Observations

of the

OWENS VALLEY RADIO OBSERVATORY

California Institute of Technology

Pasadena, California

1963

6. SOME DECIMETER OBSERVATIONS OF VENUS DURING THE 1962 CONJUNCTION

by

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ABSTRACT

The flux from Venus was measured at various frequencies, giving blackbody disk temperatures of 580°K ± 60° at 10.7 cm, 596°K ± 100° at 18 cm and 616°K ± 100° at 21 cm.

An attempt was made to measure the size of the planet at a wavelength of 9.4 cm with an interferometer with a baseline of 5184 wavelengths aligned east-west. Only a very small part of the amplitude-spacing spectrum was observed, but the observations are not what would be expected of a uniform or limb darkened disk.

I. INTRODUCTION

Near the inferior conjunction of Venus in 1962, various measurements were carried out at the Owens Valley Radio Observatory with a variable spacing interferometer consisting of two ninety-foot equatorially-mounted paraboloids. These measurements were carried out in conjunction with other programs, and for the most part the telescopes were involved with Venus measurements only when Venus was near culmination.

The measurements fall naturally into two groups. The first is a set of short baseline measurements in Sept.-Oct. of the flux coming from the planet at frequencies of 1420 and 1666 Mc/s, and several scattered measurements made at 2841 Mc/s. The second is an attempt to measure the angular diameter of the planet with a baseline of 5180 wavelengths at a frequency of 3184 Mc/s.

All measurements were made with each antenna having a balanced crystal mixer with each half of the mixer followed by its own IF preamplifier, whose outputs were combined in such a phase as to cancel the noise from the klystron local oscillator. The signals from the two antennas are then multiplied together to form the interference fringes. The IF bandpass is approximately 4 Mc/s at 10 Mc/s.

II. THE FLUX MEASUREMENTS

1. At 2841 Mc/s.

At this frequency, Venus near conjunction is a powerful and conspicuous source with the interferometer. It is possible to reduce the uncertainty due to noise below the uncertainty in absolute flux calibration in only a few minutes of observing time. Sometimes the amplitude of the interference fringes was simply read from a chart record, and in other cases an electromechanical integrating system was used (Morris, Clark and Wilson 1963). The flux from Venus was compared with the flux from the radio source 3C 295. The absolute flux of 3C 295 was taken to be 10.8×10^{-26} W $m^{-2}(c/s)^{-1}$ at 2841 Mc/s, as given by Kellermann (1963) from inter-comparisons of several sources of similar strength with the flux from Cas A, Tau A and Cyg A. The accuracy of the absolute calibration is estimated to be better than 10%. This error is larger than noise and indicates the actual uncertainty in the 10.7 cm fluxes given in Table 1.

2. At 1420 and 1666 Mc/s.

At these frequencies the limiting factor in the measurements is the confusion from weak sources in the beam at the same time as the planet. Because of the other programs utilizing the interferometer at the same time, the phase of the confusion signal was not determined with sufficient accuracy to subtract the confusion from the measurements, although the amplitudes of the background sources were observed in all the positions after the planet had left. The very high temperature observed on Sept. 27 is probably due to confusion, as a flux corresponding to a Venus disk temperature of about 300° was found there after the planet had moved on, though Mills (1960) reports no source there. The fluxes for 3C 295 used at these frequencies were also obtained or interpolated from Kellermann (1963), and are 20.0×10^{-26} W $m^{-2}(c/s)^{-1}$ at 1420 Mc/s and 17.3×10^{-26} W m^{-2} $(c/s)^{-1}$ at 1666 Mc/s. The estimated uncertainty in the average values given in Table 1 remains about 100° and results from confusion.

III. THE SIZE MEASUREMENTS

In an attempt to measure the size of Venus, the telescopes were placed at a baseline of 1600 feet or 5180 wavelengths at 3184 Mc/s. These measurements were also made with a hybrid mixer receiver, double sidebands of 4 Mc/s bandwidth at ± 10 Mc/s from the center frequency. The antenna was linearly polarized with E-vector east-west. The fringe spacing was 40" at the meridian, corresponding to slightly less than 3 seconds of time. To reduce the fringe period to a convenient value, a phase rotation was introduced into one of the two local oscillators, the rate of which could be adjusted manually to produce a fringe period of about 72^s. The interferometer output was then run through an R-C filter tuned to a 72^s period, whose bandwidth would correspond to that of a 12^s time constant. A lumped constant step variable delay line and two 1-microsecond fixed cable delay lines, all at IF, were used to equalize the delay between the two antennas as the hour angle of the source changed (Read 1960). The observing procedure was to set the delay line 25 nanoseconds greater than the setting needed to observe the central fringe of the interference meter, observe the slowed fringes until the central fringe had been observed, and then advance the delay line by 50 nanoseconds. Several small diameter sources, principally 3C 295, were observed to calibrate the sensitivity of the system. 3C 295 requires about 5% correction for resolution.

