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RADIATION AND REFLECTIVITY OF VENUS IN DECIMETER WAVES

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SUMMARY

A two-layer model is proposed for the structure of Venus' upper mantle, which would allow to explain a series of experimental data related to its radioemission in decimeter waves. The two-layer structure is also in agreement with the low values of Venus' reflection factor (~1%), measured in the 3.6 cm wavelength. It is noted that a good physical analogue of the considered model may be the sand desert.

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A series of hypotheses were brought forth for the explanation of intense radiation of Venus in radioband. Of them, the most reliable is apparently the hothouse hypothesis, according to which the observed radiation is emitted by planet's surface heated to a high temperature on account of hothouse mechanism in its lower atmosphere [1]. It is then assumed that the strong hothouse effect is due to experimentally established presence in Venus of carbon dioxide and water vapor [1, 2]. The hothouse hypothesis allowed us to explain a large number of experimental data on planet's radioemission, such as the frequency and phase dependences of its emission in centimeter and microwaves [3, 4], results which were obtained by Venus' disk scanning from Mariner-2 [5], and so forth.

Lately, however, new data have appeared, which still have not found their explanation within the framework of the hothouse hypothesis. Related to these, are, in particular, the results of measurements of Venus' brightness temperature $T_{ЯB}$ in decimeter band, which was found to be 50 to 100 degrees lower in the 30 - 70 cm than in shorter wavelnngths [6 - 8]. The possibility was considered in [9] to explain this drop with the help of cold " holey" or "porous" ionosphere, effectively absorbing decimeter radiowaves. However, it was shown in [10] that the "porous" ionosphere hypothesis cannot be made to agree with the results of radar investigations of the planet.

A. D. Kuz'min and B. Dzh. Klark [11] observed the polarization of Venus' limbs in 10.6 cm and found that the degree of polarization corresponds to the value of the dielectric constant ε of surface formations, equal to 2.5. Estimates of ε were also made on the basis of radar measurmments of planet's reflectivity in decimeter waves. The respective calculations resulted in a value $\varepsilon \approx 4$ [12], which differs significantly from data of work [11]. This discrepancy between the value of the dielectric constant of Venus' surface layers, determined by two different and independent methods, is considered by Plummer and Strong [13] as an indication that the received radiation of planet's rough surface is determined by two components. One of them the thermal radiation of the rough surface and the other - the nonpolarized nonthermal radiation arising in its cloud cover.

It may be shown, however, that for the agreement of experimental results with the hothouse hypothesis, it is not required to introduce into the planet's model atmosphere a new emitting layer, as is done in [9, 13]. Assume that Venus' upper mantle, responsible for its emission in decimeter waves, consists of a hard bedrock, which is covered by a thin layer of matter with lesser density (Fig.1). The brightness temperature of surface emission in the wavelength λ in a direction characterized by the angle θ, that is, $T_Я(\lambda,\theta)$, will then be determined by the radiation of the upper layer and that of the bedrock, attenuated during its passage through the upper layer, i.e. :

$$T_{ЯB}(\lambda, \theta) = T_{\Pi} \cdot [1 - R(\varepsilon_1, \theta)] \left\{ 1 - e^{-\frac{\gamma_1(\lambda) \cdot d_1}{\cos\theta_1}} + [1 - R_1(\varepsilon_2/\varepsilon_1 \theta_1)] \cdot e^{-\frac{\gamma_1(\lambda) \cdot d_1}{\cos\theta_1}} \right\}. \quad (1)$$

Here T_{Π} is the thermodynamic temperature of the upper mantle, d_1 is the thickness of the upper layer, ε_1 and γ_1 are respectively the dielectric constant and the absorption coefficient of the matter forming it, ε_2 is the dielectric constant of bedrock matter. $R(\varepsilon_1,\theta)$ is the reflection factor of planet's surface according to width, $R_1(\varepsilon_2/\varepsilon_1,\theta_1)$ is the absorption coefficient of the interface between the upper layer and the bedrock, according to the width, and the angles θ and θ_1 are linked by the relation $\sin\theta = \sqrt{\varepsilon_1}\,\sin\theta_1$. The absorption coefficient γ_1 is link d with λ by the relation

