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SPACE RESEARCH INSTITUTE

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THE INTERACTION OF THE SOLAR WIND ELECTRONS IN THE OPTICAL UMBRA OF VENUS WITH THE PLANETARY ATMOSPHERE- THE ORIGIN OF THE NIGHTTIME IONOSPHERE

To be presented to Symposium on Solar
Wind Interaction with Venus (SIV 3) IAGA Assembly,
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I. Introduction

The information now available about the nighttime ionosphere of Venus has been obtained from single observations of Mariner-5 [1] and Mariner 10 [2] spacecraft radio occultations and from multiple observations of the same kind, made by satellites Venera-9 and Venera-10 [3,4] . The observational results demonstrate considerable variability of Venus' nightside ionosphere, i.e. height distributions of electron concentrations $n_e(h)$ have one or sometimes two maxima at heights of about 120 to 140 km. Usually (though not always) electron number density in the upper maximum exceeds n_e in the lower.

It is rather difficult to interpret how Venus' nightside ionosphere forms, the details of its structure and its variability. Possible sources of ionization in the Venus nighttime ionosphere have been discussed, they are solar wind proton fluxes turbulized behind the near-Venus bow shock that partially penetrate the nightside atmosphere of the planet; cosmic rays; scattered solar radiation L_α , CO_2 charge exchange with He^+ - ions transported from the dayside ionosphere, meteoric ionization [1, 5 to 7] . All the hypotheses mentioned have not either interpreted satisfactory n_e-values observed or (and) have not used as a basis direct experimental data about ionization sources.

Direct measurements of an electron plasma component made on Venera-9 and 10 satellites in the optical umbra of Venus at altitudes of about 1500-2000 km revealed that intense electron fluxes exist there, with energies exceeding several tens of electron-volts [9-11]. Electrons with such energies, when colliding with neutrals in the nighttime atmosphere of the planet, can ionize them and, therefore, can be one of the sources producing the nighttime ionosphere of the planet. As was shown in [11] , the electron number-fluxes detected $j_{ec} \sim 10^8 cm^{-2}s^{-1}$ are sufficient to produce a nighttime ionosphere with an maximum electron number density $n_{em} \sim 10^4 cm^{-3}$ which coincides with the data of radio-occultation experiments [1 to 4] .

The present paper shows that in the nighttime ionosphere n_{em} - value obtained by radio occultaion methode obviously depends on the intensity of electron fluxes with the above mentioned energies, measured above 1500 to 2000 km. It implies that such electron fluxes reach ionospheric altitudes and do play an essential part for nighttime ionosphere formation.

Below is given the procedure used for calculating profiles of electron concentration $n_e(h)$ in the nighttime ionosphere from the measurements of electron fluxes in the optical umbra of Venus; electron density values n^c_{em} in the calculated profile maximum are compared with the data from radio occultation measurements n_{em} .

Calculations of $n_e(h)$-profiles were made in this paper under the assumptions somewhat different from those used in [11] and in some aspects they describe the process of ionization more accurately.

These calculations and comparison of the $n_e(h)$ profiles thus calculated with experimental will be given after a brief description of the procedure and basic results of the Venera-9 and Venera-10 radio occultation measurements. Part of the preliminary data of these measurements was published [3,4] and part of them was kindly supplied to us by M.Kolcsov, N.Savitch and their colleagues.

II. Summary of the procedure and basic results of radio occultation experiments of Venus' satellites

During the flight of Venera-9 and Venera-10 satellites multiple dual-frequency radio occultation of the nighttime ionosphere of the planet was carried out. Measurements were made during 19 radio occultation sessions from October 24 to December 7, 1975 [3,4] .

During these sessions the satellite transmitter was sending to the Earth two coherent monochromatic signals in L (λ_1 =32 cm) and S (λ_2 =8 cm) - RF regions. The ground-based center received the signals, digital computers were used for measuring their frequencies, and analog computers for measuring their reduced phase difference $\Psi = (\lambda_1/\lambda_2)\varphi_1 - \varphi_2$. Fig.1 from [4] shows examples of raw data on $\Psi(t)$. The entire variation of Ψ from the recording of the ionosphere effect and until the given time (t), is proportional to the integrated electron concentration $N_e(t)$ along the radio path in the ionosphere of the planet. As Fig.1a shows during the October 28, 1975 session, $\Psi(t)$ (and therefore $N_e(t)$) had one distinct maximum and during the November 2, 1975 session two distinct time spaced maxima. Hence the solution of an inverse problem will obviously result in $n_e(h)$-profiles having on these days one and two maxima, respectively. $\Psi(t)$ -value recording on November 4, 1975 (Fig.1) radically differs from the first two recordings by the width of its upper maximum. The recordings mentioned illustrate considerable variability of Venus' night-time ionosphere.

The electron concentration profile $n_e(h)$ in the ionosphere was calculated by solving the inverse problem under the assumption of spherically symmetric ionosphere and with refraction neglected. To reduce the effect of plasma, present along the radio-path, on $n_e(h)$ determination the mean variation of the reduced phase difference over the path portion where the ionosphere did not effect the measurements was extrapolated to the subsequent path portion. This was done during a period equal to that of radio occultation, then these mean variations were subtracted from the measuremental results. Preliminary ballistic data were used provide heights for measuremental results; possible height shift for $n_e(h)$ profiles obtained can be ±10 km [4] . The Venus radius was taken as 6050 km for calculations. R.m.s. errors of n_e-values calculated were determined at heights where the ionosphere still has no effect, they were 90 to 250 cm^{-3} from session to session [3] .

Fig.2 from [4] shows $n_e(h)$ profiles calculated for three sessions, their $\Psi(t)$ recordings are given in Fig.1.

All $n_e(h)$ profiles obtained during 19 sessions can be provisionally subdivided into two major groups: with two (13 profiles, e.g. Fig.2b) or with one (3 profiles, e.g. Fig.2a) distinct n_e maxima. Electron concentration values in the upper maximum, n_{em} $(3$ to $16)\cdot10^3 cm^{-3}$ are usually higher than those in the lower maximum $(2$ to $11)\cdot10^3 cm^{-3}$ which is shifted relative to the upper by 17 to 24 km.

