HIGH SPECTRAL RESOLUTION INTERFEROMETRIC PLANETARY OBSERVATIONS IN THE 7–25 μ REGION

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Abstract. The thermal emission spectra of Venus, Mars, Jupiter, and the moon were observed at the coude focus of the McDonald Observatory 107-inch telescope in the 400–1400 cm^{-1} spectral range with spectral resolutions of 0.3–0.7 cm^{-1}. A preliminary interpretation of the Venus/lunar ratio spectrum allows identification of four upper state CO_2 bands in the Venusian atmosphere at 791, 828, 865, and 961 cm^{-1} and confirms previous observations of the broad absorption-like depression around 890 cm^{-1}. The rotational structure of the 791 and 961 cm^{-1} bands is well developed at this spectral resolution.

During three 10 day periods, between March and June 1969, the thermal emission spectra of Venus, Mars, Jupiter, and the moon were observed at the coudé focus of the recently completed 107-inch telescope of the McDonald Observatory. Spectra were recorded from 400–1400 cm^{-1} with spectral resolutions in the range of 0.3–0.7 cm^{-1}. The spectral range covers numerous intervals where the earth atmosphere is sufficiently transparent to permit precise measurements of planetary and lunar intensities.

A double beam Fourier transform spectrometer of the type described by Hanel *et al.* (1969) was modified for these observations. First, the spectral range was extended to the long wavelength limit of the beam splitter substrate (potassium bromide) by the use of copper-doped germanium detectors. Second, the spectral resolving capability of the instrument was increased by a new drive system which permitted movement of the Michelson mirror up to a distance of 5 cm. Third, the motion of the auxiliary mirrors used for calibration purposes was automated.

The observational procedures of this series of measurements followed the procedures established for the 1967 observations from the Harvard Observatory, Hanel *et al.* (1968). During each daily sequence of observations, measurements were obtained of the radiation from (1) blackbodies at room temperature, and about 25 °C warmer, (2) from the sky with and without the telescope, and (3) from the planetary and lunar object. The sky adjacent to the planet was measured in order to eliminate thermal emission from the telescope as well as from the earth's atmosphere. Lunar spectra were taken primarily to be able to remove the effect of absorption within the telescope and within the earth's atmosphere, at least in weak and moderately strong absorbing spectral regions.

Data reduction has progressed to a point where some spectra of Venus are available for inspection. Presented here are the initial results of the thermal emission spectra of Venus in the 10–13 μ region. Calibrated spectra reduced to absolute levels outside the earth's atmosphere and spectra of Mars and Jupiter are being prepared for publication at a later date together with a more detailed description of the observational procedures and instrumentation used.

The spectrum shown in Figure 1 was taken on April 20, 1969, at an instrumental

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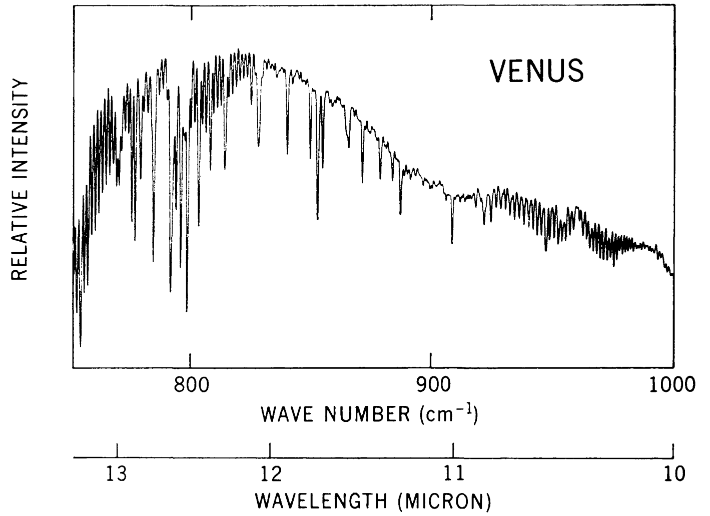

Fig. 1. Relative intensity spectrum for Venus. The spectral resolution is approximately 0.67 cm^{-1}. The spectrum is the average calculated from 32 interferograms and represents approximately 19.5 min of observing time. Telluric water vapor, carbon dioxide, and ozone lines appear in absorption.

resolution of 0.67 cm^{-1}. Displayed is the difference of the spectra obtained while viewing the planet and while viewing the adjacent sky almost simultaneously. The spectrum has been corrected for the responsivity of the interferometer. The spectrum of Figure 1 represents the emission from Venus multiplied by the transmission functions of the earth's atmosphere and the telescope. The planetary diameter was almost

