HIGH-RESOLUTION OBSERVATION OF THE VENUS DAYGLOW SPECTRUM 1250-1430 Å

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ABSTRACT

The spectrum of the dayglow of Venus between 1250 and 1430 Å has been measured in high-resolution with the International Ultraviolet Explorer. Seven exposures which were made with the short wavelength camera in the high-dispersion mode using the large aperture were combined to give a total exposure time of 309 min. The atomic oxygen lines at 1302.2, 1304.9, 1306.0, and 1355.6 Å are present. In addition, the (14,3) and (14,4) bands of the carbon monoxide fourth positive system at 1317 and 1354 Å respectively are identified. These bands are compared with synthetic spectra, showing the excitation mechanism to be fluorescent scattering of solar Lyman alpha radiation.

INTRODUCTION

From April to August of 1979 the Pioneer Venus Orbiter Ultraviolet Spectrometer obtained spectra of the Venus dayglow at a resolution of 13 Å. Figure 1 shows a portion of a sum of 480 of these spectra which were obtained at illumination, emission, and phase angles less than 60°. The data are shown as the solid curve. The identification in these data of carbon monoxide fourth positive bands (CO4+) in the (14,v") progression resolved some long-standing uncertainties in the interpretation of the Venus dayglow (Durrance, et al., 1980). A synthetic spectrum of this progression is shown as the dotted curve. A prominent unblended feature in this spectrum was identified as the CO4+ (14,5) band at 1392 Å. The (14,3) and (14,4) bands at 1317 and 1354 Å are blended with atomic oxygen (OI) 1304 and 1356 Å lines, and were identified through inference.

We present here a high-resolution spectrum of the Venus dayglow in which the atomic oxygen and carbon monoxide features are resolved. The spectrum was obtained from observations made with the International Ultraviolet Explorer satellite (IUE) at a resolution of about 0.4 Å. It is also shown that the theory of the excitation mechanism as scattering of solar Lyman alpha is consistent with the shape of the observed CO4+ bands.

OBSERVATIONS

Venus is a particularly difficult object to observe with IUE. It is outside the restricted region around the sun only near its greatest elongation when its visual magnitude is about -4. This extreme brightness saturates the Fine Error Sensor (FES) tracking system so that it is not possible to automatically track during an observation or to point precisely at a location on the disk.

Tracking is accomplished by calculating the drift rate of the planet with respect to the stars in spacecraft-centered coordinates and converting these to spacecraft gyro rates. The precise location of the planet is then determined by minimizing the figure of scattered light in the FES image after the crescent of Venus is placed over the large entrance aperture of the spectrometer. The image of Venus is only slightly larger than the aperture so a substantial reduction in the reflected light for the FES camera is seen. It is estimated that the center-of-light can be found with this technique to an accuracy of about ± 2 arc sec.

On April 12, 1980, during the time of Eastern elongation, a series of 7 exposures were made with the short wavelength camera in the high-dispersion mode using the large aperture. Exposure times varied from 20 to 60 min. with a total exposure time of 309 min. To minimize the effects of drift during each observation, the exposure was stopped periodically while the scattered light figure in the FES image was recentered and then the exposure was continued. Also for some of these observations the large aperture was offset toward the bright limb in order to enhance the airglow intensity relative to that of the disk.

A large background is present in these spectra as can be seen in Figure 2 which shows a portion of the sum of the gross spectra for all 7 observations. Altogether 7 overlapping echelle orders are shown which cover the region from 1280 to 1380 Å. The data shown here have been smoothed with a 9-point running average and are overplotted with the estimated background which was determined as follows: Since the spectrum is expected to have no continuum, or at most a very weak one, the spectra are assumed to consist only of emission lines plus a large background. Order 107 was assumed to consist of background only which was determined as a 25-point smooth of the data, after the removal of any reseaux. This background was then used to mask out the emission lines in order 106; that is, the background for order 106 was then determined as a 25-point smooth of the data excluding any points which were higher than the background of order 107 by an amount that was determined visually. This process was then repeated for successive orders, each time using the background of the adjacent order to form a mask.