Between the maxima n_e are 3 to 10 times lower than within them and not more than (1 to 3)$\cdot 10^3 cm^{-3}$. The characteristic height of the upper maximum is about 137 km. If a profile has one maximum the latter is usually at the height characteristic to the upper maximum of two-maxima profiles. Emphasis should be given to the profiles with narrow upper maxima (4 to 6 km) and several narrow maxima with n_e (5 to 7)$\cdot 10^3 cm^{-3}$, those were received on November 4 (Fig.2c) and 5, 1975. The narrow layers seems to be similar to sporadic formations typical for the E_s-region of the Earth's ionosphere. A typical feature of the Venusian nighttime ionosphere is its small extent from 30 to 50 km in different sessions.

Thus multiple radio occultation measurements in the nighttime ionosphere of Venus made on-board Venera-9 and Venera-10 satellites have yielded phenomenological classification of height profiles $n_e(h)$ over the nightside of the planet. In the context of this information it has become obvious that different results of radio occultation experiments obtained by American Mariner-5 [1] and Mariner-10 [2] vehicles are also the evidence to the considerable variability of nighttime ionosphere parameters.

III. Calculations of an electron concentration profile

Ion production rate in the ionosphere, due to electron fluxes measured in the optical umbra of Venus, was calculated under the assumption of a flat and one-component nighttime atmosphere of Venus consisting of neutral CO_2 molecules concentration $n_e(h)$ of which near a height of h_o (approximately equal to that of electron concentration maximum h_m) can be written as follows:

$$n_n(h) = n_{no} \cdot \exp(-(h-h_o)/H_o), \qquad (1)$$

where n_{no} and H_o, are the concentration and scale height of neutrals at height h_o respectively. This approximation can be justified since CO_2 is the maior component of the atmosphere at ionospheric heights [12] . Contrary to [11] , where only CO_2 ionization by electrons with an ionization cross-section independent of their energy E was regarded as a dominant non-elastic process, while ionization by electrons already subject to one non-elastic collision was not taken into account, over present calculations take into account the loss of energy by ionizing electrons due to excitation and ionization, as well as ionization produced by these electrons in repeated non-elastic collisions. Energy dependences of cross-sections of various excitation processes $\sigma_i(E)$ and differential cross-sections $S_i(E,T)$ of ionization by a primary electron with energy E, which produces a secondary electron with energy T were taken in parametric terms according to [13] . Besides it was assumed in our calculations that the velocity of the primary electron did not alter its direction in elastic and inelastic collisions. The calculations in [11] were made for another extreme case i.e. isotropic angular distribution of electrons after a collision.

Calculations for two extreme cases of angular distribution of electrons after their collisions with neutrals in the atmosphere, carried out in this paper and in [11] were made due to the fact that experimental data about angular distribution of electrons after a collisions at different E, are scarce.

How the assumptions different from those in [11] effect the calculational results is discussed in Sect.V of this paper.

Since we have assumed that the velocity direction of electrons does not alter in collisions and the energy an electron loses during elastic collision event is very low ($\leq (4m/M)E \approx 5 \cdot 10^{-5} E$ [14] where m is the electron mass, M is the CO_2 molecule mass), in the approximation considered elastic collisions can be neglected. In this case variations in the electron distribution function $f(E, \vartheta, h)$ over a layer dh thickness can t written as follows:

$$\frac{d f(E,\vartheta,h)}{dh} = \frac{n_n(h)}{\cos\vartheta}\Big\{ f(E,\vartheta,h)\Big[\sum_i \sigma_i(E) + \sum_i \int_0^{(E-I_i)/2} S_i(E,T)\,dT\Big] - \sum_i f(E+W_i,\vartheta,h)(1+W_i/E)\,\sigma_i(E+W_i) - \sum_i \int_0^{E} f(E+I_i+T,\vartheta,h)(1+(I_i+T)/E)\,S_i(E+I_i+T,T)\,dT \Big\} \quad (2)$$

where ϑ - is the angle at which an ionizing electron enters the atmosphere, W_i is the mean energy lost by the electron in the i^{th} excitation process and I_i - is the threshold energy of the i^{th} ionization process (from Tables in [13]).

The first and the second terms in (2) describe the decrease of the number of electrons with energy E due to losses of electrons energy in excitation and ionization acts; the third and the fourth terms describe the increase of the number of electrons with energy E due to the influx of electrons which initially had higher energies and lost energy W_i as a result of excitation and energy (I_i+T) because of ionization. In the equation (2) we neglected the electrons with energy E, produced by ionization and consequently the additional ionization they produced.

The equation (2) integrated with use of computer. As an initial condition an isotropic dist:ibution was assumed consisting of two groups of electrons with concentrations and temperatures n_1, T_1 and n_2, T_2, respectively:

$$f(E,\vartheta,h)_{h\to\infty} = (m/2\pi K)^{3/2}\left[n_1 T_1^{-3/2}\exp(-E/KT_1) + n_2 T_2^{-3/2}\exp(-E/KT_2)\right], \quad (3)$$

The equation (2) illustrates that f should be known at height h up to energies equal to max $(E+W_i, 2E+I_1)$ to determine the values f with E energy at height $h-dh$. Hence at high energies the initial condition (3) was replaced by the following condition:

$$f(E,\vartheta,h)_{h\to\infty} = 0, \quad E > E_{max}. \quad (4)$$

The calculations were done under the assumption that $E_{max}=300$ ev (the measurements of electron plasma component on Venera-9 and Venera-10 were carried out with retarding potential $U_R \leq 300$ V of the electron analyzer and, thus, the ionization of the Venus atmosphere by electrons with energy > 300 ev was also neglected.

