Fig. 3 and 4 of [26] , shows that j_e value differed more than by one order of magnitude on both cases. Since it is difficult to assume that ORPA recorded extremal electron fluxes at two these orbits, the conclusion that the electron fluxes in the nightside ionosphere are stable [26] seems to be groundless.

The variability of ionizing electron fluxes, obtained from the RPA measurements of plasma electron component onboard Venera-9, 10 above the nightside of the planet (Fig. 1,2) corresponds to n_e variability in the main peak of the nightside ionosphere as observed by radio occultation experiments [19, 25] and cannot be a reason to reject the electron fluxes as the main ionization source in the vicinity of h_{max}.

On the correlation of suprathermal electron fluxes and ion density in the ionosphere

The second argument of Spenner et al. [26] in favor of O^+-ions transported from the dayside of Venus as the main ionization source in the nightside ionosphere, is based on the comparison of the measurements of ion density n_i and suprathermal electron fluxes along the PVO orbit. Whereas the suprathermal electron fluxes were relatively stable, n_i varied within significantly greater limits and variations of both values where not correlated. This argument also can be criticized both from metodical and physical viewpoints.

Indeed, Spenner et al. [26] compared n_i and j_e values (see Fig. 3-5 in paper [26]) which were not measured directly but were determined from the retardation curves measured by ORPA. In determination of n_i the measured current voltage characteristic was approximated by the analytical expression dependent on ion component parameters of the ionospheric plasma [29] . In nightside ionosphere of Venus, where essential and irregular variations of plasma ion component were observed, this method can lead to the unstability of the ion density estimations, i.e. variations of n_i values estimated could exceed the real variations of this parameter. On the other hand, in the determination of j_e from the retardation characteristic it was assumed $dj_e / dU_T \geqslant 0$, that leads to smoothing of electron fluxes variations [26] . So, on the base of data presented in [26] it is difficult to judje on relative variability of j_e and n_i . Note that n_i value was determined from PVO with ≈ 3 times better spatial resolution than j_e value (see Figures 3-5 in [26]) that also can bring to impression of greater n_i variability due to possibility to register small scale variations of this parameter.

From the physical point of view even a methodically unreprouchable comparison of the relative j_e and n_i variations and lack of correlation both values at the heights above 180 km in the Venus nightside ionosphere does not supply useful information on the predominant ionization source in the vicinity h_{max} . Indeed, the comparison of local satellite measurements of j_e

and n_i can be reasonable only at the smaller heights, where the condition of local chemical equilibrium is fulfilled. Above 180 km the $n_e(h)$-profile could be defined by unlocal diffusive and/or convective processes. Under the chemical equilibrium when the suprathermal electrons provide the main ionization peak $n_i \sim \sqrt{j_e \cdot n_n}$. As n_n is often and irregular vari~~able in~~ the nightside atmosphere [30], the more significant variation of n_i as compared with j_e variations can be observed (dependent on the amplitude and "phase" of n_n variations) and variations of both values can be uncorrelated. In this case lack of correlation between local j_e and n_i values and different variability of these parameters at the higher ionospheric heights shouldn't be considered as an argument against the electron impact ionization source in the main nightside ionosphere peak.

In general, a search of correlation of any parameters necessitate elimination of all experimentally uncontrolled factors as far as possible. For example, if Spenner et al. [26] compared their j_e measurements with n_i values at h_{max} altitude (not along the orbit) it would be possible to ignore n_n variations. Indeed, at variable h_{max} altitude the n_n variations should be significantly less as compared to those at any fixed altitude since $n_n(h_{max})$ is determined only by the neutral atmosphere scale height and the cross-sections of electron-neutral ionizing collisions [8, 9]. This comparison is quite similar to that between $n_{e\,max}$ calculated from the electron spectra measured by RPA onboard Venera-9, 10 and $n_{e\,max}$ values by the radiooccultation experiment as proposed by Gringauz et al. [10, 11]. As a result the correlation of both values was revealed. This method, however, also has disadvantages due to the fact that the electron spectra and radio-occultation data were obtained non-simultaneously and at different regions. This circumstance is possibly responsible for comparatively low (coefficient correlation $\simeq 0.6$) though positive correlation of measured and calculated values of $n_{e\,max}$ [10,11].