THEORY AND DISCUSSION

Since carbon monoxide is present in the Venus upper atmosphere (Niemann et al., 1979), fluorescent scattering of solar radiation is a plausible excitation mechanism to explain its airglow emissions (Barth, 1969). In particular Kassal (1976) has shown that the scattering of solar Lyman alpha by the CO4+ (14,0) band is comparable to or greater than the scattering by the rest of that system for CO column densities $\sim 10^{17} cm^{-2}$.

A high-resolution synthetic spectrum of the CO4+ (14,v") progression which assumes fluorescent scattering of solar Lyman alpha as the excitation mechanism has been produced. The details of this spectral synthesis are given in an earlier paper (Durrance et al., 1980) and will not be included here.

The data minus the fitted background are shown in Figure 3. The OI 1302.2, 1304.9, 1306.0, and 1355.6 lines are resolved and easily visible in this spectrum. A reseau at the position of the 1302.2 line has been removed so the relative intensity of this line is not accurately indicated here. A synthetic spectrum of the CO4+ (14,3) and (14,4) bands is shown plotted below the data and is offset for clarity. They are both resolved although the (14,4) band is not completely separated from the OI 1355.6 line. The agreement in position, shape, and relative intensity is quite good.

Agreement between theory and data is shown with more detail for the (14,4) band in Figure 4. The high-resolution synthetic spectrum has been degraded to 0.4 Å resolution using a rectangular slit function to agree with the data. The atomic line, using the same procedure for degrading the resolution, is also included for comparison. In this figure the data have been filtered with a low pass filter and the synthetic spectrum is normalized to the data. It can be seen here that the agreement between theory and data is quite good although there does appear to be a small discrepancy in the intensities of the satellite branches.

CONCLUSIONS

With IUE it has been possible to obtain high-resolution spectra of the Venus dayglow in the 1250-1430 Å range which resolve the CO4+ (14,3) and (14,4) bands from the OI 1304 and 1356 Å lines. Comparison of these CO bands with synthetic spectra confirms the conclusion that they arise as a result of the fluorescent scattering of solar Lyman alpha.

REFERENCES

Barth, C.A., "Planetary Ultraviolet Spectroscopy", Appl. Opt., 8, 1295-1304, 1969.

Durrance, S.T., C.A. Barth, and A.I.F. Stewart, "Pioneer Venus Observations of the Venus Dayglow Spectrum 1250-1430 Å", J. Geophys. Res., 7, 222-224, 1980.

Kassal, T.T., "Scattering of Solar Lyman-Alpha by the (14,0) Band of CO", J. Geophys. Res., 81, 1411-1412, 1976.

Neimann, H.B., R.E. Hartle, W.T. Kasprzuk, N.W. Spencer, D.M. Hunten and G.R. Carigan, "Venus Upper Atmosphere Neutral Composition: Preliminary Results from the Pioneer Venus Orbiter", Science, 203, 770-772, 1979.

