DISTRIBUTION OF RADIO BRIGHTNESS OVER THE DISK OF VENUS AT A WAVELENGTH OF 8 mm

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Abstract

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DISTRIBUTION OF RADIO BRIGHTNESS OVER THE DISK OF VENUS AT A WAVELENGTH OF 8 mm*

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As is known, the integral characteristics of the radio emission of the planet Venus have not made it possible to choose between the existing models of the structure of its atmosphere. A very sensitive characteristic of the models is the law of darkening toward the limb of the planet’ s disk. Already the first estimates of the distribution of radio brightness over the disk of Venus, carried out at Pulkovo in 1962 ([1]), then from aboard the spacecraft Mariner II ([2]), and recently interferometrically in polarized radiation ([3]), have made it possible almost completely to reject the hypothesis of a cold surface and a hot ionosphere (see ([4])).

The present observations at a wavelength of 8 mm were carried out in order to determine the nature of the absorption of millimeter radio emission from a hot surface by the planet’ s atmosphere. All existing hypotheses on the origin of this absorption may be divided into three groups:

1. The absorption occurs in a narrow, practically isothermal layer of the atmosphere ([4–7]).
2. The absorption is caused by induced transitions in a carbon-dioxide or nitrogen atmosphere at high pressures ([8,9]). In this case the absorption coefficient χ is proportional to the square of the density ρ of the absorbing gas ($\chi \propto \rho^2$).
3. The absorption is caused by an unidentified agent and the absorption coefficient χ is proportional to the atmospheric density ($\chi \propto \rho$). It is easy to show that all three models give different laws of darkening of the radio brightness toward the limb of the planet’ s disk. With a negative temperature gradient, the first model gives the least darkening, the last the greatest.

Fig. 1. *a* –a curve, averaged over several records, of the passage of Venus through the directional pattern of the Pulkovo radio telescope at a wavelength of 8 mm after removal of the low-frequency and high-frequency noise of the

Fig. 1

Figure 1: Fig. 1

Figure 2

Figure 2: Figure 2

radiometer on the basis of the theory of antenna smoothing ([10]); the position of the ephemeris disk of the planet is also shown; *b* –results of observations from aboard Mariner II at a wavelength of 13.5 mm

The observations were carried out at Pulkovo on 6–22 IX 1967 with the large Pulkovo radio telescope, which has a resolving power of $15'' \times 4'$ at a wavelength of 8 mm. According to the theory of antenna smoothing ([10]), such a resolution makes it possible to obtain 8 independent readings in a one-dimensional

* The main results of the present work were reported on 13 X 1967 at the jubilee session of the Scientific Council of the Main Astronomical Observatory of the Academy of Sciences of the USSR.

of the radio-brightness distribution near the inferior conjunction of Venus. The radiometer noise dispersion was 0.3° K for an integration time of 1 sec.

In our ground-based experiment the resolving power in linear measure was practically equal to the resolution from the Mariner II spacecraft [(2)]; however, the possibility of many repetitions of the experiment made it possible to obtain a higher signal-to-noise ratio.

The transit curve of Venus, processed by a rigorous spectral method [(10)], averaged over 10 records and corrected for the smoothing action of the integrating circuit, is shown in Fig. 1a. Fig. 1b shows the only Venus scanning curve existing in this wavelength range, obtained with a radio telescope aboard the Mariner II spacecraft at a wavelength of 13.5 mm [(2)].

The signal-to-noise ratio on this curve is 30. This is quite sufficient for estimating the effective angular size of Venus at a wavelength of 8 mm. The size of the transit curve at the half-power points is $42'' \pm 0''.5$.

Fig. 2. Choice of a limb-darkening model. Along the abscissa is a parameter characterizing the degree of limb darkening (see text); along the ordinate is the expected width of the Venus transit curve through the radio-telescope beam. Circles are calculated values for different models; the cross is the experiment.

The comparison of the observations with models is given in Fig. 2. Along the abscissa is plotted a certain parameter characterizing the degree of darkening of the radio brightness toward the limb of the planet' s disk. As in [(1)], this parameter is the effective Gaussian size of the planet, which gives the same half-width of the transit curve of the planet through a Gaussian beam as does a rigorous smoothing of the specified darkening law by the radio-telescope beam pattern. The calculated distributions over the disk of Venus were computed for the mean model of the atmospheric structure according to V. I. Moroz [11].

As follows from Fig. 2, the observations agree best of all with the assumption of absorption of millimeter radio emission in a dense near-surface layer and contradict the hypothesis of absorption in the clouds.

Establishing the nature of the absorption of millimeter radiation by the solid surface of the planet makes it possible to estimate roughly the intensity of vertical turbulent mixing in the lower atmosphere of the planet. Indeed, knowing the heights of the effectively radiating layers of the atmosphere at different wavelengths (according to the model with induced absorption [9]) and the amplitude and phase of the seasonal temperature variations in these layers (data on the phase behavior at the corresponding wavelengths), one can estimate the length of the thermal wave propagating from the harmonically heated surface into the atmosphere. Analogous waves are observed in the terrestrial atmosphere. The length of the thermal wave is determined by the turbulent thermal diffusivity, i.e., by the intensity of the vertical pulsations of the wind. Such estimates, made on the basis of the published [4] data on the phase behavior of the brightness temperature of Venus, lead to values of wind pulsations close to terrestrial ones. Taking into account the unevenness of the planet' s surface, this fact apparently imposes strict limitations also on the horizontal components of the wind velocity. To refine these estimates, systematic measurements of the phase behavior of the brightness temperature of Venus in the centimeter wavelength range are now being carried out at the Main Astronomical Observatory of the Academy of Sciences of the USSR.

In conclusion, let us dwell on a small asymmetry of the transit curve of Venus at a wavelength of 8 mm (see Fig. 1). The eastern half of Venus turns out to be $12 \div 18^\circ$ K warmer than the western half. This asymmetry cannot yet be explained by instrumental effects. Two explanations are possible.

1. Since the observations were carried out at a phase angle of 140° (about 10% of the disk of Venus was illuminated by the Sun), the asymmetry is consistent with the dependence found in [12] of the brightness temperature of Venus on phase, provided that in [12] the delay of heating at 8 mm relative to phase was determined incorrectly.

2. The infrared emissivity of the eastern part of Venus is higher than that of the western part. In this case even an isothermal surface would heat the near-surface layer of the atmosphere in the east more strongly than in the west. A difference in the properties of the western and eastern parts of the disk of Venus also follows from radar data (see the bibliography in [4]).

To separate these effects, further measurements of the distribution of radio brightness at various phases are necessary, as well as a study of the dependence, on wavelength, of the distribution over the disk of the radar reflection and of the polarization of the planet' s own surface radiation.

Thus, observations of the distribution of radio brightness over the disk of Venus at a wavelength of 8 mm lead to the following conclusions.

1. The observed darkening toward the limb is in good agreement with the hypothesis of absorption of millimeter radiation from the hot surface in regions with an adiabatic gradient $\sim 10^{\circ}$/km.
2. The observations contradict the assumption of strong absorption of millimeter radio emission in the planet' s cloud layer, which imposes constraints on the water content of the clouds.
3. The observations contradict the hypothesis of strong winds in the atmosphere of Venus.
4. An asymmetry has been found in the distribution of radio brightness over the disk of the planet: the eastern side (illuminated by the Sun after inferior conjunction) is 12—18° K hotter than the western side. The cause of this effect has not been definitively established.

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Note: Figure translations are in progress. See original paper for figures.