Sulfur Dioxide and Carbon Disulfide in the Venus Clouds

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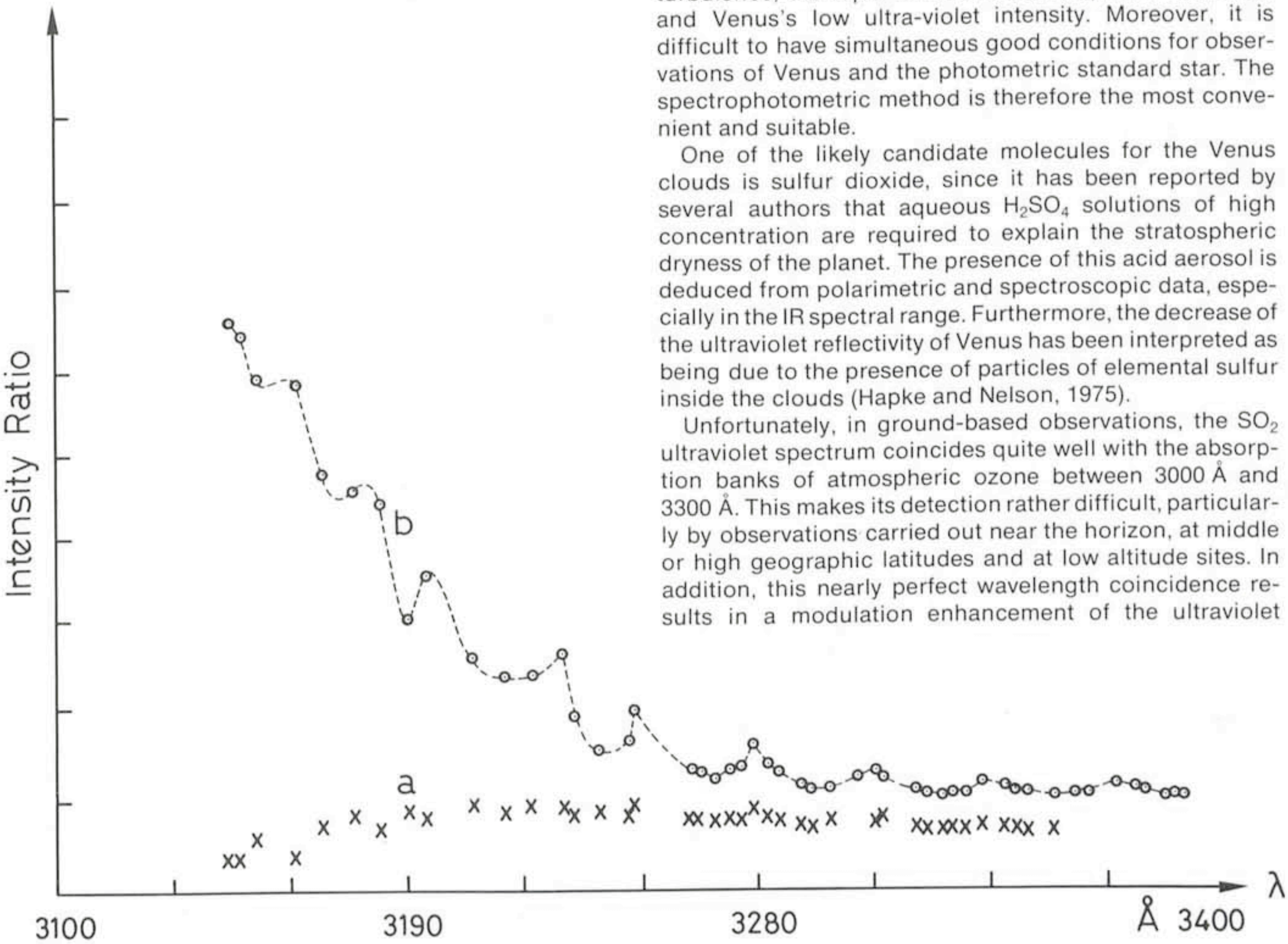
Exciting results were obtained from the Pioneer Venus spacecraft as it reached our mysterious neighbour planet in late 1978. In contrast to our own life-supporting, oxygen-rich atmosphere, that on Venus is dense, hot and poisonous. Spectroscopic observations near the atmospheric cut-off at 3000 Å were recently made at La Silla by Drs. C. T. Hua and G. Courtès (Laboratoire d'Astronomie Spatiale, Marseille), together with Dr. N. H. Doan (Observatoire de Lyon), showing for the first time that there may be carbon disulfide in the Venus clouds, adding a compelling malodorous reason for not going there!