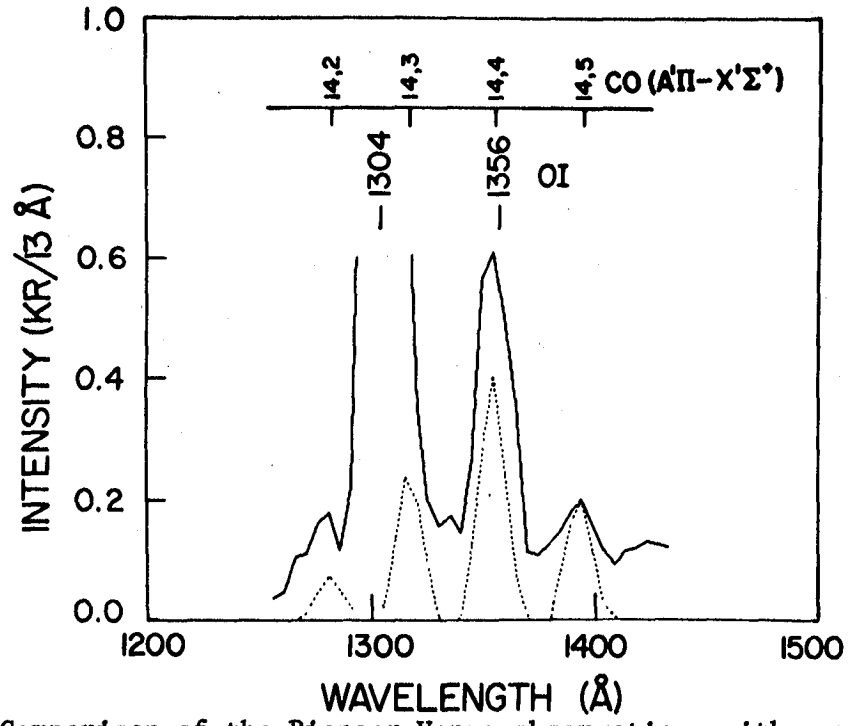

Figure 1. Comparison of the Pioneer Venus observations with a synthetic spectrum of the CO4+ (14,v") progression. The solid curve is the observations, which were obtained at illumination and emission angles less than 60°, and the dotted curve is the synthetic spectrum degraded to 13 Å resolution.

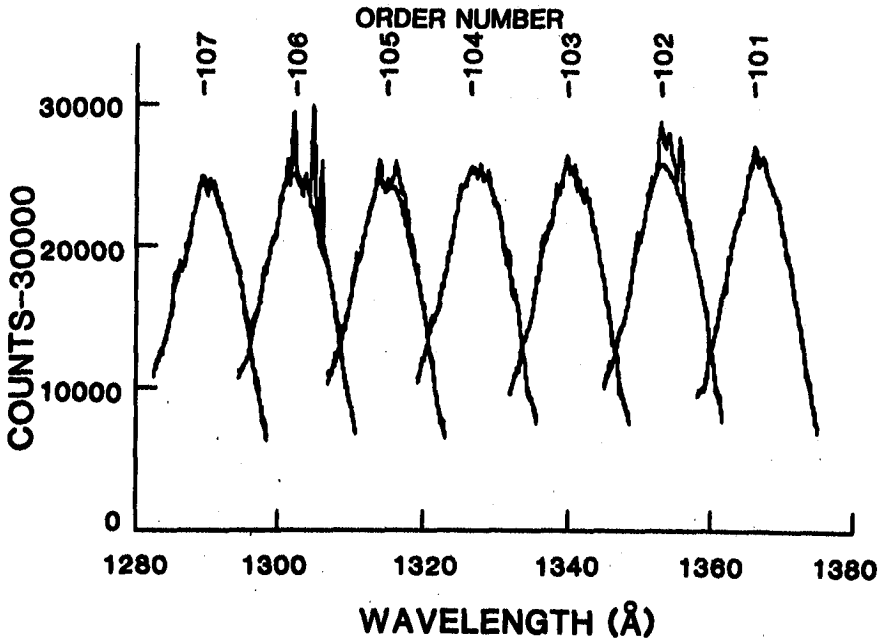

Figure 2. IUE spectrum of the Venus dayglow 1280-1380 Å. This is a sum of 7 different observations for a total exposure time of 309 min., using the short wavelength camera in the high-dispersion mode with the large aperture. The fitted background is shown as the smooth curve.