After the determination of $f(E,\vartheta,h)$ at height h the rate of ion production at this height, q(h), was calculated by the formula:

$$q(h) = 4\pi n_n(h)/m^2 \int_0^\infty E\left[\sum_i \sigma_i(E) P_{i\,auto} + \sum_i \int_0^{(E-I_i)/2} S_i(E,T)\,dT\right] \int_0^{\pi/2} f(E,\vartheta,h) \sin\vartheta\, d\vartheta\, dE \quad (5)$$

where P_i auto is the efficiency of autoionization in the i^{th} process of excitation (see [9]). The concentration of ionosphere electrons, as in [4] , was assessed from the condition of local equilibrium of ion production and recombination: $q - \alpha n_e^2 = 0$, thus

$$n_e(h) = \sqrt{q(h)/\alpha}, \quad (6)$$

where α is the coefficient of CO_2^+ dissociative recombination with electrons was considered to be equal to $3.8\cdot10^{-7}$ cm^{3}sec^{-1} [15] and its electron energy dependence was not taken into account.

IV. Comparison of electron concentration in nighttime ionosphere calculated from electron fluxes measured in the Venus umbra with data of radio occultation measurements

In Fig.3 in $X, \sqrt{Y^2+Z^2}$ coordinates (x-axis passes trough the Venus center and is directed to the Sun) the circumplanetary section of the Venera-9 orbit (November 25, 1975) is shown by a full curve, and of Venera-10 (December 3, 1975) is shown by a dash and dot curve. Fig.4 illustrates results of measurements of plasma electron component made at the above mentioned sections of orbits during their deepest penetration in the optical umbra. The corresponding parts of orbits are shown by a thick lines in Fig.3. In Fig.4 the lengths of vertical straight lines demonstrate within which limits currents I_e, recorded by a wide-angle electron analyzer (±40°), oriented in the antisolar direction, varied for 10 seconds with the constant U_R - retarding voltage at analyzing grids of a sensors. In Fig.4 smooth curves give values of I_e, calculated similarly to [16] based on the characteristics of the electron analyzer [17] under the condition that the distribution function of electrons around the satellite is isotropic and can be approximated by the expression (3) with n_1 =0.8 cm^{-3}, T_1 =13 eV , n_2 =0.04 cm^{-3}, T_2 =100 eV is a full curve and with n_1 =3,3 cm^{-3}, T_1 =15 eV , n_2 =0.2 cm^{-3} T_2 =100 eV is a dash-and-dot curve. Fig.4 illustrates that with this approximation of electron distribution function the estimated values of electron currents agree with the measured value of I_e over a wide range of U_R.

Using the above given distribution function parameters (3), according to the methode described in Section III, the electron concentration profiles $n_e(h)$ were calculated; in Fig.5 they are shown by smooth curve; by a dashed curve - for electron measurements on November 25, 1975, and by a dash-and-dot curve with two dots - for measurements on December 3, 1975. The calculation of profiles was carried out with the following values (formula (1)) of parameters of the Venus night-side neutral atmosphere: n_{no}=2.10^{9}cm^{-3}, h_0 =140 km, H_o=5 km. In Fig.5 the full and dash-and-dot broken lines illustrate the profiles $n_e(h)$ from the data of the radio occultation experiment made on November 25 in about 12 minutes and on December 3, in about 18 minutes after the deepest measurement of electron spectra inside the optical umbra.

Fig.5 demonstrates that with chosen atmosphere parameters $n_e(h)$-profiles calculated by the measured electron fluxes are in agreement with radio occultation profiles by the height of electron concentration maximum, by the value of electron concentration in it and by the profile width.

The increase of values $n_e$max (see Fig.4 and Fig.5) determined by radiomethod, coincides with the growth of measured electron fluxes.

Let us make more comprehensive comparison between the n^c_{em} electron concentration in the maximum of estimated profile and the data of radio occultation measurements n_{em} . In Table 1 for the dates, when it was possible to make a comparison there were given the parameters of electron distribution function n_1, T_1, n_2, T_2, determined from electron spectra, measured in the deepest available part of Venus optical umbra, U.T.-time of spectrum measurement, average height h and zenith angle $\chi_\odot$ - of the corresponding satellite orbit section and electron concentration value n^c_{em} in the profile maximum calculated from distribution function parameters given in Table. The Table also demonstrates the values n_{em} in the maximum of radio occultation profiles for the same dates, UT-time of radio occultation observations, χ_R - zenith angle of points of tangency of the planet surface by a radioray.

In Fig.6, n^c_{em} dependence of n_{em} is plotted according to data of Table I. As Fig.6 illustrates, the values of electron concentration n^c_{em} in profile $n_e(h)$ maxima calculated from the electron flux measurements in Venus optical umbra, correlate with the results of radio occultation measurements n_{em}. The correlation coefficient is approximately equal to +0.6, according to data of Table I.

V. Discussion

Thus the above $n_e(h)$-profiles calculations as well as results [11] have shown that the measured in the optical Venus umbra electron fluxes can result in the nighttime ionosphere formation with $n_{em} \sim 10^4 cm^{-3}$ in accordance with the radio occultation measurement [1-4] (see Fig. 5,6 and Table 1).

The correlation of the ionization source intensity (n^c_{em} values) with the n_{em} radio occultation measurements (Fig.6) gives evidence that several tens ev electrons are important ionization source in the nighttime Venus atmosphere and seem to be responsible for the upper maximum in $n_e(h)$-profile at heights ~ 140 km. However, the electrons with energies considered cannot reach the height of the lower maximum of the ionosphere observed by 17÷24 km (i.e. by (3÷5) H_o) lower than upper maximum [3,4] , and other ionization sources should be used for its explanation.

At the same time it follows from the correlation of n_{em}^{c} and n_{em} that as far as the electrons with energies of several tens ev reach maximum altitudes there is no any mechanism that effectively prevents electrons with such energies from penetrating inside the night-side atmosphere. The magnetic field parallel to the Venus surface in a major part of its night-side atmosphere could be such a mechanism. The measurements of the Venus magnetic field at the discussed ionospheric heights were not carried out (at the heights of Venera-9 and Venera-10 flights ($\gtrsim$ 1500 km) the magnetic field behind Venus depends on the interplanetry magnetic field, it stretches towards the Sun [18] and consequently mainly is not parallel to the planet surface); the correlation of n_{em}^{c} and n_{em} indicates that apparently there is no stable magnetic field parallel to the planet surface at height $\lesssim$ 1500 km.

