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A TWO-LAYER MODEL OF VENUS' ATMOSPHERE
(Interpretations of Radar Observations)

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(Interpretations of Radar Observations)

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SUMMARY

A two-layer model atmosphere of Venus is considered. It satisfies the data of both the radioastronomic and radar measurements, including the measurements at 3 cm. It shows a considerable decrease of the effective cross-section of Venus' reflection at short wavelengths. The first upper absorbing layer, being "cold", determines the spectrum of its proper radiation, but is transparent for the radiation with wavelength $\lambda > 3$ cm. This is why it does not affect the results of radar observations. The second absorbing layer, being near the planet's surface, and therefore "hot", absorbs the centimeter radiation and determines the frequency dependence of the effective Venus' reflection but does not influence the brightness temperature of the planet, for the temperature of this layer is similar to that of planet's surface.

A surface absorbing layer may be a lower row of clouds, containing $(1 \div 2) \cdot 10^3$ g/cm^2 of dust or about 2 g/cm^2 of polar liquid with equipartition time of $(1 : 2) \cdot 10^{-11}$ sec.

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The results of radar observations of Venus [1] show that the effective reflection cross-section σ_{eff} of the planet is approximately constant within the wave band from 70 to 20 cm, and equal to about 0.15; it decreases significantly in shorter wavelengths (see Fig.1). Such a rapid decrease of $\sigma_{eff}(\lambda)$ is difficult to explain by the frequency dependence of the reflection factor of the lunar surface's material. It is more natural to assume that the observed character of the dependence $\sigma_{eff}(\lambda)$ is conditioned by the absorption of short radiowaves in Venus' atmosphere.

Postulating that the atmosphere of Venus is transparent within the 20 to 70 cm band, and taking into account the dual passage of the radar signal through the planet's atmosphere, we shall obtain that in order to satisfy the experimental radar data in 12.5 and 3.6 cm waves, the optical thickness τ of the atmosphere must be respectively $0.13 \div 0.20$ and 1.4.

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* DVUKHSLOYNAYA MODEL' ATMOSFERY VENERY (Ob interpretatsii radiolokatsionnykh nablyudeniy).

It is well known that the only reliably exposed component of Venus' atmosphere is carbon dioxide [2]. The main component of Venus' atmosphere is unknown. It may possibly be constituted by nitrogen. Neither is excluded the possibility if presence of inert gases, for example, Ar and Ne. At normal pressure CO_2 and N_2 are symmetrical molecules , incapable of interaction with vhf radiation and thus not absorbing the passing radiowaves. However, at higher pressures occurring during collisions of molecules, the deformations create for a short time an induced dipole moment, causing the nonresonsnace absorption of vhf radiation. The absorption coefficient depends on pressure p_0 and frequency ν and is determined by the relation

$$\varkappa = \varkappa_0 \frac{p^2 \nu^2}{(T/273)^n}. \qquad (1)$$

As is well known [1], the available data on Venus' proper radioemission, obtained from radioastronomical observations, agree well with the so called Venus model with "cold" atmosphere. In this model it is assumed that the atmosphere of Venus is colder than the surface and is absorbing in microwave band and transparent in longer wavelengths.

The most correct calculation of Venus model with "cold" atmosphere for the case of induced absorption in carbon dioxide and nitrogen has been completed by Ho, Kaufman and Thaddeus [3]. Having determined from the laboratory experiments, conducted in the 240 – 500°K temperature range at pressures to 130 atm, especially for that aim the parameters n = 5 and

$$\varkappa_0 = (15.7 f^2_{CO_2} + 3.90 f_{CO_2} f_{N_2} + 2.64 f_{CO_2} f_{Ar} + $$
$$+ 0.085 f^2_{N_2} + 1330 f_{H_2O}) \cdot 10^{-8}\ cm^{-1}, \qquad (2)$$

where f_{CO_2}, f_{N_2}, f_{Ar} and f_{H_2O} are respectively the relative content in CO_2, N_2, Ar and water vapors, they reached the conclusion that radioastronomical data on Venus' proper radioemission agree satisfactorily with the calculations at pressures near planet's surface $p_0 = 100 \div 300$ atm. However in the wavelength of 3.6 cm, of particular interest to us, the optical thickness of such an atmosphere constitutes in all $\tau = 0.11$, thus by one order less than that required for the interpretation of data of radar measurements. But the increase of optical thickness to the required magnitude $\tau = 1.5$ cm with pressure increase to $p_0 = 300 \div 1000$ atm leads to the disagreement of such a model with the data of radioastronomical observations.

Another possible absorbing medium in the atmosphere of Venus could be the cloud layer. However, calculations by one of us [4] conducted vor a cold (T = 300°K) cloud layer, satsifying the radioastronomical measurements, have shown that the optical thickness of such a layer constitutes at 3.6 cm wavelength $\tau \simeq 0.1$ and, consequently, such a layer can not explain the data of radioastronomical observations either. The indicated contradiction may be overcome in the atmosphere of Venus with presence of two absorbing layers. The first one, upper layer, being "cold" determines the spectrum of proper radioemission, but does not influence the results of radar measurements, for even in the hhortest possible wave of radar measyrements, i. e., 3.6 cm, the absorption in this layer is quite small. The second absorbing layer, located near the surface of the planet and thus being "hot" absorbs the centimeter radiation and determined the spectrum of the effective cross-section of Venus' radar reflection, but it does not exert any substantial influence on the magnitude of the measured brightness temperature of the planet, for the temperature of this layer is close to that of its surface.

