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No. 96 CALIBRATION OF WEAK 1.4 AND 1.9  $\mu$  H<sub>2</sub>O ABSORPTIONS

by G. P. KUIPER AND D. P. CRUIKSHANK

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ABSTRACT

This paper summarizes laboratory measurements of the intensity of the 1.4 and 1.9  $\mu$  water-vapor bands in support of airborne observations of the planets Venus and Mars.

The Venus observations and moon comparisons described in *Comm. LPL* No. 95 require an approximate calibration of the 1.4 and 1.9  $\mu$  bands of water vapor so that the observed absorptions may be converted to abundance. The calibrations must match the astronomical spectra in resolution in order that the measured absorptions refer to the same features. Only a few laboratory spectra were obtained with the interferometer used in the observations of Venus and the moon before it was returned to Cambridge, Mass. These are reproduced in Figure 1. As noted in the legend, the spectra were obtained at the ambient pressure of 70 cm Hg so that the absorption depths may be enhanced by pressure broadening relative to the 200 mb atmospheric records. Record *c* is unduly noisy; records *a* and *b* are a good match for the astronomical records.

All other calibrations were made subsequent to the return of the interferometer, using the A-spectrometer of LPL with a very wide slit so as to simulate the band resolution used in the interferometer. Two sets of records were obtained, one at the ambient laboratory pressure (70.5 cm) and one at the reduced pressure of about 15 cm, corresponding to the 200 mb atmospheric level from which the planetary observations were made. Since the water vapor has a much smaller scale height than the atmosphere at large, even at that level (*Comm. LPL* No. 93,

Table 1), the pressure of 200 mb or 15 cm is considered more representative than the average of 100 mb.

Figure 2 reproduces the records obtained in laboratory air at  $p = 70$  cm with the water-vapor content determined with a wet- and dry-bulb thermometer and a variable air path. Each band is characterized by its three branches, the depths of which can be measured without much ambiguity and should not be dependent on the precise value of the spectral resolution. The results of these depth measures are shown graphically in Figure 3. The central (*b*) branch of the 1.9  $\mu$  band has been omitted since it cannot be used on Venus, owing to the strong CO<sub>2</sub> band 012 and the solar Paschen  $\alpha$  line, which together obliterate the H<sub>2</sub>O absorption.

The curves of growth in Figure 3 have a nearly parabolic shape for amounts in excess of 8–10  $\mu$  of water vapor, i.e., the band intensity increases approximately as the square root of the abundance. The 72  $\mu$  points of Figure 2, though outside the diagram, were measured and used in drawing the dashed curves of Figure 3. Even for smaller amounts some curvature is present. Since pressure broadening extends the linear part of the curve of growth, it follows that pressure effects are present even for these smaller amounts of water vapor, which is not surprising in view of the width and spacing of the