The estimates obtained in [11] and these results given in this paper show that the electrons with energy of several tens of electron-volts interacting with the CO_2 neutral atmosphere will produce an ionization maximum at heights where $n_n \sim 2 \cdot 10^9 cm^{-3}$. This consequence of the ionization source properties makes it possible to estimate the concentration of the night-side neutral atmosphere at the height of ionization maximum ($\sim$ 140 km) also as $\sim 2 \cdot 10^9 cm^{-3}$. In daily averaged models of the Venus atmosphere characterized by the upper atmosphere temperature T_{∞} =450° [12] and T_{∞} =380°K [19] the neutral concentration corresponding this value is located at heights of about 170 and 165 km. However, for example, in [20,21] where the daily variation of the upper atmosphere temperature with the average level of solar activity, is considered the value of T_{∞} varies from about 700 ÷ 800° in the daytime to about 300°K at night. The period of Venera-9 and Venera-10 operation is close to the solar activity minimum (flux of solar radiation with a wavelength of 10.7 cm during the period considered in this paper was within $(70 \div 77) \cdot 10^{-22} wm^{-2} Hz^{-1}$ [22]), therefore it can be assumed that in the Venus atmosphere T_∞ was $< 300°K$. The parameters of the neutral atmosphere in the neighbourhood of $h \sim 140$ km, used in the calculations, can be obtained, for example, h=100 km is taken as a datum level from the model [12] and the calculation (from the barometric formula) of the neutral concentration with $T_\infty \sim 200°K$ for higher altitudes can be carried out.

Some cases given in Table 1 demonstrated the discrepancy between the height of the calculated maximum h_m^c and the radio occultation profile maximum height h_m (on the October 31 $h_m^c - h_m \approx 5$ km, on October 3- and on November 1 $h_m^c - h_m \approx 15$ km). In our opinion this discrepancy has no physical sense and is associated with possible height estimation uncertainty, in radio occultation data, which according to [4] can be $\pm$ 10 km.

The estimates of the Venus night-side atmosphere ionization produced by meteors [7] showed that the intensity of the source considered in effect can be sufficient for producing ionization in the atmosphere with n_{em} also coincident with experimental data. According to these estimates meteoric-ionization maximum is at a height where $n_n \sim 10^{12} \div 10^{13} cm^{-3}$ [7] . As was shown above the electrons with energy of several tens e.v. can produce an ionization maximum a height where $n_n \sim 2 \cdot 10^9 cm^{-3}$ and, concequently, meteors can contribute only to a production of lower n_e maxima.

Let us consider the reasons, which can lead to notcoincidence of values of n_{em} calculated and observed by radio occultation method. It may be caused by time variations of ionization source intensity and by horizontal gradient n_e in the night-side ionosphere. As Table 1 illustrates, times of electron spectrum measurements and radio occultation times differ by 10 to 20 min. The characteristic time for establishment of n_e in the ionosphere $\tau \approx (\alpha\, n_{em})^{-1} \approx 6$ min with $n_{em} \sim 7 \cdot 10^3 cm^{-3}$ and if ionizing electron fluxes vary in the time-interval between plasma and radio occultation measurements, the ionosphere can be considerably changed to the moment of radio occultation. Time variations of plasma concentration along the radio occultation path and possible horizontal gradients in the Venus night time ionosphere can lead to errors of n_e observation by the radio occultation method (see, for example, the review in [23]). On the other hand, the calculated values of n^c_{em} can contain errors due to the fact that the model for the Venus neutral atmosphere was not accurate and atmosphere dynamics was not taken into account.

As it was mentioned in Section III in the calculations of n_e(h)-profiles several assumptions, different from those in [11] were used.

Therefore the effect of different calculation methods on the ionosphere parameter estimations should be investigated. According to [11] , ionosphere parameters of the November 25 and the December 3, 1975 can be assessed. The values of omnidirectional electron fluxes $j_{eo}(E \geq 40$ ev) equal to $0.8 \cdot 10^8 cm^{-2} sec^{-1}$ and $2.4 \cdot 10^8 cm^{-2} sec^{-1}$ correspond to the current values (see Fig.4), recorded by electron analyzer on those days with U_R=40 v, taking into account the analyzer characteristics [17] and under the assumption of electron isotropic distribution function. The equation (9) from [11] makes it possible to estimate height h_m with the night-side atmosphere parameters, used in this paper, as

$h_m \sim 139$ km. In so doing from the equation (11) in [11] the concentration of $n_{em} \sim 6 \cdot 10^3 cm^{-3}$ and 10^4 cm^{-3} respectively on the 25^{th} of November and the 3^d of December, can be obtained; these values differ from the values given in Table I by not more than 20%. The shape of $n_e(h)$-profile calculated by the method of section III, differs from $n_e(h)$ shape in [11] (Chapman layer) by greater width at half height ($3.9H_o$ and $3.6H_o$ respectively) due to slower decay of $n_e(h)$ at height lower than h_m. Slower decay is associated with the fact that ionization produced by electrons during repeated non-elastic collisions at lower height was taken into account. According to the calculations made in this paper the height of ionization maximum h_m is by $(0.2 \div 0.4)H_o$ lower, than h_m, from formula (9) from [11] , it can be qualitatively explained by the neglecting of electron scattering in the present paper.

So the change of a calculation method in the present paper (as compared with [11])slightly effects the ionosphere parameters estimation and the sensitivity of correlation between n^c_{em} and n_{em} to the change of method of calculations is comparatively low.

VI. Conclusions

1. Electron fluxes measured in Venus' umbra are sufficient to produce the nighttime ionosphere with $n_{em} \sim 10^4 cm^{-3}$.

2. The correlation of the electron number-fluxes in the Venus umbra and the data of radio occultation measurements of n_{em} in the nighttime ionosphere is revealed.

3. Electrons with energies of tens of eV are apparently responsible for the upper maximum in the $n_e(h)$ profile in the nighttime ionosphere.

4. Concentration of neutral particles at heights of the upper ionization maximum ($\sim$ 140 km) is $n_n \sim 2 \cdot 10^9 cm^{-3}$.