$$\gamma_1(\lambda) = 2\pi\cdot(\mathrm{tg}\ \Delta/\rho_1)\cdot\rho_1\cdot\sqrt{\varepsilon_1}\cdot\frac{1}{\lambda} \qquad (2)$$

where we denoted by ρ_1 and $\mathrm{tg}\ \Delta$ respectively the density and the tangent of the matter's losses angle (that forms the upper layer). In order to determine the brightness temperature of Venus' radiation, expressions(1) must be integrated over the solid angle Ω_B, occupied by the planet:

$$T_{\text{ЯB}}(\lambda) = \frac{1}{\Omega_B}\int_{\Omega_B} T_{\text{ЯB}}(\lambda,\theta)\cdot d\Omega_B = \int_0^{\pi/2} T_{\text{ЯB}}(\lambda,\theta)\cdot\sin 2\theta d\theta. \qquad (3)$$

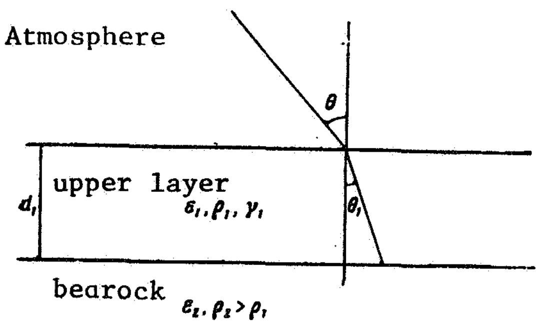

Fig.1. Two-layer model of Venus' upper mantle structure

It follows from expressions (1)-(3) that as λ rises, decrease takes place in the contribution of the upper layer to total planet's radiation, and, to the contrary, an increase in the contribution of the bedrock. As it emerges into the atmosphere, part of the upper layer radiation is reflected back from the surface into the medium. As to that of the bedrock, it undergoes twice the partial reflection before it emerges outside: from the interface and from the surface. This is why, as λ increases, drop in $T_{\text{ЯB}}$ must take place, and the smaller the quantity ε_1 or the greater the ratio $\varepsilon_2/\varepsilon_1$, the greater the drop.

Computations of Venus' brightness temperature for the two-layer structure model of its upper mantle were conducted with the aid of formula (3) in the 5 - 75 cm wavelength range. During the calculations, the results of which are

[N. B.] In formulas, figures and text we preserved the original subscripts, namely B for "Venus", Я for "brightness"

Plotted in Fig.2, it was assumed that the upp r layer consists of pulverized granite and has the following parameters: T_{Π} = 670°K; $tg\Delta/\rho_1$= 0.004 [14]; ε_1 = 1,5; 2,2 and 2,5. The corresponding values of ρ_1 were determined from the relation between the dielectric constant and the density of the pulverized gra nite, which is brought out in [14]. Following were the values taken for ε_2: 9 (granite) and 10 (sandstone). The values of $R_1(\varepsilon_2/\varepsilon_1,\theta_1)$ and $R(\varepsilon_1,\theta)$ were found with the help of Fresnel reflection factors. The thermodynamic temperature of the surface, assumed for calculations, corresponds within the limits of measurement errors to the temperature at the antisolar point of the planet obtained in [11]. Plotted in Fig.2 are also the results of measurements of brightness temperature of Venus [6 - 8]. Comparison of the curves obtained for $T_{\text{яB}}$ with experimental results shows that the two-layer model of near-surface layer structure of the soil allows us to explain the drop of planet's brightness temperature in the decimeter region of the spectrum.

Plotted in Fig.3 are the dependences of Venus' reflectivity on wavelength, $R_B(\lambda)$, computed for the case of perpendicular incidence of the wave on the sur face (θ = 0). From it one may see that the two-layer structure of the upper mantle agrees well with the experimentally determined values of planet's reflectivity in the decimeter band. From Fig.3 it follows also that for the upper mantle structure considered here, the values of R_B in decimeter and centimeter waves must strongly differ. The low value of Venus' reflectivity (~ 1%), measured in λ 3.6 cm, may serve as a corroboration of this [15].