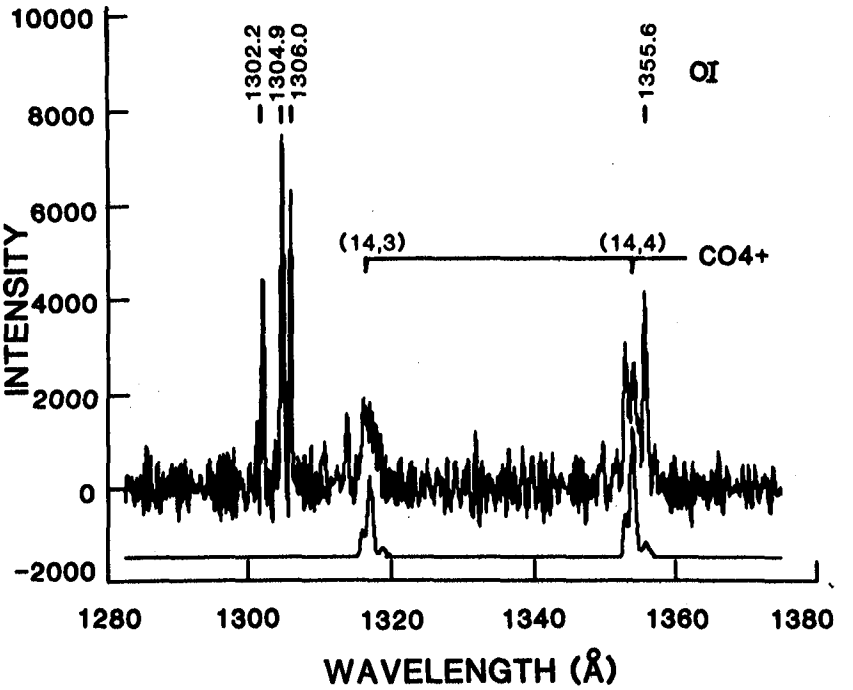

Figure 3. Comparison of the CO4+ (14,v") progression with the observations. The jagged curve is the data minus background. The solid curve is the synthetic spectrum degraded to 0.4 Å resolution and offset for clarity.

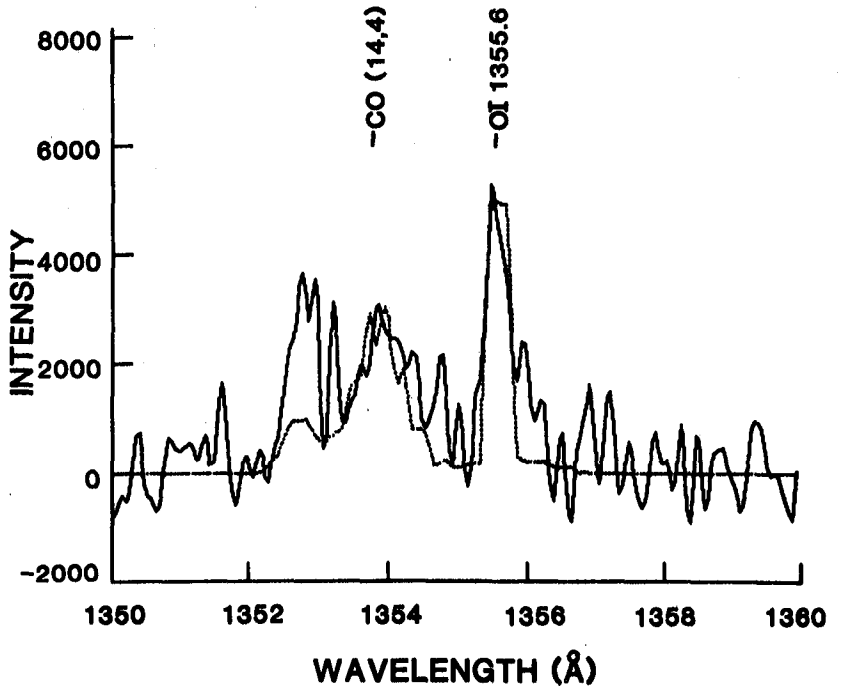

Figure 4. Comparison of the synthetic spectrum of the CO4+ (14,4) band and the OI 1355.6 line with the observations. The solid curve is the data and the dotted curve is the theory.