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**Abstract**

**Full Text**

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### ASTRONOMY

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## RADIO-ASTRONOMICAL OBSERVATIONS OF VENUS WITH HIGH RESOLVING POWER

*(Presented by Academician V. A. Kotel'nikov on 21 XII 1962)*

In October–November, at the Main Astronomical Observatory of the Academy of Sciences of the USSR, observations were carried out of the radio emission of Venus at a wavelength of 3.02 cm, using the large Pulkovo radio telescope with a variable-profile antenna (VPA) <sup>(1)</sup>. The aim of the measurements was to evaluate the character of the distribution of radio brightness, using the high resolving power and high accuracy of coordinate measurements on the VPA.

**Fig. 1.** Spectrum of spatial frequencies of the distribution of radio brightness  $T(x)$ .

$$1—T_B = \delta(x - 1'/2) + \delta(x + 1'/2);$$

$$2—T_B = 1 \text{ for } x \leq 1'/2, T_B = 0 \text{ for } x > 1'/2;$$

$$3—T_B = |1'/2 - x| \text{ for } x \leq 1'/2, T_B = 0 \text{ for } x > 1'/2$$

The fundamental possibilities for obtaining information on the distribution of radio brightness are evident from Fig. 1. Curves 1, 2, 3 are spectra of spatial frequencies <sup>(2)</sup> of different radio-brightness distributions for several limiting conceivable models: two point sources at a separation of  $1'$ , a uniformly bright disk of the same diameter, and a disk with a linear decrease of brightness from center to edge. Acting as a spatial-frequency filter, the VPA at a wavelength of 3.02 cm makes it possible to investigate all spatial frequencies up to  $\omega = D/\lambda = 3500$ . The accuracy with which the amplitudes of the harmonics are determined is set by the accuracy of knowledge of the “frequency characteristic” of the antenna filter, or of the form of the antenna radiation pattern, and by the signal-to-noise ratio. To increase the signal-to-noise ratio, a radiometer with a single-circuit parametric amplifier of about 200 MHz was constructed at the Main Astronomical Observatory of the Academy of Sciences of the USSR; the noise temperature of the radiometer with the antenna was about 500°K, and the sensitivity in antenna temperature was about 0.07°K with a time constant of  $1^s.6$ .

To determine with maximum accuracy the form of the radio-telescope radiation

pattern in the horizontal section, the distribution of the field in the antenna aperture was investigated. Phase errors in the aperture were carefully measured with the aid of a control invariant wire measure and eliminated with an accuracy of  $\sim 1/30\lambda$ . The distribution of the amplitudes of the illumination field in the aperture was determined using a noise-signal generator moved along the midline of the VPA shields. The usual electrodynamic calculation (in our case one-dimensional) made it possible to determine the form of the pattern.

The width of the diagram at the half-power level was found to be  $1'20 \pm 0'03$ , which practically coincides with the commonly adopted value  $1.2\lambda/D$ ; the size of the diagram at the  $-20$  db level is  $3'1 \pm 0'04$ .

Observations were carried out on the meridian. The position of the primary radiator relative to the plane of symmetry of the APP was controlled geodetically with an accuracy of  $\pm 0.5$  mm, which corresponds to a displacement of  $\pm 2''$  of the diagram on the sky.

**Fig. 2.** Sample record of the transit of Venus.  
16 XI 1962,  $\tau = 1^m6$

A sample record of the curve of the passage of Venus through the directional diagram is given in Fig. 2. The averaged transit curve over 15 days near inferior conjunction is shown in Fig. 3. Careful processing of the observations made it possible to draw the following conclusions.

1. The discrepancy between the temperature obtained by optical and radiometric methods cannot be explained by the presence of powerful radiation belts, similar to what occurs on Jupiter<sup>(3)</sup>. The flux of radio emission from the region of radius  $R = 6R_{\text{Venus}}$  does not exceed 3% of the radiation flux associated with the visible disk of the planet. Reducing the assumed size of the emitting belts will lead to an even lower limit.

**Fig. 3.** Averaged transit curve of Venus. Mean over 15 days.  
 $\tau = 1^s5$ ;  $\lambda = 3.02$  cm

2. Radio emission is practically absent at a distance of  $1.07R_{\text{Venus}}$  from the center of the planet's disk, i.e., the height of the radio-emitting region does not exceed 420 km above the cloud cover of Venus.
3. The results of measurements of the effective dimensions of Venus are shown in Fig. 4. Here the abscissa gives the values of the parameter  $\sigma_i$  of the Gaussian curve  $\exp(-x^2/\sigma_i^2)$ , representing the real distribution of radio brightness in such a way that this Gaussian curve gives the same broadening of the directional diagram as the real brightness distribution. The solid curve shows the dependence of the width of the transit curve on  $\sigma_i$  under various assumptions about the distribution of radio brightness.

As can be seen from Fig. 4, the observed width of Venus' s transit curve is clearly inconsistent with hypotheses predicting an increase in brightness toward the edge of Venus' s disk (a semitransparent ionosphere<sup>(4)</sup>, the hypothesis of

microdischarges in the atmosphere <sup>(5)</sup>, etc.). The observed width is somewhat smaller than follows from the assumption of radiation from the solid surface of a planet with  $\varepsilon = 4$ . (The discrepancy is still greater with the model of an isothermal optically thick ionosphere or atmosphere, and also with a solid surface with  $\varepsilon = 1$ .) If this discrepancy is real, i.e., if there is appreciable darkening toward the limb, it can be explained by absorption of radiation from the surface (or from a near-surface layer) in a cold atmosphere <sup>(6-8)</sup>. However, further observations with greater resolving power are required for a quantitative estimate of this effect. Observations of this effect at shorter wavelengths, where it may be stronger, are also desirable.

**Fig. 4.** Results of angular measurements of the effective dimensions of Venus

4. An attempt to determine the phase variation of the radio temperature from the displacement of the center of gravity of the radio emission led to a negative result. When the fraction of the illuminated surface was varied from 0 to 0.1, the displacement of the coordinates of the center of gravity of the radio emission was  $0''.01 \pm 0''.13$ . Hence it may be concluded that the amplitude of the variable component of Venus' s brightness temperature at a wavelength of 3.02 cm does not exceed  $170^\circ \text{ K}$  (taking the mean temperature of the unilluminated disk to be  $570^\circ \text{ K}$ ). This is consistent with the data of Kuz' min and Salomonovich <sup>(9)</sup> and is clearly inconsistent with Lilly' s latest data <sup>(7)</sup>.

In summary, it may be said that the high-resolution observations are in closest agreement with the model of a hot surface and a cold atmosphere <sup>(7)</sup>. According to this model, the temperature of the planet' s solid surface is about  $600^\circ \text{ K}$ , while the temperature of the atmosphere drops sharply to  $234^\circ \text{ K}$  in the upper layers of the cloud cover. The model also assumes the presence of large pressures (20–100 atm.) near the surface.

Observations of planets with high-resolution radio telescopes provide very valuable information about the physical conditions on the planets. In a number of cases this information cannot be obtained by studying the integrated radio emission of the planets. In such cases, either rocket observations or ground-based observations with a resolving power substantially less than  $1'$  are necessary. This resolution is difficult to achieve with ordinary paraboloids <sup>(1)</sup>. At the Main Astronomical Observatory of the Academy of Sciences of the USSR it is intended to improve substantially the accuracy of alignment and the surface quality of the CPP for a further increase in resolving power at shorter wavelengths.

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

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