The two-layer model of soils' upper layer structure on Venus allows us to explain, in the final resort, the discrepancies between the values of ε, determined from radar and polarization experiments. Kuz'min and Klark [11] investigated the radiations of visible planet disk's limbs, where the angles θ and, consequently θ_1 are considerably different from zero. It may be shown by simple calculations, that because the bedrock radiation at limbs is considerably attenuated and that their emission is mainly determined by the upper layer with low dielectric constant. Therefore, the two-layer model explains the indicated discrepancy by the fact that, in one case, the signal received is that reflected from the center of the visible disk, and the other - the emission from its limbs.

A good physical analogue of the above considered structure of Venus' upper mantle appears to be apparently a sand desert.

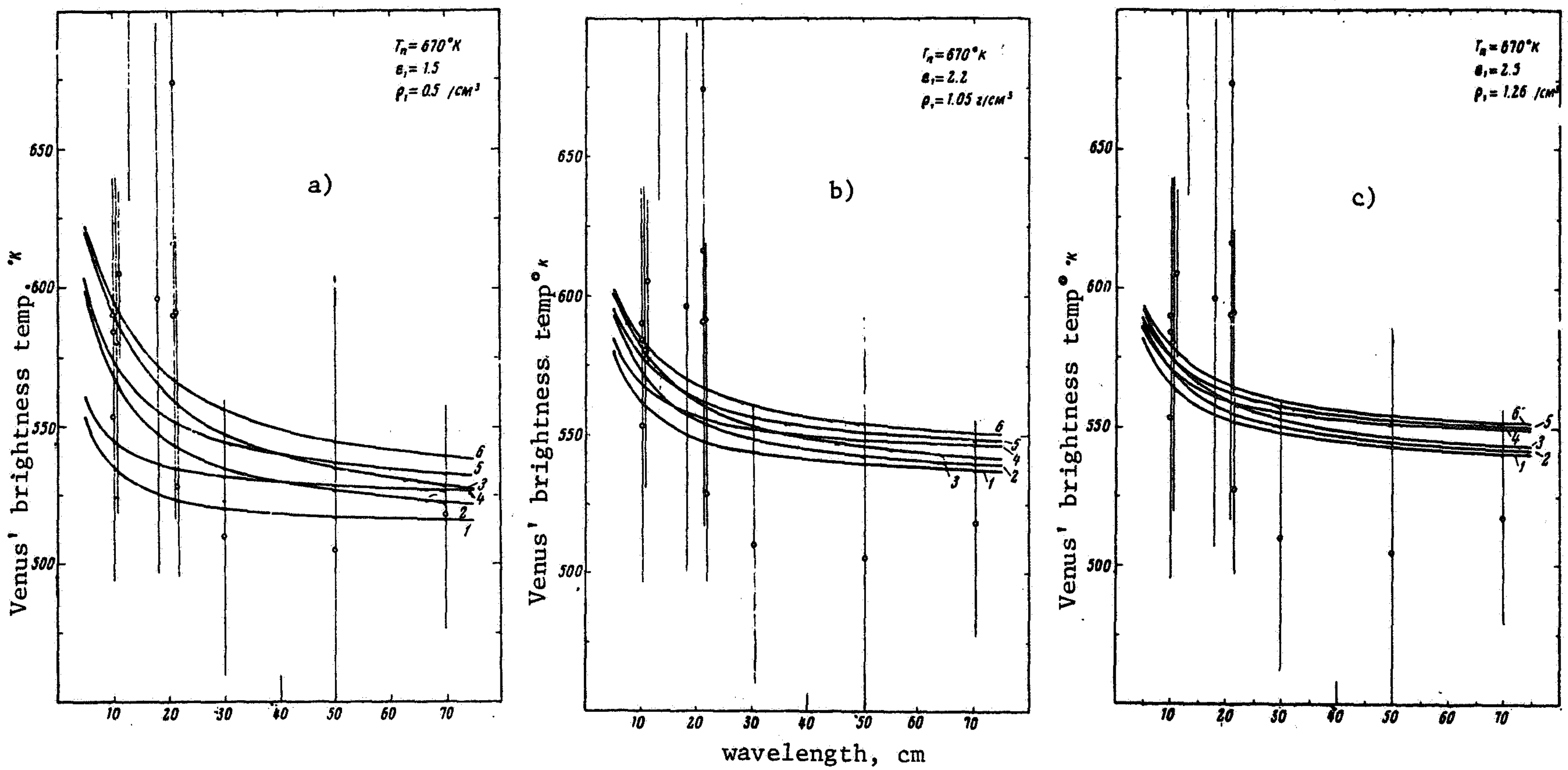

Fig.2

Depnndence of Venus' brightness temperature on wavelength

a) $\varepsilon_1 = 1.5$, 1) $d_1 = 100$ cm, $\varepsilon_2 = 10$; 2) $d_1 = 300$ cm, $\varepsilon_2 = 10$; 3) $d_1 = 500$ cm, $\varepsilon_2 = 10$; 4) $d_1 = 100$ cm, $\varepsilon_2 = 9$; 5) $d_1 = 300$ cm, $\varepsilon_2 = 9$; 6) $d_1 = 500$ cm, $\varepsilon_2 = 9$. b) $\varepsilon_1 = 2.2$; 1) $d_1 = 100$ cm, $\varepsilon_2 = 10$; 2) $d_1 = 150$ cm $\varepsilon_2 = 10$; 3) $d_1 = 200$ cm, $\varepsilon_2 = 10$; 4) $d_1 = 100$ cm, $\varepsilon_2 = 9$; 5) $d_1 = 150$ cm, $\varepsilon_2 = 9$; 6) $d_1 = 200$ cm, $\varepsilon_2 = 9$. c) $\varepsilon_1 = 2.5$; 1) $d_1 = 100$ cm, $\varepsilon_2 = 10$; 2) $d_1 = 125$ cm, $\varepsilon_2 = 10$; 3) $d_1 = 150$ cm, $\varepsilon_2 = 10$; 4) $d_1 = 100$ cm, $\varepsilon_2 = 9$; 5) $d_1 = 125$ cm, $\varepsilon_2 = 9$; 6) $d_1 = 150$ cm, $\varepsilon_2 = 9$

