BALLOON TELESCOPE STUDIES OF VENUS

John Strong

Johns Hopkins University
Baltimore, Maryland

In this presentation I intend to review the work on Venus carried out by the Johns Hopkins University balloon astronomy group. This work has been reported by Bottema et al. (1964a and 1964b).

My approach to the problem of Venus represents a minority opinion about the interpretation of the available data, the radio emission data in particular. I would like to keep open the question of the origin of the radio emission because I believe that it is not entirely surface emission but that some nonthermal process such as that suggested by Tolbert and Straiton (1962) is active. However, before going into this question, I wish to describe the evidence for the existence of ice-crystal clouds in the upper Venusian atmosphere as obtained by our balloon astronomy group.

I. Determination of Water Vapor in the Atmosphere of Venus

Venus was observed with a 30-cm telescope suspended from a balloon at an altitude that was above 99.9% of the Earth's water vapor and 97% of the Earth's CO_2. The telescope was oriented with a Sun tracker and a star tracker. Radiation was measured in the band at 1.13 μ, with a grating spectrometer of 2 A resolving power. This portion of the spectrum was scanned once every 10 sec with a set of 21 exit slits arrayed to match 21 H_2O absorption line groups. The radiation passing through was received by a chilled photomultiplier with S-1 surface, and its response was recorded on paper.

From 120 such records we have determined that the modulation produced by the water absorption, when the line groups were scanned, was 10.5 ± 0.5 %. By calibration, this modulation is the same as that produced by 9.8×10^{-3} gm/cm^2 of water vapor at atmospheric pressure. We were also able to measure the influence of the doppler shift on our recorded data. At one point in each scan cycle a mercury-discharge spectral line at 11287 A was passed through one of the exit slits and was recorded as a modulation in the reference-level spectrum. Measurements from this fiducial line to the Venus water dips, taken from 20 scans, exhibit a doppler shift of 0.49 ± 0.05 A, in agreement with a shift of 0.495 A calculated from the orbital motions of Venus and the Earth.

The pressure at the cloud level is poorly known but is thought to range between 90 and 600 mb. The amounts of water vapor calculated from our data for gravitational atmospheres at these base pressures are:

22.2×10^{-3} gm/cm^2 for the 90-mb case

5.2×10^{-3} gm/cm^2 for the 600-mb case

The respective mixing ratios would be 2.5×10^{-4} and 0.87×10^{-5}.

II. Determination of the Existence of Ice Clouds

A second balloon experiment was carried out in October 1964 with a low-dispersion grating, utilizing three detectors in place of slits. The following scans were carried out:

40 scans of the Venus spectrum

12 scans of the spectrum of adjacent sky

10 scans of a tungsten lamp

18 scans of the solar spectrum

The spectra, which covered a range from 1.7 to 3.4 μ, were corrected for water vapor using the results of our previous measurements to obtain an absorption spectrum of water vapor above the cloud tops. The work of Kuiper was used to correct for the CO_2. Our observed and corrected spectra are indicated by the solid line in Fig. 1. Also shown in Fig. 1 is the reflection spectrum of a $-39°$C laboratory ice cloud. The agreement is excellent!

These corrections not only strengthen our inference that the Venus clouds consist of ice but also confirm our prior determination of the quantity of water vapor above them.

The existence of water vapor and ice clouds allows an explanation of one of the mysteries of the observations of Venus: namely, that the temperature of the shady side of the planet does not fall more than a few degrees short of the temperature of the sunny side as measured in the 8 to 14 μ band, even though the shady side has several months to cool off. This is a circumstance that model builders have been somewhat more complacent about than we have. The failure to cool is due to the

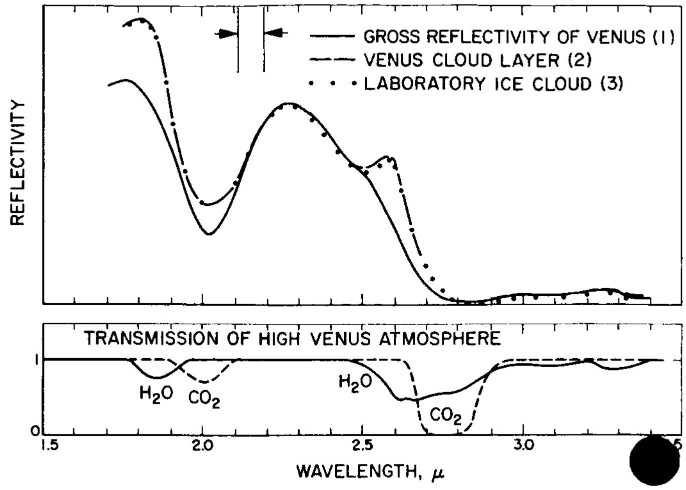

Fig. 1. Reflection spectrum of Venus clouds, showing correction for upper Venusian atmosphere. (From the *Journal of Geophysical Research*)

liberation of latent heat of H_2O vapor, of about 620 calories per gram, as that vapor condenses to form clouds.

Menzel and Whipple (1955) have pointed out in their discussion of the atmosphere of Venus that the Schaefer point is $-39°$C, the temperature below which saturated water vapor cannot be cooled without spontaneous nuclearization and crystalization. This temperature is precisely the temperature assumed by many high-level cumulus clouds on Earth. Menzel and Whipple calculate 13.0×10^{-3} gm/cm^2 of saturated water vapor above the Venus clouds.

We interpret the work of Clark and Kuzmin on the radio emission of Venus assuming that the measured brightness temperature is due in part to surface emission and in part to emission of the clouds. Our calculations show that T_b would be reduced by 168°K and the average temperature would be 238°C.

In summary, it seems to us that Venus is becoming the more interesting planet now that the *Mariner IV* photographs have lessened the romance that Lowell had fastened so securely on Mars. The data that are now coming in must be criticized harshly, and modern methods should be used to consider all possibilities, or we will not be on time or even live to see the day when the mysteries of Venus are resolved.

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