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Table 1

Symbol	Date	Satellite	Electron measurements								Radio occultations		
			UT	n_1, cm^{-3}	T_1, ev	n_2, cm^{-3}	T_2, ev	$n^e_{em} \cdot 10^{-3}$	h, km	χ_e^o	UT	χ_R^o	$n_{em} \cdot 10^{-3}, cm^{-3}$
♦	10.28.75	Venera-9	03.48	1,4	13	0.09	100	7.2	1700	142	03.59	150	16.0
▼	10.30.75	Venera-9	04.08	-	-	0.6	70	9.4	1600	143	04.18	151	5.3
○	10.31.75	Venera-10	07.05	-	-	0.38	50	7.0	1800	152	07.20	146	7.4
▲	11.01.75	Venera-9	04.26	1.3	17	0.16	100	9.0	1500	143	04.36	152	7.9
●	11.23.75	Venera-9	08.02	-	-	0.07	100	3.3	1300	157	08.13	162	5.4
■	11.25.75	Venera-9	08.21	0.8	13	0.04	100	5.3	1200	158	08.34	165	2.9
△	12.03.75	Venera-10	05.43	3.3	15	0.2	100	11.9	1700	154	06.01	157	15.5
◊	12.05.75	Venera-10	07.08	1.1	9	0.16	100	7.1	1800	155	07.28	159	7.0
□	12.07.75	Venera-10	08.33	0.6	13	0.18	70	6.5	2100	157	08.54	160	8.8*)

*) in the upper maximum

Figure Captions

Fig.1. The examples of primary phase differences data in the radio occultation experiments: a) October,28, b) November, 2 and c) November, 4, 1975.

Fig.2. $n_e(h)$ profiles, calculated from data of the radio occultation experiments: a) October, 28, b) Npvember, 2 and c) November, 4, 1975.

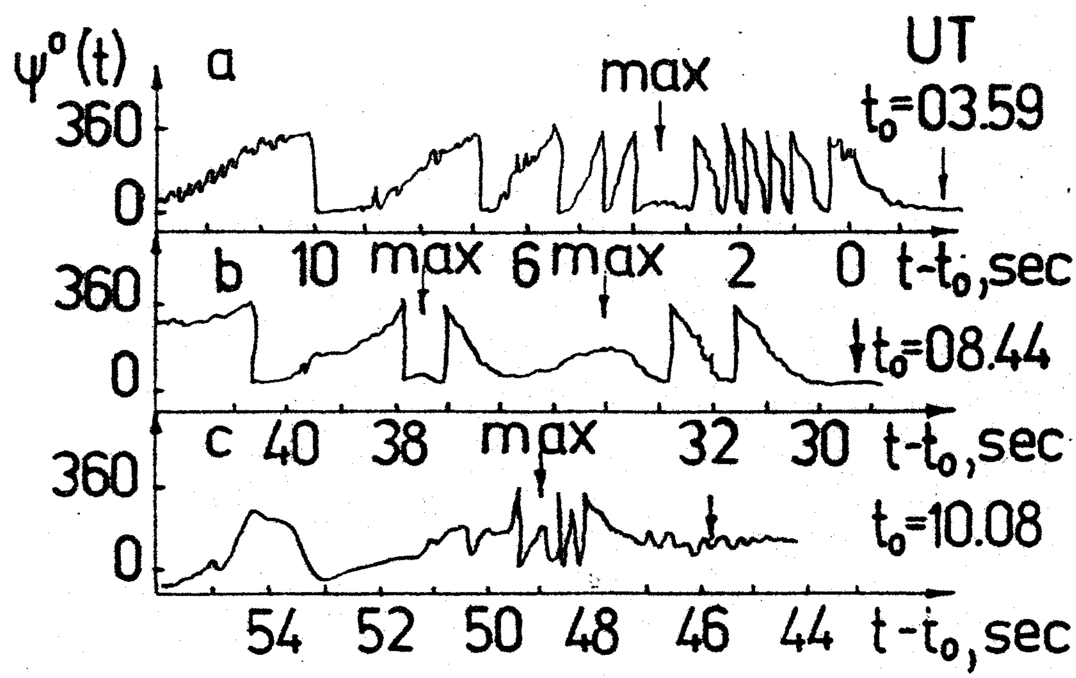
Fig.3. Circumplanetary orbit sections of Venera-9, November, 25, 1975 and Venera-10, December, 3, 1975.

The orbit sections where measurements, given in Fig.4, were carried out, are shown by a thick line.

Fig.4. Currents I_e, recorded by electron analyzers with various values of retarding potential V_R on their analyzing grids, November, 25, and December, 3, 1975.

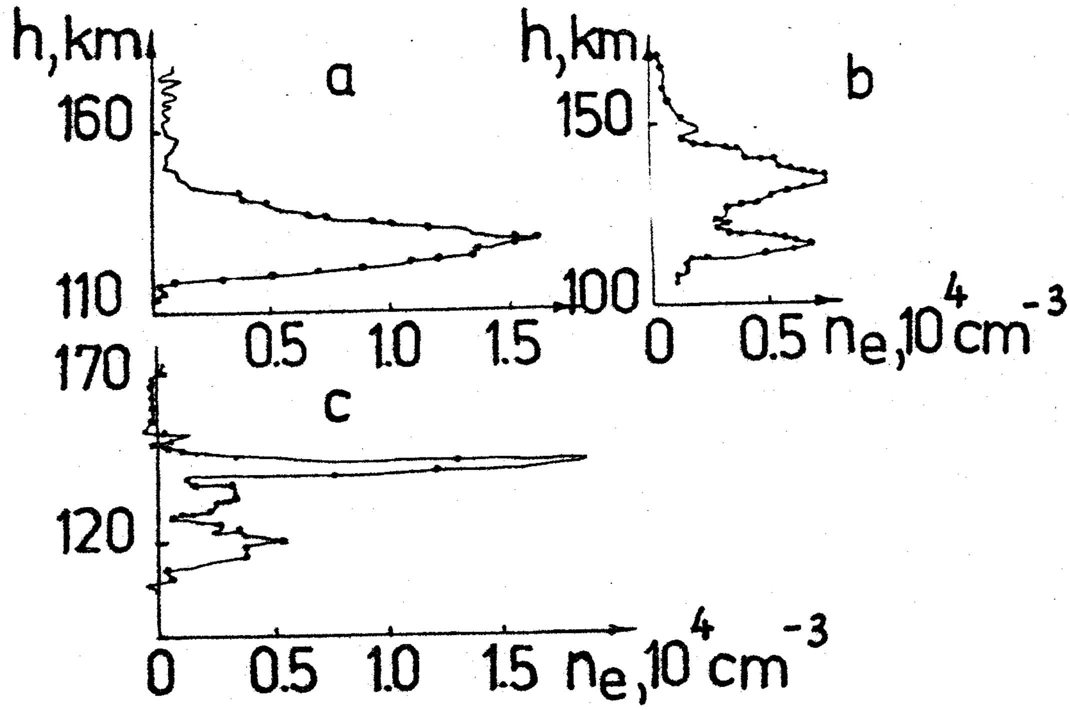
Fig.5. The comparison of $n_e(h)$ profiles, calculated from data of the radio occultation experiment, November, 25 and December, 3, 1975 with the profiles calculated from data (given in Fig.4) of electron flux measurements, – – – November, 25 —··— December, 3, 1975.