On comparison between model calculations and experimental data

Comparison between calculated $n_i(h)$ profiles of some ion components in the Venus nightside ionosphere and satellite information on these ion component is a quite complicated problem now, since calculations include a number of uncontrolled parameters of the nightside neutral atmosphere and of the ionization source. The eventually calculated $n_i(h)$-profiles are also compared not with the concrete measurements of $n_i(h)$ above the certain region of Venus at the certain moment of time but with the data on n_i distributed along the satellite orbit, i.e. spreaded in time, and above planetary nightside.

Thus, not every difference between the results of model calculations and experimental data permit one to make conclusions on the nature of physical processes responsible for the nightside ionosphere formation. The differences inevitably imply the restriction of the model as well as the uncertainty of initial data. So, in comparison of model calculations and experimental data we can surely compare now only qualitative peculiarities of calculated and "measured" $n_i(h)$-profiles (the most independent on the model used and its parameters) and only those differences should considered to be essential which cannot be eliminated by any permittable variations of the model.

Let us consider from this viewpoint the results of the comparison of experimental data with model calculations made by Spenner et al. [26] under assumptions that only the fluxes of suprathermal electrons or only O^+ ions downward diffusion are responsible for formation the night ionosphere. In both cases the calculated profiles are compared with the "smoothed mean" profiles of $n_{O^+}(h)$ and $n_{O_2^+}(h)$ whereas for specific orbits the number densities of ions might differ from the "mean" ones by more than the order of magnitude ([18] , see also Figs 3 to 5 in [26]) due to the night ionosphere variability. Taking into account the additional variability of the night neutral atmosphere [30] and of the fluxes of ionizing electrons (see above Figs 1, 2) the factor 2 difference of the "mean" density of O_2^+ in the vicinity of h_{max} from that estimated under an assumption that ions O_2^+ are produced due to electron impact ionization is not essential. It can be also noted that the intensity of an electron source of ionization used by Spenner et al. [26] is underestimated by about factor 2 (according to the estimates of these authors) due to neglection of electrons with energy > 70 eV contribution to the ionization of neutrals.

On the other hand, the formal coincidence of O_2^+-density with the value estimated under an assumption that ions O^+ transported from the Venus' dayside are the sources of O_2^+-ions is not euristic. In this case the value of the downward diffusive flux of O^+-ions $j_{O^+} \approx 10^8$ cm^{-2}s^{-1} which has not been measured directly in the experiment influence on model calculations as an upper boundary condition. The estimates of j_{O^+} are based on measurements of the horizontal transport of O^+-ions made near the terminator of the planet for its small part [23] .

The suggestion that the horizontal fluxes of O^+-ions are homogeneous over the whole terminator and the sufficiently indeterminate and variable thickness of the layer where they are flowing, and the suggestion that the essential part of transported O^+-ions will diffuse just downwards over the Venus' nightside make the estimations of j_{O^+} value true at least by an order of magnitude if ever true. Hence, based on the comparison of $n_{O_2^+}$ in the vicinity of h_{max} with the results of calculations it is impossible to give preference to O^+-ions transport from the Venus' dayside against the electron impact ionization as a main source of ionization at these heights.

It should be also noted that not within the whole range of heights the results of model calculations by Spenner et al. [26] made under both assumptions are in agreement with the profiles of $n_{O^+}(h)$ and $n_{O_2^+}(h)$ presented in the same paper [26] . At higher altitudes ($\gtrsim$180 km) the O^+ density calculated under the assumption that suprathermal electrons are the only source of ionization is too small as compared with the "smoothed mean" profile of $n_{O^+}(h)$ [26] . However, in the case when the O^+-ions downwards diffusion is the only source of ionization the O_2^+ density estimated for the same heights differs also at least by an order of magnitude from the smoothed profile of $n_{O_2^+}(h)$ (see Fig. 11 of [26] though this paper affirms ~~that in this~~ case both profiles of $n_{O^+}(h)$ and $n_{O_2^+}(h)$ are reproduced). Taking into account that the model of the variable night atmosphere used in calculations and the profiles of $n_{O_2^+}(h)$ and $n_{O^+}(h)$ of the variable ionosphere with which the results of calculations have been compared both were not obtained for any certain data it is difficult to make a definite conclusion on reasons of these differences. From our point of view the most possible reason of these disagreements of calculations with experimental data is the inadequacy of the mathematical model to the conditions of the Venus' night ionosphere at high altitudes that might be connected with dynamical processes being neglected and the role of diffusion overestimated at these altitudes.