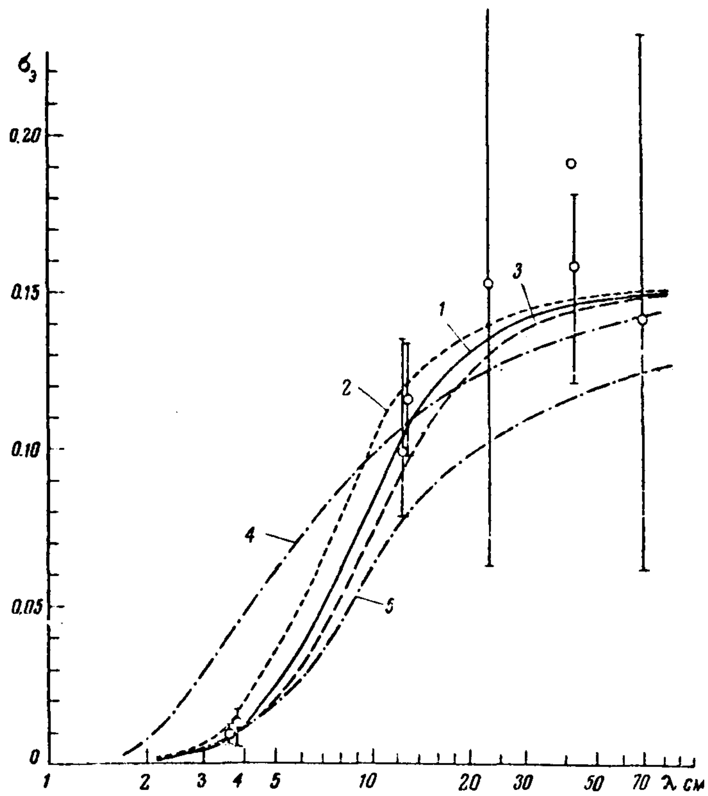

Fig.1. Dependence of the cross-section of Venus' radar reflection σ_{eff} on wavelength :

1) calculation for the liquid-drop aerosol, M = 3 g/cm^2; $t_p = 1.5 \cdot 10^{-11}$ sec; 2) same for M = 3 g/cm^2, $t_p = 1 : 10^{-11}$ sec; 3) same for M = 3 g/cm^2, $t_p = 2 \cdot 10^{-11}$ sec; 4) calculation for the dust aerosol, M = 1000 g/cm^2; 5) same for M = 2000 g/cm^2, the dots correspond to experimental data

The near-surface absorbing layer may be the lower stratum of clouds. If the clouds are of dust (quartz dust), in order to obtain the required absorption the content of dust in the clouds must constitute $(1 \div 2) \cdot 10^3$ g/cm^{-2}, which corresponds to quite a considerable dust contentration -- several kilograms/m^3 . Moreover, absorption in the dust aerosol agrees poorly with the frequency dependence $\sigma_{eff}(\lambda)$ (see Fig.1). A better agreement with the experiment is obtained when the clouds contain drops of polar liquid. In this case, utilizing a method analogous to that used in [4], we shall obtain that for clouds consisting of drop-liquid aerosol, the best agreement with experiment is obtained for a content in clouds of polar liquid

$M \stackrel{\sim}{=} 3$ g cm^{-2} with relaxation time $t_p = (1 \div 2) \cdot 10^{-11}$ sec. Water can not be such a liquid, for at T = 600°K its relaxation time is $\sim 10^{-15}$ sec.

Moreover, the water vapor, attending the liquid phase at pressure near the surface p $\sim$ 200 atm, required for the existence of liquid water at such high temperatures, would have at 3.6 cm wavelength an optical thickness $\tau > 100$, i.e., by numerous orders better satisfying the experimental data (the considerations on the absence of liquid water refer only to the lower-layer).

Nor is it possible to interpret the data of radioastronomical and radar observations by aerosol of identical chemical composition, but situated in the upper and lower absorbing cloud layers. Indeed, the relaxation time of lower cloud layer's polar aerosol $t_p = (1 \div 2) \cdot 10^{-11}$ sec, satisfying the experiment, is by two orders greater than the value for the upper absorbing layer determined in [4]. Besides, the decrease in the relaxation time with increase of temperature will further enlarge this discrepancy.

The calculated spectra of the effective cross-section of radar reflection computed by the formula

$$\sigma_э(\lambda) = g\rho e^{-2\tau(\lambda)} \tag{3}$$

for $g\rho = 0.15$, $t_p = 1.5 \cdot 10^{-11}$ sec and M = 3 g/cm^2 are plotted in Fig.1. They agree with a precision to measurement errors with the experimental data, also shown in the Fig.1.

Taking into account the influence of absorption in the atmosphere, the results of polarization measurements by A. D. Kuz'min and B. Klark [5] lead to a dielectric constant of matter of Venus' surface $\varepsilon = 3.6$, which agrees well with the data of radar measurements corresponding to $\varepsilon = 3.1 - 4.7$.

Let us note in conclusion that the abundance of aerosol in the cloud layer may depend on planet's illumination by the Sun. Then the quantity σ_{eff} must depend on Venus' illumination by the Sun, which, according to latest measurements by Smith et al [6] at 3.8 cm apparently takes place indeed.

For further refining of the parameters of the model considered new radar observations of Venus are necessary, particularly in wavelengths between 4 and 12 cm, and also measurements of the phase course of brightness temperature.

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