Fig.6. The comparison of electron concentration values in $h_e(h)$ profile maxima, $n^{\mathcal{E}}_{em}$ calculated according to the measurements of electron fluxes in the planet umbra with the results of radio occultation measurements of n_{em}.



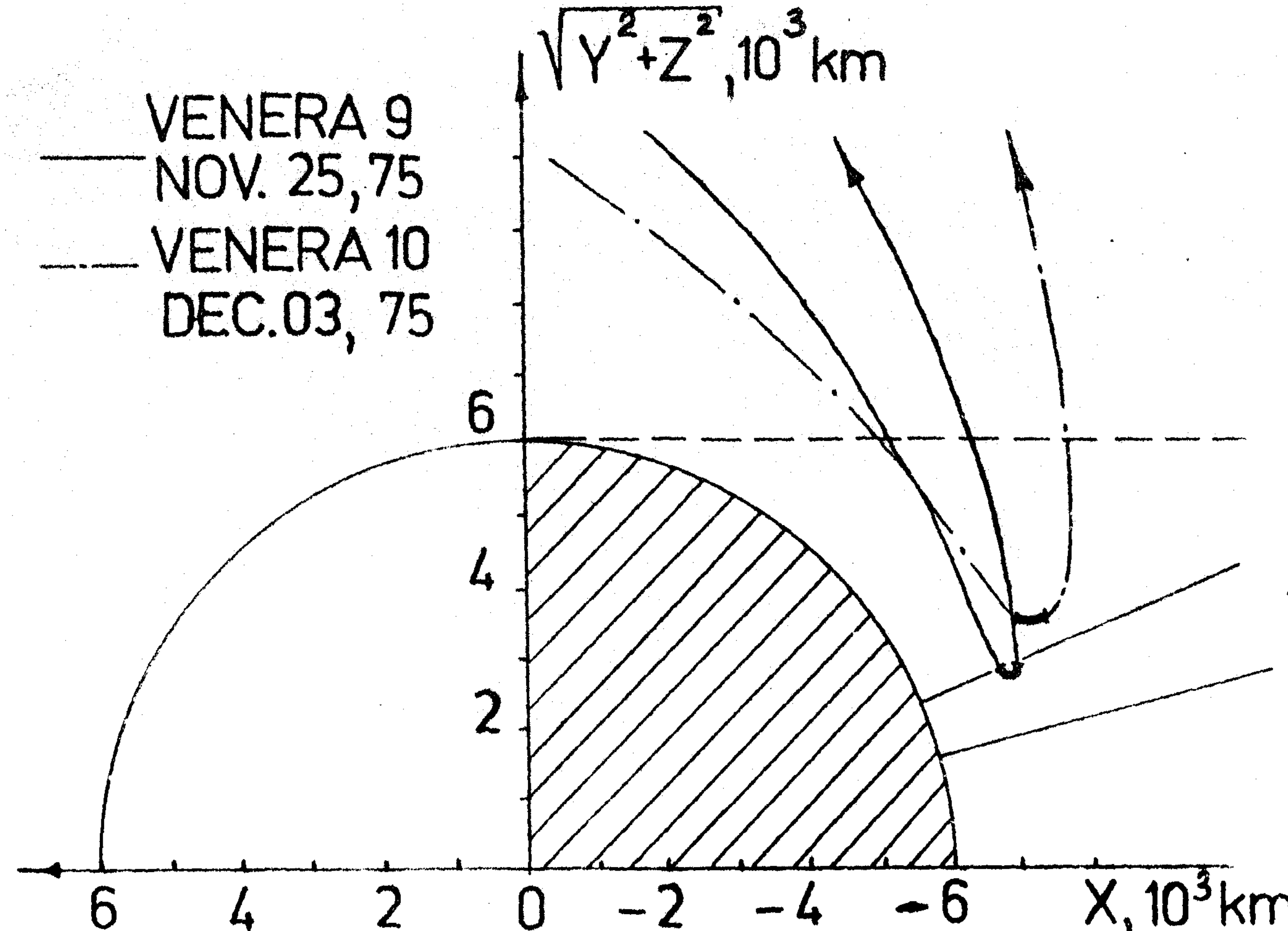
ψ°(t)
a
max
UT
t₀=03.59
360
0
10
max
6
max
2
0
t-t₀,sec
b
360
t₀=08.44
0
c
40
38
max
32
30
t-t₀,sec
360
t₀=10.08
0
54
52
50
48
46
44
t-t₀,sec

