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INFRARED SPECTRA OF CO_2 IN THE ATMOSPHERES OF EARTH AND VENUS

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The emission and absorption of radiation within a planetary atmosphere – the Earth or Venus, say – depends on the temperature, pressure, and composition of the atmosphere. Conversely, information on atmospheric constituents, temperature, and pressure can be obtained by analyzing infrared spectra.

Flight and ground-based infrared interferometer spectrophotometers (IRIS) have yielded infrared spectra that can be used for purposes of temperature inversion. For temperature inversion of the accuracy desired, the available carbon dioxide lines were insufficient. For example, at one inversion interval in the 15-μm band, a difference of 0.4 μJ (4 ergs) between theoretical and experimental radiance has been eliminated. If this difference were systematic across the entire band, it would result in a 4 K error in the inverted temperature profile in the tropospheric region sampled by this interval, with corresponding pressure errors.

So the lack of molecular lines of weaker bands of carbon dioxide hindered reliable inversion techniques. Derived temperature profiles and surface pressures reflected imprecise knowledge of the atmospheric transmission. Consequently, theoretical calculations were made for a number of these weaker bands. These computations were made to obtain three important molecular parameters, line position, intensity, and shape, necessary to the line-by-line integrating program which yields the theoretical spectra. A good fit to several terrestrial bands of carbon dioxide, including the 15-μm band, confirms the line calculation. A knowledge of the pressure and temperature dependence of the lines allows reliable transmission calculations for Venus at other temperatures, pressures, and in other spectral ranges. The resulting theoretical spectra can be displayed as transmission versus wavelength or as radiance versus wavenumber.

Figure 1 is a plot of the Earth's radiance near Brownsville, Tex., in April 1969 as observed by the Nimbus 3 satellite. The abscissa is wavenumber increasing to the right; the ordinate is radiance. The solid curve is the present theoretical calculation. The dashed curve is the experimental value; the curve is solid where experimental and theoretical agree to within the line width. The dotted curve is the old theoretical radiance; the improved agreement is clear. Blackbody curves are given for reference

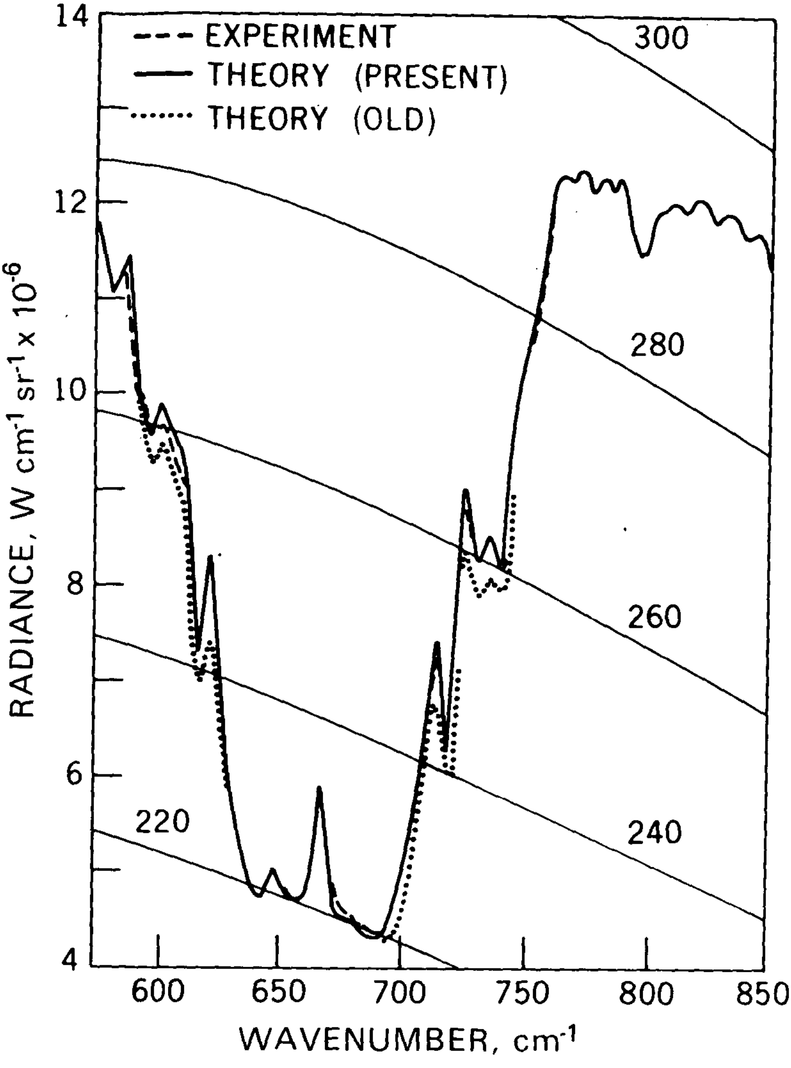

Figure 1–Earth radiance spectrum as determined by theory and as observed by the Nimbus 3 satellite over Brownsville, Tex.