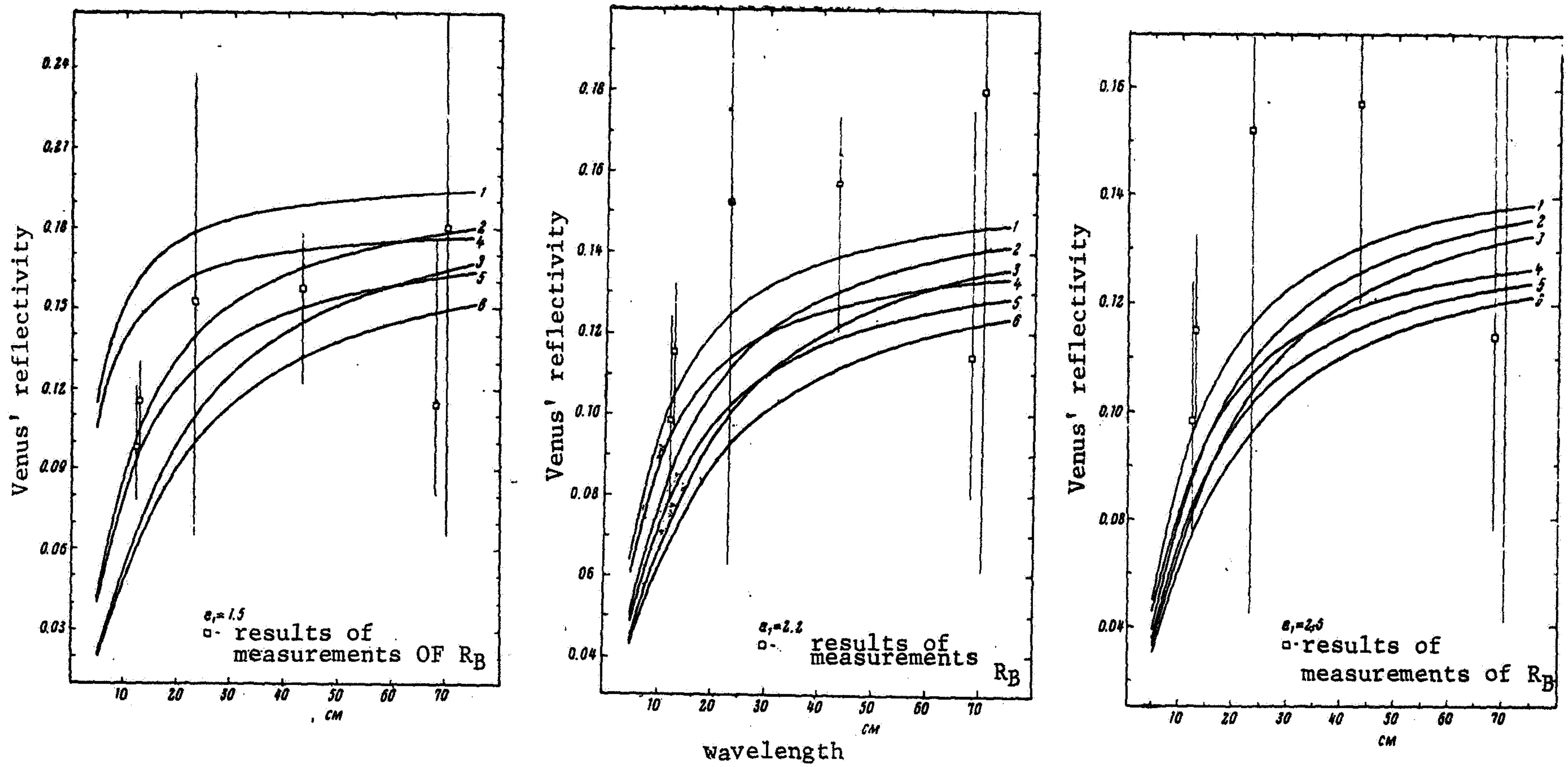

Fig.3

Venus' reflectivity as a function of wavelength

a) $\varepsilon_1 = 15$; 1) $d_1 = 100$ cm, $\varepsilon_2 = 10$; 2) $d_1 = 300$ cm, $\varepsilon_2 = 10$; 3) $d_1 = 500$ cm, $\varepsilon_2 = 10$; 4) $d_1 = 100$ cm, $\varepsilon_2 = 9$; 5) $d_1 = 300$ cm, $\varepsilon_2 = 9$; 6) $d_1 = 500$ cm, $\varepsilon_2 = 9$. b) $\varepsilon_1 = 2.2$; 1) $d_1 = 100$ cm, $\varepsilon_2 = 10$; 2) $d_1 = 150$ cm, $\varepsilon_2 = 10$; 3) $d_1 = 200$ cm, $\varepsilon_2 = 10$; 4) $d_1 = 100$ cm, $\varepsilon_2 = 9$; 5) $d_1 = 150$ cm, $\varepsilon_2 = 9$; 6) $d_1 = 200$ cm, $\varepsilon_2 = 9$ c) $\varepsilon_1 = 2.5$; 1) $d_1 = 100$ cm, $\varepsilon_2 = 10$; 2) $d_1 = 125$ cm, $\varepsilon_2 = 10$; 3) $d_1 = 150$ cm, $\varepsilon_2 = 10$; 4) $d_1 = 100$ cm, $\varepsilon_2 = 9$; 5) $d_1 = 125$ cm, $\varepsilon_2 = 9$; 6) $d_1 = 150$ cm, $\varepsilon_2 = 9$

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ANNOTATION AT CORRECTION

The Soviet AS "VENERA-4" measured the basic parameters of planet's atmosphere. (see [16]). The pressure and temperature on Venus' surface are respectively 20 atm and ~ 550°K. The carbon dioxide content in planet's atmosphere us ~ 95%, and the H_2O content is ~ 0.1 - 1.7%.

The respective calculations have shown that the optical depth of Venus' atmosphere τ_{atm} varies from 1.9 to 0.57 in λ 3.6 cm and from 0.02 to 0.06 in λ 12.5 cm, as water vapor content varies from 0.1% to 0.7%. The indicated values of τ_{atm} are insufficient for the explanation of the discrepancies in the measured values of R_B in these wavelengths by only the absorption in venusian atmosphere [17]. The accoutning of atmosphere absorption will result, however, in the decrease of the values d_1 , required for the agreement of the two-layer model of the upper mantle with the results of measurements of R_B in the redioband.

T H E E N D

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