We have recently obtained very interesting spectroscopic data concerning the clouds on Venus, in the range of 3100–3300 Å and with a resolution better than 2.5 Å/mm. The observations were carried out by means of a scanner attached at the Cassegrain focus of the ESO 1.52 m telescope, on January 27, 1979.



The ultraviolet spectrum of Venus, as observed with the ESO 1.52 m telescope. Tracing (b) shows the intensity ratio (Venus/sky background) and the absorption bands in the Venus atmosphere. The crosses (a) indicate the ratio between two separate sky measurements (see text) and that the effects of the ozone absorption bands in the terrestrial atmosphere have been cancelled.

A detailed examination of the spectra seems to indicate the presence of carbon disulfide (CS_2), rather than sulfur dioxide (SO_2) as previously thought; this conclusion is based on an extensive investigation of the UV absorption of SO_2 and CS_2.

A preliminary study concerning the optimization of the optical arrangement for the VENERA experiment of the Service d'Aéronomie and CNES proposed by Prof. J. E. Blamont facilitated our choice of the best observational parameters for our present investigation of the Venus clouds. In particular, it was found that the contrast in the UV spectral range near 3300 Å appears to pass through a maximum; this was deduced by examining various filtered photographs obtained at the Pic-du-Midi Observatory. However, until recently few ground-based or space experiments have been carried out with the aim of explaining the reason for this increase in contrast, i.e. why the clouds are better visible in this spectral range, i.e. near the atmospheric cut-off at 3000 Å.

In order to identify the nature of the absorbing molecular bands which are the probable cause of this contrast phenomenon, the best method is evidently to analyse high-resolution spectra. This is because direct photographs from the ground are limited by the atmospheric turbulence, the rapid variation of atmospheric extinction and Venus's low ultra-violet intensity. Moreover, it is difficult to have simultaneous good conditions for observations of Venus and the photometric standard star. The spectrophotometric method is therefore the most convenient and suitable.

One of the likely candidate molecules for the Venus clouds is sulfur dioxide, since it has been reported by several authors that aqueous H_2SO_4 solutions of high concentration are required to explain the stratospheric dryness of the planet. The presence of this acid aerosol is deduced from polarimetric and spectroscopic data, especially in the IR spectral range. Furthermore, the decrease of the ultraviolet reflectivity of Venus has been interpreted as being due to the presence of particles of elemental sulfur inside the clouds (Hapke and Nelson, 1975).

Unfortunately, in ground-based observations, the SO_2 ultraviolet spectrum coincides quite well with the absorption banks of atmospheric ozone between 3000 Å and 3300 Å. This makes its detection rather difficult, particularly by observations carried out near the horizon, at middle or high geographic latitudes and at low altitude sites. In addition, this nearly perfect wavelength coincidence results in a modulation enhancement of the ultraviolet spectrum of the Venus clouds, the intensity of which is already very weak at the limit of transparency of the terrestrial atmosphere.

However, a previous study by Barker et al. (1975) reported the presence of a broad absorption feature between 3200 Å and 3100 Å, from relatively low resolution spectra (10 Å). But no identification of the clouds was made. Recently, Young (1979), discussing these above data, suggested that the 3150 Å band could be attributed to carbon disulfide (CS_2).

The Observations

We observed the ultraviolet spectrum of the Venus clouds by means of a scanner with a rather higher resolution (2.5 Å). Our recent report (Hua et al., 1979) also described a method allowing us to derive the intrinsic spectrum of the planet despite the strong terrestrial ozone absorption and thus to measure the absorption bands, presumed attributable to SO_2. At the same time, Stewart et al. (1979), in an article concerning preliminary results from the NASA Pioneer Venus Orbiter, found two broad absorption features near 2100 and 2800 Å, fitting well the known SO_2 absorption bands. The main advantage of our study, however, is the use of a scanner with a higher resolution that is capable of resolving the individual molecular bands (spaced at about 20 Å interval), as compared to the 13 Å resolution of the Pioneer UV spectroscopy.