purposes. The structure of the 15-μm band of carbon dioxide is shown in this plot. In the center of the band is the strongly absorbing fundamental; at this point, one is seeing high in the atmosphere. The line shape used in this calculation and the next yields an improved agreement with the observed spectra compared with the simple Lorentz line shape previously assumed. On the high- and low-wavenumber sides of the band, one is seeing lower in the atmosphere; the transmission is greater. Certain spectral intervals on the high-wavenumber side of the band are chosen for purposes of temperature inversion. Very roughly, the idea is to sample different parts of the band to yield, after some calculation, pieces of the temperature-versus-height profile. As can be seen, the agreement in general is very good. We are continuing to investigate the differences; minor constituents may be responsible for some of these.

The plot in Figure 2 is a Venus spectrum taken at McDonald Observatory in Texas. Again, the solid curve is the theoretical calculation and the dashed curve is the experimental. The abscissa is wavenumber increasing to the right; the ordinate is radiance. The smooth curves, once again, are the Planck curves. The vertical shift between experimental and theoretical is a trivial result of calculating the theoretical spectrum with a specific Venus model based on Mariner 5 data. The agreement of line positions and relative intensities is generally very good. The differences in slope reflect interesting features of the Venus atmosphere which we are continuing to elucidate. By introducing carbon dioxide lines having the same modified Lorentz shape as in the Brownsville case, the slope of the falloff in the theoretical calculation at a wavenumber of 750 has come to more nearly agree with the experimentally observed shoulder.

In conclusion, the improvement in the transmission calculation is important for interpretation of infrared measurements made from the Nimbus 3 satellite and from the ground, as well as from spacecraft such as Mariner and possibly Planetary Explorer.

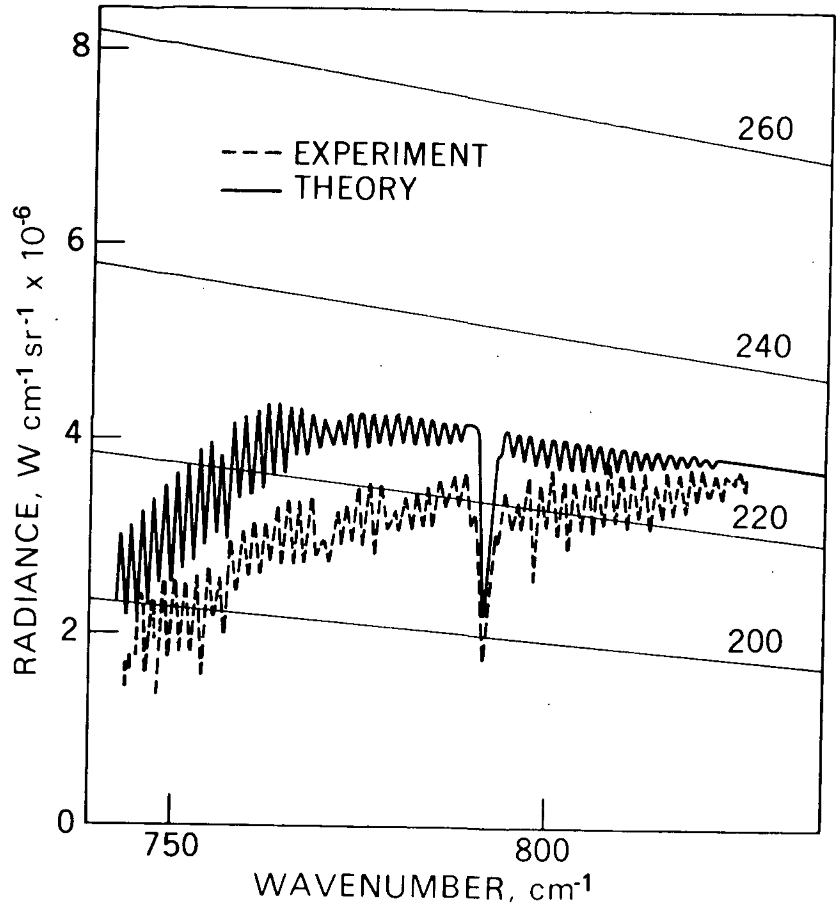

Figure 2—Venus radiance spectrum as determined by theory and as observed from McDonald Observatory.