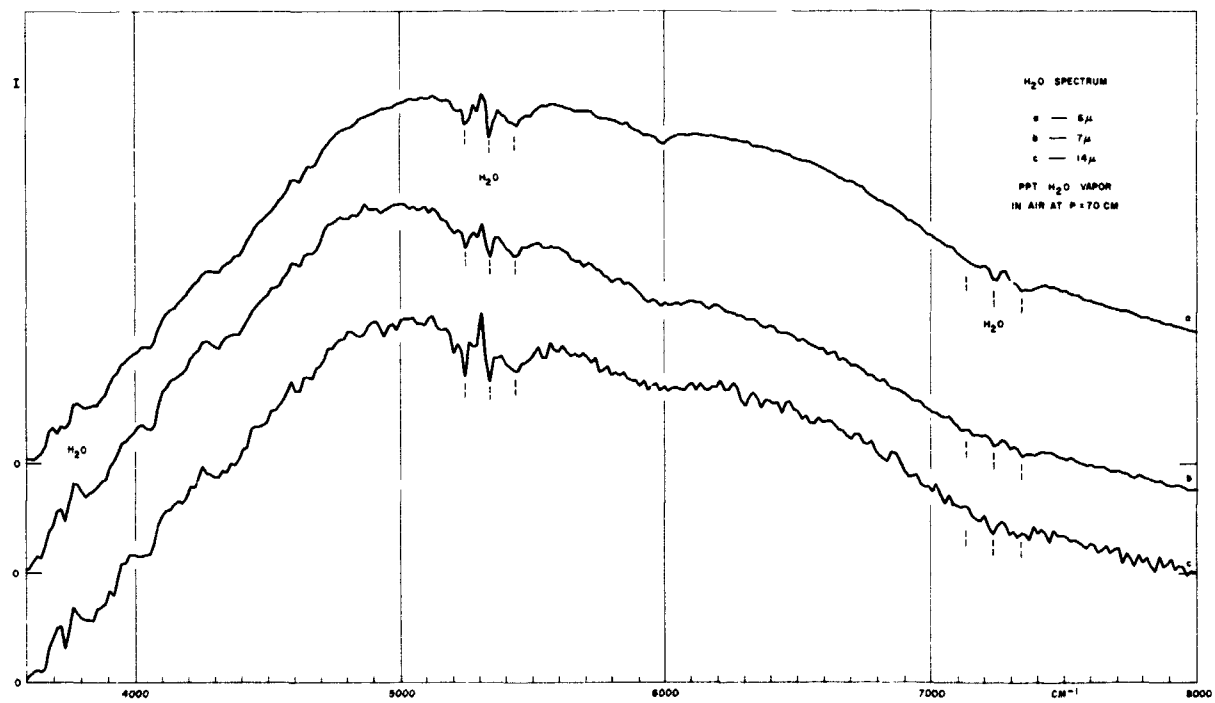


Fig. 1 Sample laboratory spectra of 1.4 and 1.9  $\mu$  bands of  $H_2O$  with Mertz interferometer.