The above consideration shows that the straightforward quantitative approach to the comparison of model results of the Venus' night atmosphere ionization with experimental data at present does not lead to proper results. Hence, to solve the problem on prevailing ionization source in the vicinity of h_{max} it seems to be necessary to reveal qualitative differences of $n_{O^+}(h)$ and $n_{O_2^+}(h)$ profiles in the cases when the only source of ionization is the fluxes of either superthermal electrons or O^+-ions diffusing downwards. If O^+-ions are diffusing downwards through the Venus' nightside atmosphere the diffusive flux of j_{O^+} remains to be practically constant (and the number density of O^+ is smoothly changes) up to heights where (due to the carbon dioxide density increase) O^+-ions begin to disappear in ion-molecular reaction: $O^+ + CO_2 \rightarrow O_2^+ + CO$. At this level j_{O^+} and n_{O^+} decrease sharply at distances of an order of carbon dioxide scale height - $H_{CO_2} \approx 3$ to 4 km. This ion-molecular reaction is in this case the only source of O_2^+-ions and, hence, the rate of their production and the O_2^+ number density both are maximum at decreasing part of the $n_{O^+}(h)$-profile. Therefore, in the case when the diffusion of O^+ is the only source of O_2^+-ions in the main peak of ionization the distance between maxima of $n_{O^+}(h)$ and $n_{O_2^+}(h)$-profiles is defined by the CO_2 scale height and is about of $H_{CO_2} \approx 3$-4 km.

In the case when the fluxes of suprathermal electrons are the prevailing source of O_2^+-ions in the vicinity of h_{max}, heights of the maxima of $n_{O^+}(h)$ - and $n_{O_2^+}(h)$-profiles are not tied so rigidly since they are defined in general by different physical processes. The O_2^+ number density reaches its maximum at heights where the probability of superthermal electrons ionizing collisions becomes close to unity. At these heights the conditions of a local chemical equilibrium are satisfied that lead to the unlimited growth of O^+ with increasing a height. However, when h is increasing diffusion processes become predominant and the O^+ peak is formed where characteristic time of diffusion and chemical processes are compared. Therefore, in case of the electron impact source of ionization the distance between the maxima of $n_{O^+}(h)$ and $n_{O_2^+}(h)$ can be significantly greater then the CO_2 scale height.

On the $n_{O^+}(h)$-profile presented on Fig. 9 of [26], based on ORPA measurements in the Venus' night ionosphere the O^+ number density peak is located at ≈ 165 km. The $n_{O_2^+}(h)$ profile peak h_{max} height was completed taking into account the radio-occultation data according to which h_{max} height in the nightside ionosphere is approximately equal to ≈ 142 km [19]. Thus, the distance between the maxima of $n_{O^+}(h)$- and $n_{O_2^+}(h)$-profiles is ≈ 23 km, i.e. essentially greater than $H_{CO_2} \approx 3$ to 4 km, and might not be explained within the framework of the concepts on downward diffusion of O^+-ions as the basic source of ionization near h_{max}. The model calculations of Spenner et al. [26] also show that the distance between the peaks of $n_{O^+}(h)$- and $n_{O_2^+}(h)$-profiles estimated within the frames of this concept does not exceed 10 km (see Fig. 12 of [26]), i.e. significantly less than the same distance according to measurements in the Venus' night ionosphere.

Since the distance between the maxima of $n_{O^+}(h)$- and $n_{O_2^+}(h)$-profiles is of obvious importance for solving the question on the prevailing source of ionization in the vicinity of h_{max} it seems to be necessary to estimate this distance and the limits of its variations using as full as possible the set of experimental data obtained onboard Pioneer-Venus. Any reliable information about a h_{max}-height for specific orbits can be obtained only by the radio occultation method since during the Pioneer-Venus experiments the pericentre altitude lower than ≈145 km over the planetary nightside was only in case of about 8 orbits [31] . Several $n_{O^+}(h)$-profiles of the Venus' nightside ionosphere were published in [18, 21] based on the data of measurements by a radio-frequency ion mass-spectrometer. According to measurements of this device, made at "established" 59th orbit of PVO, $n_{O^+}(h)$-profile has its maximum at 160 km. The number density of O^+ measured on 65th orbit [21] reaches also its maximum values approximately at the same height. These results also indicate that the distance between, h_{max} and $n_{O^+}(h)$-maximum exceeds significantly scale height for CO_2. But this conclusion might be considered as tentative. If the further thorough analysis, that certainly can be done only by the authors of the PVO plasma experiments, will show confidence of this result, the question on the prevailing source of ionization in the main peak of the Venus' night ionosphere can be considered as solved in favor of ionization by the fluxes of suprathermal electrons.