Tracing (b) in figure 1 shows the ratio I_λ (Venus)/I_λ (sky background) plotted against wavelength, as obtained on January 27, 1979, with a photoelectric scanner attached at the Cassegrain focus of the ESO 1.52 m telescope. Since the atmospheric ozone absorption (the origin of the atmospheric cut-off at 3000 Å) influences the sky background spectrum as well as that of Venus, the intensity ratio of two sky background spectra, one recorded near Venus and the other near the western horizon at the same zenith distance, should be the same for all wavelengths, cf. tracing (a). The small residuals we observe can be ascribed to local differences in the thickness of the ozone layer. Hence, the absorption features that are seen in the Venus/sky ratio (b), are only attributable to the Venus clouds. Two of the absorption bands are centred at 3150 and 3170 Å and coincide with known SO_2 bands. But the strongest SO_2 bands are observed at somewhat shorter wavelengths and it therefore appears that it is more reasonable to connect the observed features at 3150, 3190, 3204, 3235 and 3275 Å to CS_2, involving the vibrational structure. The electronic absorption spectrum of CS_2 has been extensively investigated in the past, cf. the V-system in the 2900–3300 Å range.

We presently need more observations to confirm the above preliminary conclusion. It would be worth while to extend this kind of analysis to longer wavelengths. We are now examining several 3 Å/mm coudé spectra from the 1.52 m telescope of good quality (taken by P. Bouchet and N. Bahamondes) and we hope soon to be able to present further details.

References

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NEWS and NOTES

Spectra from the ESO Schmidt Telescope

One of the most efficient means for astronomical spectroscopy is the objective-prism method, cf. the work at the GPO astrograph described in this issue of the *Messenger*, pages 10 and 29.

One of the largest objective-prisms in the world is the 1 m ultraviolet-transparent prism at the ESO Schmidt telescope. This prism gives a dispersion of about 450 Å/mm near Hγ at 4340 Å. It was provided for stellar spectroscopy and has already proved its great value in connection with extensive classification programmes.

With a moderately high dispersion in the blue and violet, the ESO prism still has a reasonable dispersion in the red, about 1500 Å/mm between 5000 and 7000 Å. It is therefore an extremely useful device for search programmes that aim at finding objects with f. inst. Hα-emission at 6563 Å and it has already yielded many new planetary nebulae and other emission objects in the Milky Way.

Now, however, it appears that there is an even more important field for the ESO Schmidt telescope. For several years now, quasars have been found with the smaller Curtis Schmidt telescope at Cerro Tololo, just south of La Silla, and in Australia with the SRC 48" Schmidt telescope at Siding Spring. These quasar searches were carried out by means of IIIa-J plates, which are sensitive to blue light and with prisms of relatively low dispersion (1800 to 2400 Å/mm near Hγ). For this reason, all of the quasars that have been found have redshifts less than about 3.5, corresponding to the Lyman α line at 1216 Å redshifted to about the red limit of the III a-J emulsion, near 5500 Å.

Searches for quasars with higher redshifts have not been possible with these telescopes, because of the very low dispersion of their prisms in the red. But, of course, the results in the blue have already had a profound impact on our knowledge about quasars, and more than half of the known quasars have been found with them, including some of the most intriguing ones with absorption lines, etc. However, the 1 m Schmidt telescope at La Silla has a sufficient dispersion (or rather resolution) in the red to make a high-redshift quasar search possible. In addition to the dispersion, the large field (5.5 × 5.5 degrees) and the faint limiting magnitude are important parameters because nobody expects to find many high-z quasars (if any at all). Remembering that the redshift, according to the majority of astronomers, is a measure of distance, it therefore seems as if the ESO Schmidt has a unique potential for looking further out into the vast expanses of the Universe than most other telescopes.

The first very deep plates have now been obtained. 180-minute exposures on red-sensitive IIIa-F emulsion show a wealth of objects of different spectral classes and are now being searched by a number of astronomers, in ESO and outside. No high-z quasars have been found so far, but the search has just begun. It is probable that any Lyman α-emission lines near 6000 Å or further to the red will be very broad and maybe also rather shallow. Unfortunately, the IIIa-F emulsion is not equally sensitive to all wavelengths, there are spectral regions where it is particularly sensitive and which therefore appear as "humps" on the otherwise "flat" spectra. These features can easily be confounded with emission features, and careful measurements are necessary to confirm whether they are intrinsic, i.e. belong to the astronomical