Venus was observed at several hour angles to vary the effective baseline. Unfortunately, with the frequency and baseline used, the observations of interest were made at large hour angles, where the behavior of the system is not as well known as at the meridian. The observations were made on Dec. 6-9 and were reduced in both baseline and intensity to Dec. 6.5 UT when the diameter of the planet was 50". The observations are presented in Fig. 1. Also presented are the visibility functions to be expected from a uniform disk and from a thin ring both of 50" diameter. The error flags indicate the scatter in the observations at a given effective baseline. There are several possibilities for systematic error, especially since the observations of interest were taken at large hour angles and the calibrators were observed rather nearer the meridian. Below are listed some of the possible sources.

a) An error in the step delay line. If the line is not a pure delay, phase coherence is lost and the size of the fringes is decreased. However, these delay lines have previously proved satisfactory for similar baselines and, further, the shape of the amplitude vs. delay curve appeared to be about constant at all hour angles, though it was not very carefully observed at large hour angles, indicating that the bandpass of the coherent signal was about constant.

b) Pointing errors. There were insufficient strong point sources to adequately calibrate the pointing of the antennas, and the pointing error corrections on one antenna were made by surveying the antenna baseframe to the same orientation it had at the previous spacing, and using the same correction curves, a procedure which seemed justified by measurements on 3C 295 and Cyg A, both far north of Venus. Subsequent measures at much shorter baselines, where one may calibrate on larger sources than are visible at 5000 wavelengths baseline, indicate that this calibration was adequate and that even at large hour angles the pointing was probably within 2 1/2', where the beam is down by only 5%.

c) Seeing. It is well known that the seeing disk can sometimes exceed 40" in diameter, and that the desert in daytime has notoriously bad seeing. However, one would expect seeing to affect the calibrating point sources nearly as much as the planet, and further, the observations at large negative hour angle, taken just before or during sunrise, should show much less effect than those taken at large positive hour angles at about noon. The observations of the planet taken in both positions show little or no difference, and from this result we have assumed that the effect of seeing is negligible.

The two-dimensional amplitude spacing spectrum is the Fourier transform of the brightness distribution of the planet (Moffet 1962). With the baseline fixed at 1600 feet east-west and the hour angle changing, the effective baseline traces a curve in the spacing plane, which for objects near the equator is approximately a straight line aligned east-west. If this be the case, the visibility along this line is the Fourier transform of the fan beam scan of the planet. Observations with sufficient sensitivity along the amplitude spacing spectrum thus yield uniquely the strip scan brightness distribution. However, the present measurements essentially constitute only a small part of the amplitude spacing spectrum, so, rather than inverting the transform directly, we must fit reasonable models to the data. Several models can be fitted because the data occupy such a small part of the amplitude spacing spectrum. The data might, for instance, be interpreted as representing a uniform disk 15% larger than the visible planet, or as a thin ring containing 1/4 the flux from the planet at the limb of the uniform disk. It is not possible to explain the observations by a strong pole darkening due to polar cooling, though this will tend to lower the transform.

In summary, these measurements tend to indicate that all of the flux from Venus at 9.5 cm does not arise from a uniform or limb darkened disk.

TABLE 1

Results of Venus Flux Measurements

Frequency (Mc/s)	Date	Spacing λ	Disk Temp. $^{\circ}K$
2841	10/29	600	586
2841	12/3	300	574
2841	Average		580
1666	10/10	350	572
1666	10/11	350	622
1666	Average		596
1420	9/26	300	630
1420	9/27	300	908
1420	9/27	300	865
1420	9/27	300	849
1420	9/28	300	343
1420	9/29	300	410
1420	10/1	300	307
1420	Average		616

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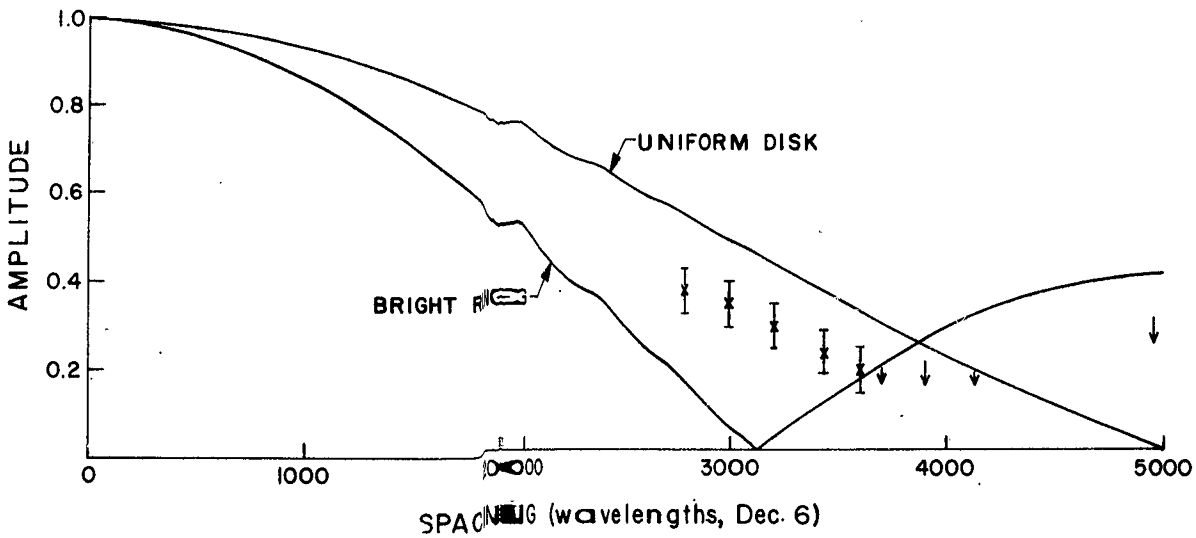

FIGURE 1. THE OBSERVED PORTION OF THE AMPLITUDE SPACING SPECTRUM OF VENUS COMPARED WITH THOSE OF A UNIFORM DISK AND OF A THIN RING THE SAME DIAMETER AS THE PLANET.