Discussion and conclusions

As follows from the consideration of this paper the attempt made by Spenner et al. [26] based on additional experimental data to suggest more specific arguments in favor of transport of O^+-ions from the day side as prevailing source in the Venus' night ionosphere peak by use of new experimental data leads rather to the opposite conclusion, that of in [26] . Without considering again methodical errors of Spenner et al. [26] let us now sum up all the facts that are known about both sources of ionization suggested for explaining the formation of the main ionization peak.

The electron fluxes with energy of several tens of electronvolt were recorded over the Venus' nightside by three independent instruments: by wide-angle retarding potential analyzer onboard the Venera-9, -10 satellites at altitudes of $\gtrsim$1200 km Gringauz et al.[6-13] and directly in the planetary ionosphere by the electrostatic analyzer Intrilligator et al. [16] and the ORPA Spenner et al., 1981 [26] on board the PVO. In all three experiments rather similar fluxes were measured; the altitude dependence of their intensity has not been found [26] . Hence, one can consider as reliably established the fact that the fluxes of suprathermal electrons produce some ionization of the Venus' night atmosphere since the existence in atmosphere of electrons with energy much higher than the ionization potential of neutrals must lead to their ionization.

The fact that O^+-ions transport from the dayside of the planet is the source of ionization in the night ionosphere has been established less reliably. The transport of such ions through the terminator possibly exists (Knudsen, Spenner et al., [23]), however, the further destiny of O^+-ions and the value of their diffusion flux just downwards to the dense layers of the night atmosphere is mostly hypothetic.

The value of the ionizing electron fluxes is sufficient to form a $n_e(h)$ profile with $n_{e\,max}$ of the order of $10^4 cm^{-3}$ [8-13, 16, 26] in the night ionosphere. The Venera-9, -10 data on the electron fluxes revealed their variability (see Figs 1, 2) that rather well correspond to the variability of the Venus' night ionosphere, and the correlation of the intensity of this ionization source with the results of radio-occultation measurements of $n_{e\,max}$ (Gringauz et al., [10, 11]). All this provides an evidence that suprathermal electrons could be the basic source of the Venus' night ionosphere ionization peak. There are not similar evidences in favor of the fact that O^+-ions transported from the day side of the planet can be such a main source.

Moreover, the previous sections showed that if the diffusion flux of O^+-ions downwards determines the formation of the main O_2^+-peak of the night ionosphere the distance between maxima of $n_{O_2^+}(h)$- and $n_{O^+}(h)$-profiles must not be large and equal, by the order of magnitude, to the carbon dioxide scale height $H_{CO_2} \approx 3$ to 4 km. The published experimental data show that in the night ionosphere the distance between peaks of $n_{O_2^+}(h)$- and $n_{O^+}(h)$-profiles seems to be much larger and approximately equal to 20 km [18, 21, 26] (this conclusion requires the further experimental confirmation). In such a case the formation of the main ionization peak can not be explained by O^+-ions diffusion, and the suprathermal electrons fluxes remains to be the only real pretender to the role of the prevailing source of ionization in the vicinity of the main peak. The conclusion on the presence of the local chemical equilibrium at this heights (F_1-layer) is the natural consequence of the prevailing role of the electron source of ionization in the vicinity of h_{max} ; then the transition to the diffusive equilibrium will occur at heights of $n_{O^+}(h)$-profile peak (F_2-layer).

Of course, the electron impact ionization is not the only source of ions in the Venus' night ionosphere. To explain the lower peak it is necessary to use other sources of ionization some of which has been already mentioned in Introduction. It is more difficult to explain all features in the distribution of the ion number-density in the night ionosphere at heights above the $n_{O^+}(h)$-profile peak. Here, when characteristic times for establishing the equilibrium state of the ionosphere is increasing the nonstationary processes and the convective transport as well begin probably more essential role. The contribution of O^+-ions transport from the dayside of the planet to the formation of the night ionosphere can also be probably essential at these altitudes as it was reported earlier in [12, 13, 24] .