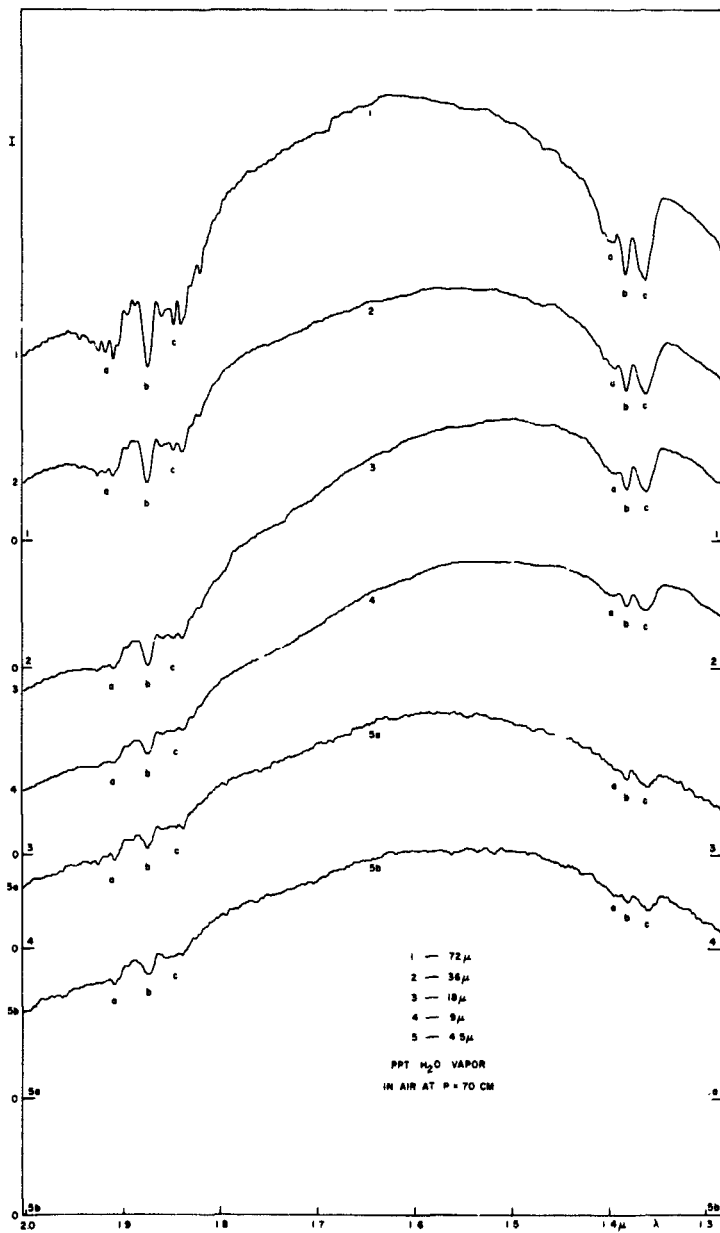


Fig. 2 Laboratory calibration spectra of 1.4 and 1.9  $\mu$  water-vapor bands made at atmospheric pressure using A-spectrometer with adjusted resolution.

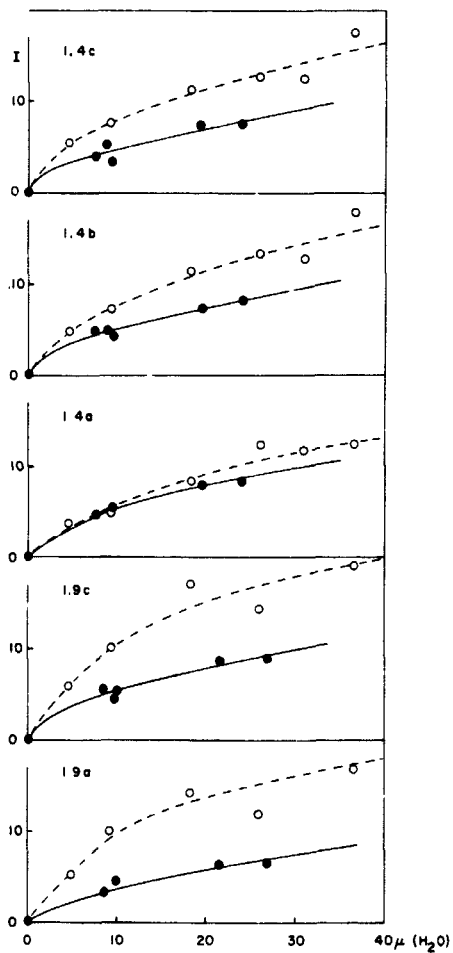


Fig. 3 Curves of growth of five absorption features of water vapor identified in Fig. 2 using two pressures: (1) lower, measures made at 200 mb (solid dots and full-drawn line); (2) upper, measures at ambient laboratory pressure,  $p = 70$  cm, based in part on Fig. 2.

unresolved rotational lines responsible for the bands (in other words, the individual rotational lines are no longer weak even for a shallow band).

The calibrations at  $p = 15$  cm Hg were made with a single-pass tube, 6.76 m long, equipped with pump and manometer; the water-vapor content of the ambient laboratory air was progressively increased by boiling water and measured at the time the air was admitted to the tube.

Normally three records were obtained for each of the following amounts of water vapor per meter in the ambient laboratory air:  $3.7 \mu$ ,  $4.3 \mu$ ,  $4.3 \mu$  (on a second day),  $9.7 \mu$ , and  $12.5 \mu$ . The tube pressures were not quite the same for the  $1.4 \mu$  and  $1.9 \mu$  bands. The percentage absorptions were derived and plotted in Figure 3. The comparatively

small additional abundance due to the 37 cm laboratory air path was multiplied by an extra factor 1.5 to allow approximately for its higher pressure.

It is seen that pressure affects different branches differently, with the intensity ratio at a given abscissa reaching  $\sqrt{p_1/p_2} = 2.2$  in some cases. The pressure effect is small in the  $a$  branch of the  $1.4 \mu$  band.

Calibrations with different resolution will be published as needed in future programs.

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