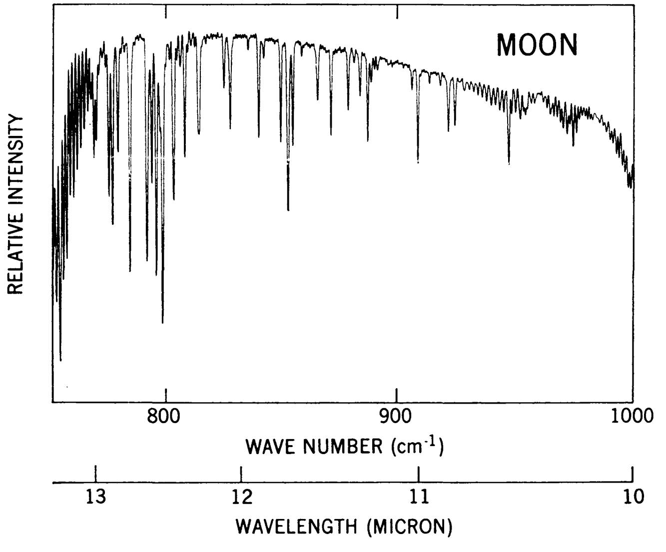

Fig. 2. Relative intensity spectrum for the moon recorded at the same spectral resolution as the Venus spectrum shown in Figure 1.

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56 sec of arc while the circular field of view of the instrument covered only 30 sec of arc. The telescope was set to track the center of the apparent disk. At that time Venus was completely dark except for a small illuminated crescent.

Most of the observed spectral features are associated with the pure rotational lines of water vapor in the earth's atmosphere. The wings of the 667 cm^{-1} CO_2 and 1050 cm^{-1} O_3 telluric bands are evident in the 750 and 1000 cm^{-1} regions respectively.

To correct the Venus spectrum of Figure 1 for the effects of telluric and telescope transmission, a spectrum of a maria area near the center of the illuminated lunar disk was taken, Figure 2. The lunar spectrum was recorded on April 27, and, therefore, the transmission function of the earth's atmosphere may not be the same as it was while observing Venus. The amount of water vapor in the earth's atmosphere during both the Venus and lunar observations was similar and in this very transparent portion of the

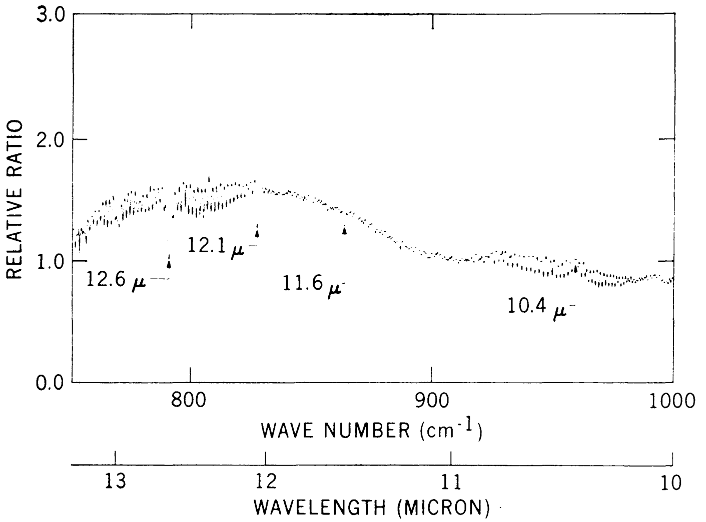

Fig. 3. Ratio of the Venus and lunar spectra of Figure 1 and Figure 2. Four vibration-rotation bands of $^{12}C^{16}O_2$ have been identified and the broad absorption-like feature near 900 cm^{-1} should be noted.

telluric spectrum the telluric transmission functions for both observations should be the same, to a first order of approximation. This is indeed the case as may be seen in the Venus lunar ratio spectrum of Figure 3. The strong water vapor lines visible in the Venus and moon spectrum have disappeared in the ratio spectrum.

The general shape of the ratio spectrum curve and the observed spectral features are due to the emergent radiation from Venus. To date, four upper state $^{12}C^{16}O_2$ bands have been definitely identified at 791.45 ($02^20 \rightarrow 11^10$, 12.6 μ), 828.18 ($03^10 \rightarrow 12^20$, 12.1 μ), 864.51 ($03^10 \rightarrow 20^00$, 11.6 μ), and 960.96 ($10^00 \rightarrow 00^01$, 10.4 μ) cm^{-1}. The first three bands are of the perpendicular type while the latter represents a parallel band. The rotational line structure of the two stronger bands at 791 and 961 cm^{-1} is well-developed at this spectral resolution. The decline of the ratio spectrum in the 750 cm^{-1} region is associated with absorption in the Venus atmosphere from the R branch of the $^{12}C^{16}O_2$ ν_2 fundamental. The appearance of a line structure of the CO_2 bands indicates that the emission comes from a region in the Venus atmosphere where a negative temperature lapse rate exists.

Also apparent in the ratio spectrum is the broad absorption-like feature near 900 cm^{-1} that has previously been seen in the spectra of Sinton and Strong (1960), Hanel *et al.* (1968), and Gillett *et al.* (1968). It has generally been assumed that this depression is due to particles of the cloud layer. Further analysis based on model atmosphere calculations is being pursued.

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