Figure captions

Fig. 1 Values of the collector current electron retarding potential-analyzer I_e and the omnidirectional flux of electrons J_e with energy $\gtrsim eU_T$ averaged over 10 sec are shown for four values of retarding potential U_R. All the Venera-9 and -10 measurements are given made in the Venus' optical umbra at distances $\gtrsim 1000$ km from the umbra edge at altitudes $\lesssim 2000$ km over the planetary surface.

Fig. 2 Examples of electron spectra measured in the Venus' optical umbra by the wide-angle electron analyzer on board the Venera-9 satellite on 7.11.75, 5^h25^mUT(a). 1.II.75, 4^h27^m UT (c), 29.11.75, 9^h00^m UT (e) and on board the Venera-10 satellite on 22.II.75, 22^h43^mUT(b) 24.II.75, 23^h59^m UT(d).

Measurements were made for the following values of the Sun's zenith angle χ and the height h : 141°, 1300 km (a); 144°, 1900 km (b); 140°, 1300 km (c); 148°, 1300 km (d); 160°, 1400 km(e).

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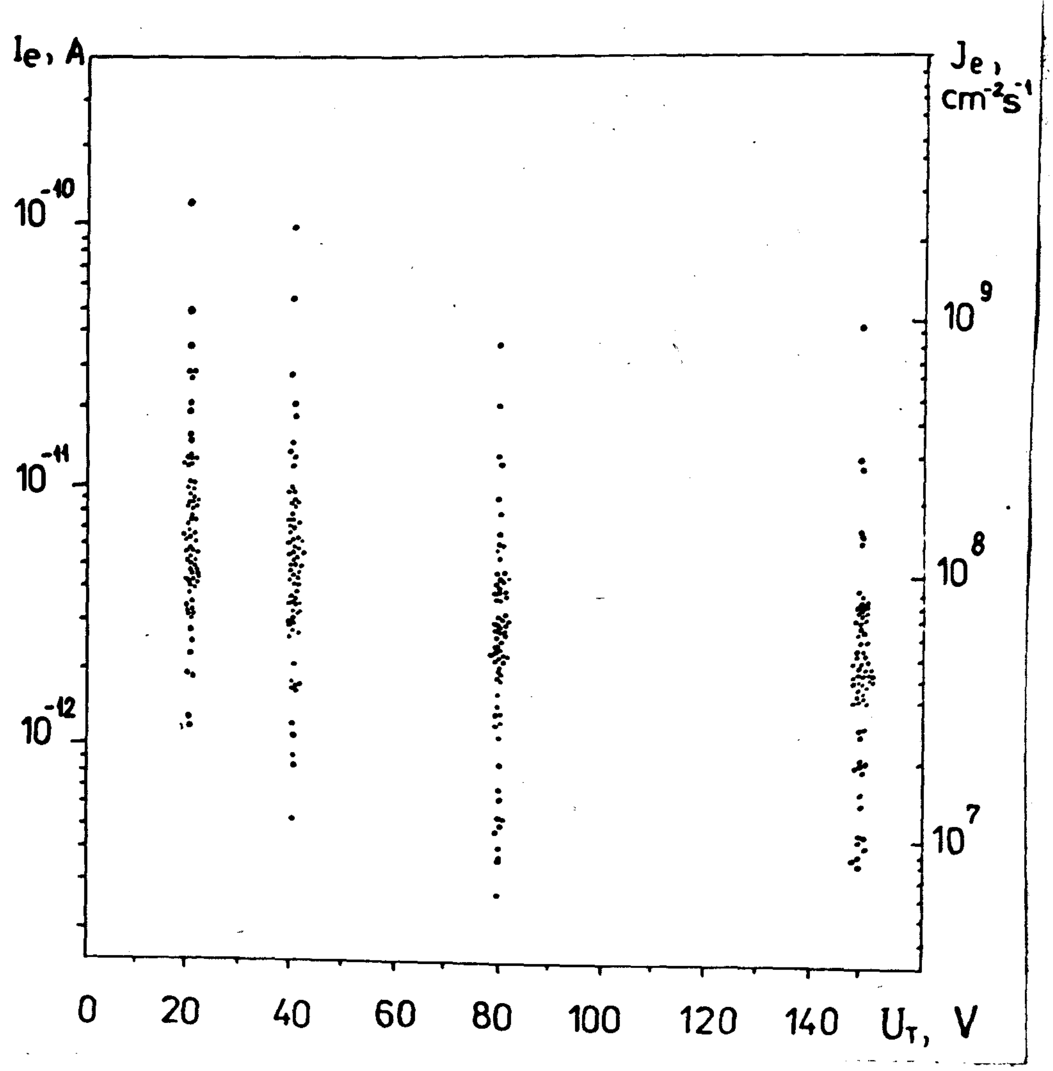
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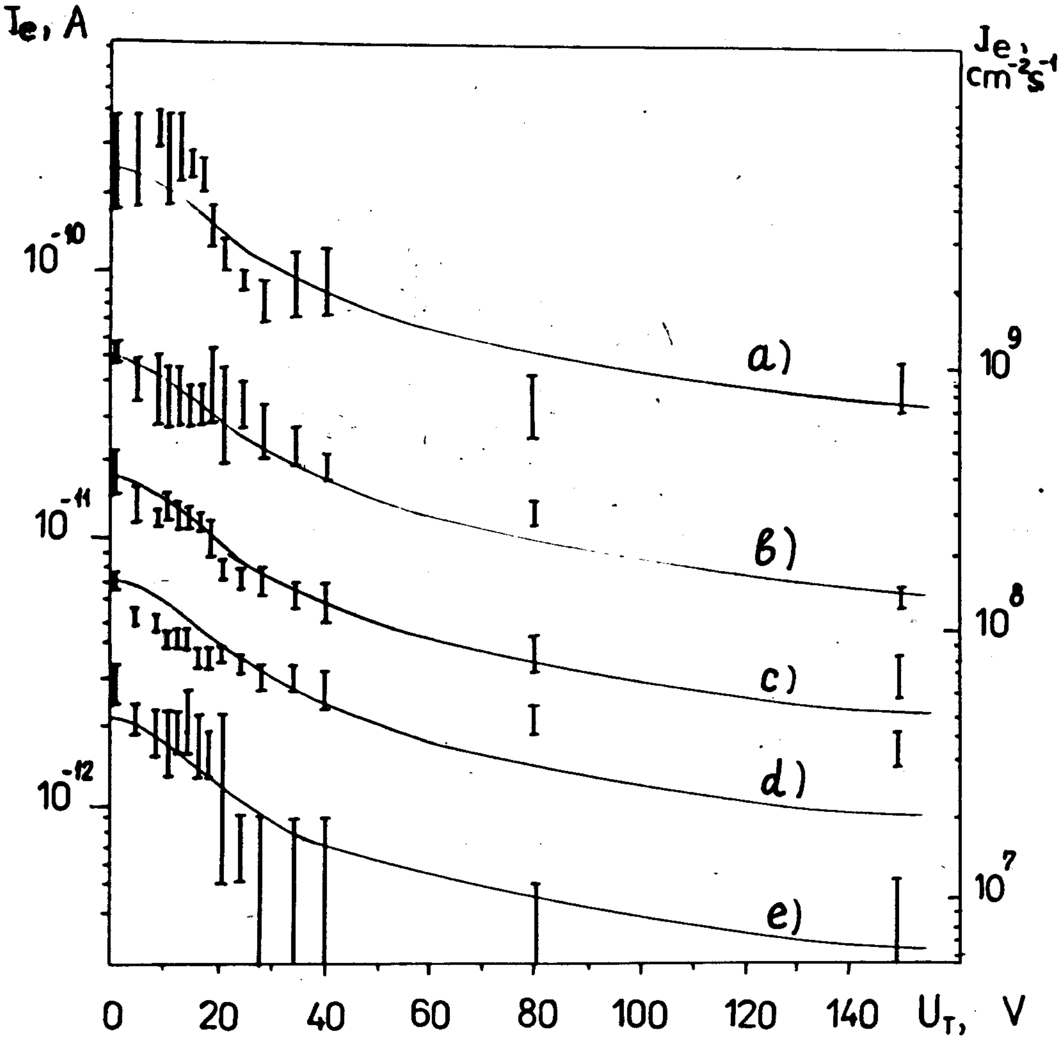
UT, V

Fig. 1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10⁸
10⁷
a)
б)
c)
d)
e)
0
20
40
60
80
100
120
140
U_T, V

Fig. 2