Fig.1



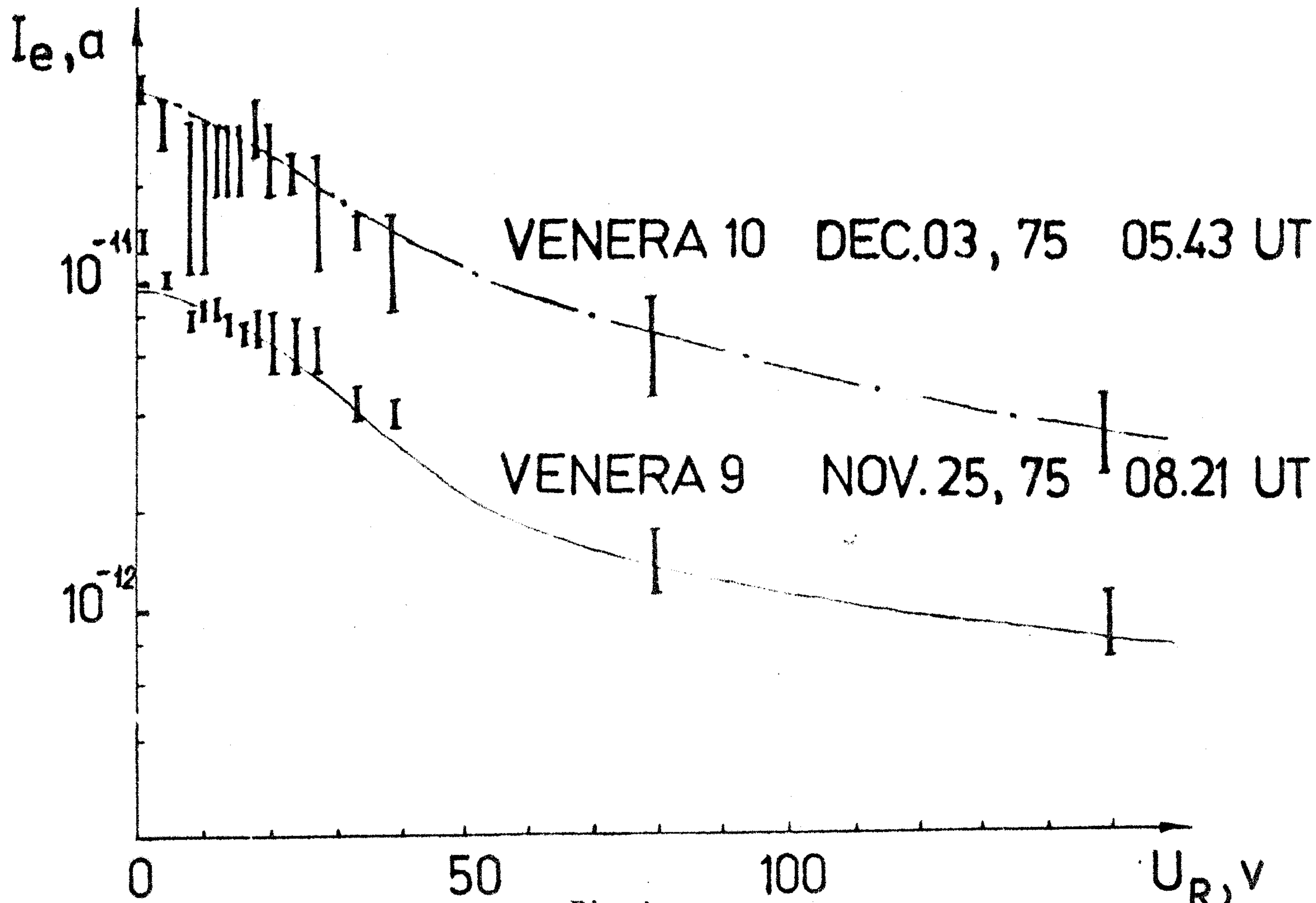
h,km
a
160
110
0.5
1.0
1.5
h,km
b
150
100
0
0.5
n_e,10^4 cm^-3
170
c
120
0
0.5
1.0
1.5
n_e,10^4 cm^-3

Fig.2



$\sqrt{Y^2+Z^2}$, 10^3 km
VENERA 9
NOV. 25, 75
VENERA 10
DEC.03, 75
6
4
2
χ=157°
χ=165°
6
4
2
0
−2
−4
−6
X, 10^3 km

Fig.3



I_e, a
10^{-11}
10^{-12}
VENERA 10 DEC.03, 75 05.43 UT
VENERA 9 NOV. 25, 75 08.21 UT
0
50
100
U_R, v

Fig.4

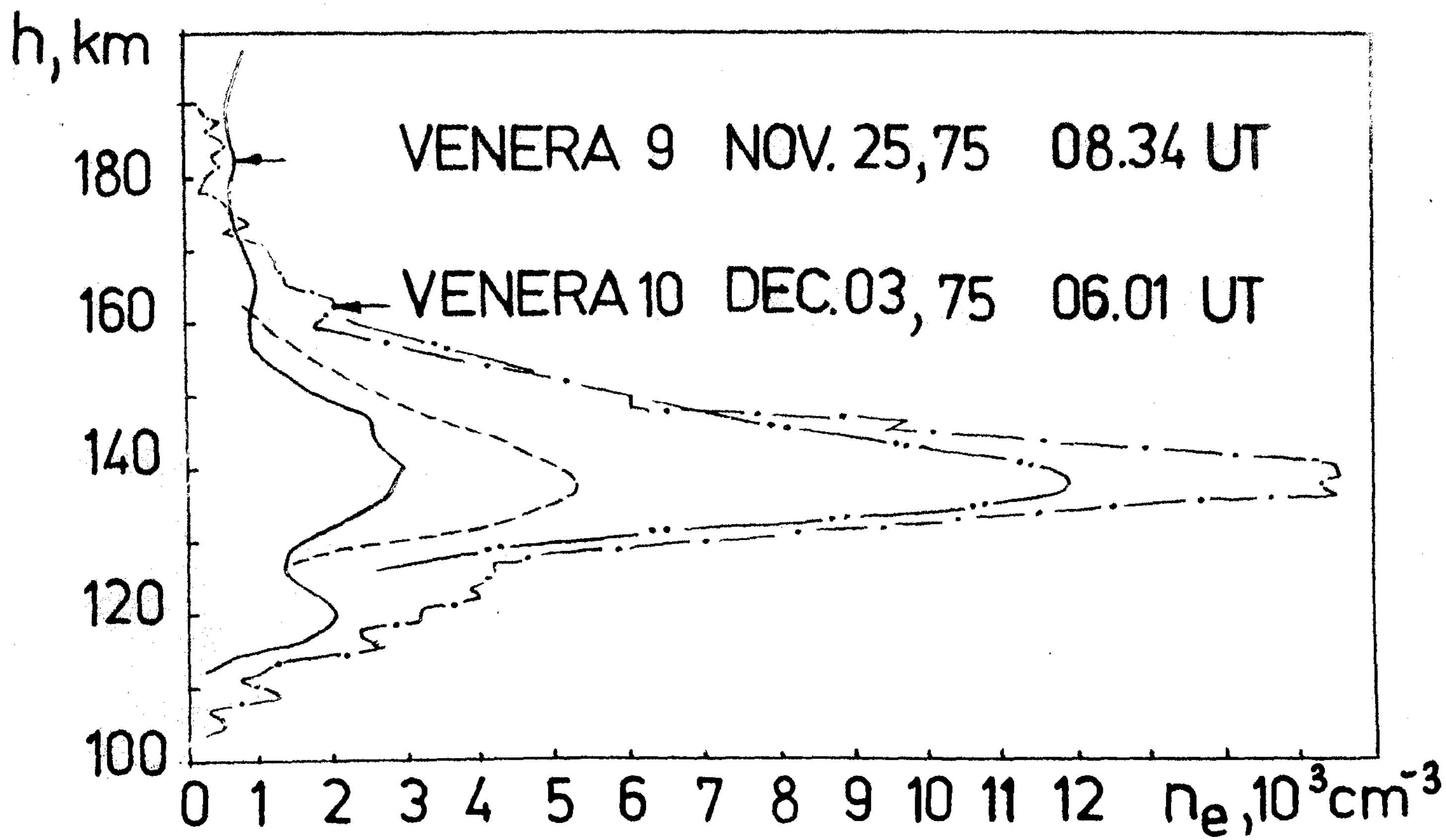
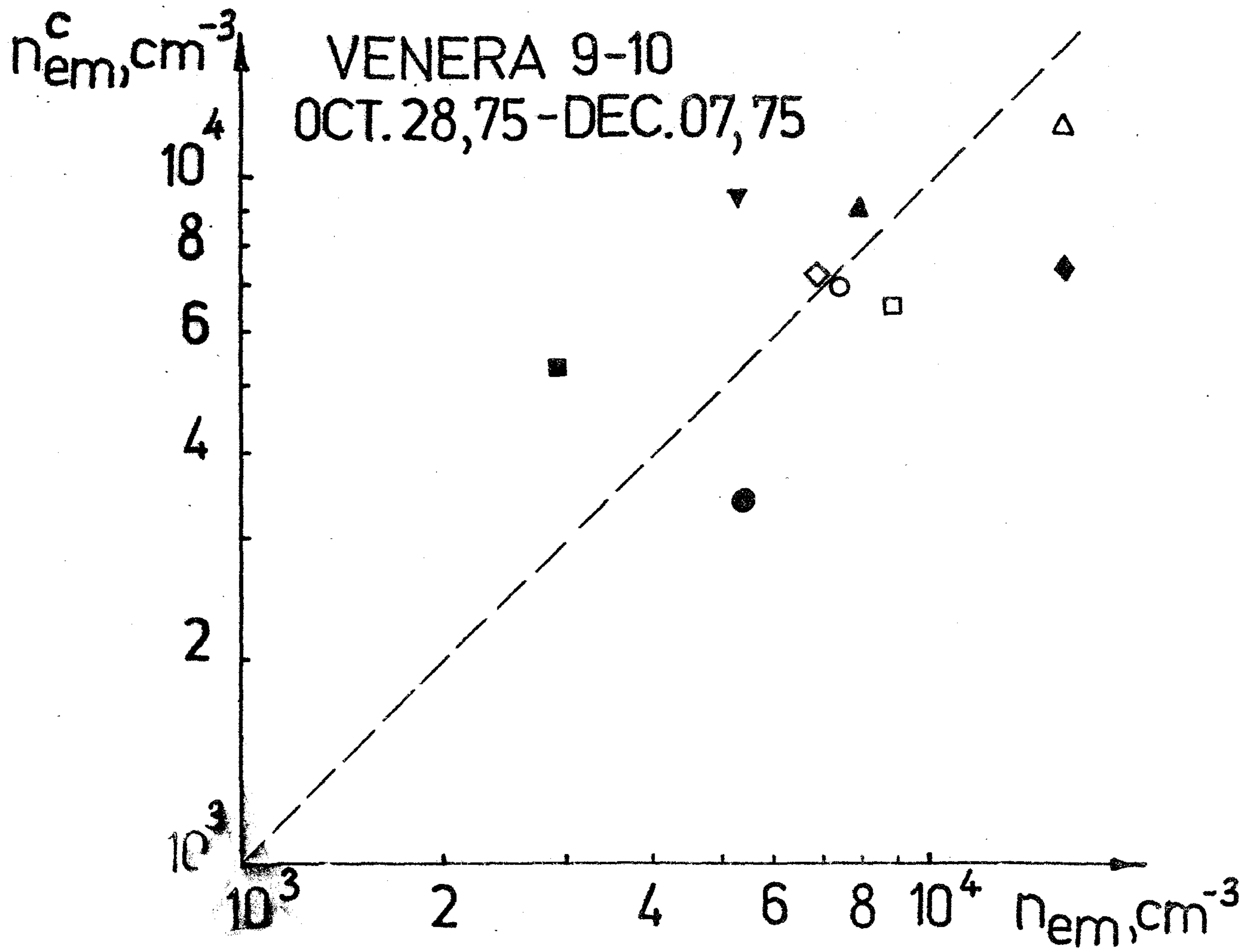

h, km
180
160
140
120
100
VENERA 9 NOV. 25,75 08.34 UT
VENERA 10 DEC.03, 75 06.01 UT
0 1 2 3 4 5 6 7 8 9 10 11 12
$n_e, 10^3 cm^{-3}$

Fig.5



n^c_{em},cm^{-3}
VENERA 9-10
OCT. 28,75 - DEC. 07,75
10^4
8
6
4
2
10^3
10^3
2
4
6
8
10^4
n_{em},cm^{-3}

Fig.6

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