Martian Dust Storm: Its Depth on 25 November 1971

Abstract. *Carbon dioxide absorption on Mars was observed by Earth-based spectroscopy at 10,500 angstroms. Its abundance was equivalent to a partial pressure of 2.0 millibars instead of the normal 5.5 millibars. The dust layer was therefore opaque to a height of about 11 kilometers. On 10 December, a pressure of 5.8 millibars was found.*

Early data from the Mars orbiter Mariner 9 indicate a planetwide dust storm, filling perhaps the entire troposphere. Such a deep layer of dust can be expected to hide an appreciable fraction of the CO_2 atmosphere from Earth-based spectroscopy. This expectation is confirmed by the present measurements, whose simplest interpretation is that, on 25 November 1971 (U.T.), the "top" of the opaque cloud was one scale height (about 11 km) above the surface.

Measurements of the CO_2 band at 1.05 μm were made with an S-1 photomultiplier at the 13.7-m spectrometer of the McMath solar telescope on Kitt Peak. The techniques were essentially those used (*1*) at the 1967 opposition, except that no image stabilizer was available. The region from 10,490 to 10,499 Å (corrected for the Doppler shift between Mars and the earth) was divided into 1024 channels and scanned repeatedly for a total time of 220 minutes. The resulting spectrum is shown in Fig. 1 (*2*), and the equivalent widths are fitted to a curve of growth (*3*) in the inset. Included for comparison are the 1967 results for the same eight lines; there is a striking difference, even though the air mass factor is greater by a factor of about 1.35 for the 1971 data. The apparent amount of CO_2 is found to be $\eta N = 78.5 \pm 15$ m-atm; with an air mass $\eta = 2.8 \pm 0.2$, the abundance, N, of CO_2 is 28 ± 6 m-atm, corresponding to a partial pressure of 2.0 mb at the bottom of the column. The surface pressure found in 1967 was 5.5 mb. [It seems preferable to use the Kitt Peak result for comparison; other measurements (*4*) made that year are in good agreement.]

A second spectrum was obtained on 10 December (*5*). If plotted on the inset of Fig. 1, the equivalent widths would appear between $\tau_0 = 3.0$ and 4.1. The increase from the 1967 values is almost entirely due to the larger air mass factor. We now find $\eta N = 228 \pm 45$ m-atm and a partial pressure of 5.8 ± 1.2 mb. It is natural to assume that this is the surface pressure, essentially unchanged since 1967. We will adopt the old value because of its smaller probable error. The CO_2 abundance on 25 November was reduced by a factor 1/2.75, almost exactly $1/e$. Thus, if the dust cloud had a well-defined top, the height of this top was equal to the scale height, or 11 km at 220°K. If the cloud was hazy it must have extended even higher. The effective surface of an absorbing haze is at an optical depth of around unity (perhaps somewhat less for reflected solar radiation). In principle, a scattering haze could increase the path length of light through the gas by a considerable factor. This effect seems unlikely to be important for a Martian dust storm, which is surely composed of dark surface material. Another possibility, though still rather unlikely, would be a high scattering layer of CO_2 or H_2O crystals, as reported by Mariners 6 and 7 (*6*). Such a layer would have to scatter a large fraction of the incident light to be effective, whereas the observed layers are barely visible even at the horizon. In any case, such an interpretation would raise still more the height deduced for the top of the dust.

These two observations differ in time by 15 days, and in longitude by 152°. More work will be needed to decide whether the dust has subsided for good, or is merely patchy.

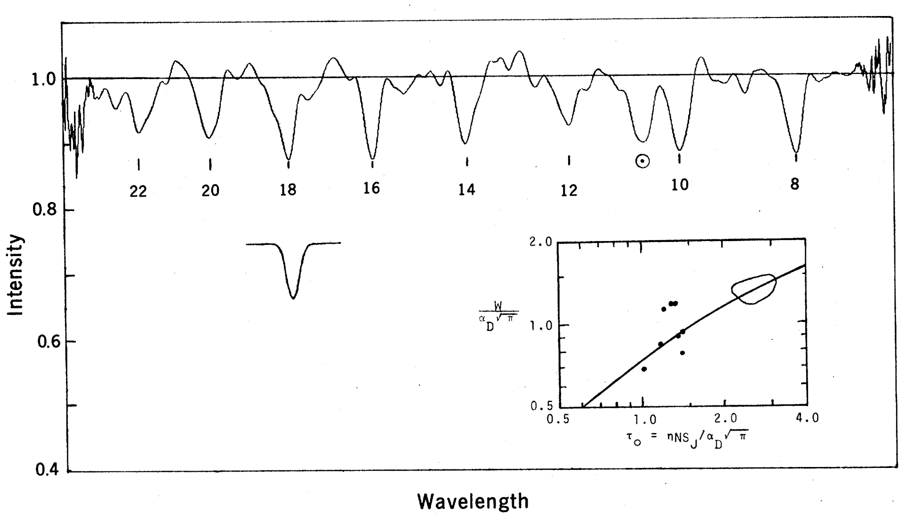

Fig. 1. The Mars spectrum of 25 November, showing the CO_2 lines with rotational quantum numbers *J*, and one solar line. The small inset shows the final instrumental profile after numerical smoothing. In the large inset, the points are the observed equivalent widths, fitted to a theoretical curve of growth; the fit gives the projected CO_2 abundance ηN. The symbols are explained in (*3*). The irregular curve encloses the equivalent points from the 1967 spectrum (*1*).

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References and Notes

1. M. J. S. Belton, A. L. Broadfoot, D. M. Hunten, *J. Geophys. Res.* **73**, 4795 (1968).
2. Initial and final times were 0203 and 0635 U.T.; the mean longitude of central meridian was 190°. Seeing was moderately poor; it is estimated that the effective field of view was about half the planetary diameter, or 5 arcsec; the corresponding air mass factor is $\eta = 2.8 \pm 0.2$. The spectrum of Fig. 1 contains about 370 counts per channel before smoothing, which was done by convolution with a Gaussian function of 12-channel half-width (except at the ends). The stray light was assumed to be 7 percent, as in 1967 (*1*), and the dark current was 2 percent. The measured equivalent widths, in milliangstroms, are 22, 23, 16, 18, 18, 23 17, and 14 for the lines 8 to 22, and 25 for the solar line at 10,496 Å, in excellent agreement with the solar spectrum.
3. The curve of growth is figure 3 of reference (*1*). The Doppler width α_D is $\lambda_0 U/c$, where λ_0 is the wavelength, c the speed of light, and $U = (2kT/m)^{\frac{1}{2}}$ is the most probable thermal speed. The strengths S_J are for an assumed temperature of 220°K and a band strength of 6.63×10^{-5} cm^{-1} (cm-atm)$^{-1}$ [D. E. Burch, D. A. Gryvnak, R. R. Patty, *J. Opt. Soc. Amer.* **58**, 335 (1968)].
4. L. P. Giver, E. C. Y. Inn, J. H. Miller, R. W. Boese, *Astrophys. J.* **153**, 285 (1968), 4.4 mb; N. P. Carleton, A. Sharma, R. M. Goody, W. L. Liller, F. L. Roesler, *Astrophys. J.* **155**, 323 (1969), 5.9 mb.
5. Initial and final times were 0143 and 0613 U.T.; the mean longitude of central meridian was 38°. The counting rate was down by a factor about 0.6 and the dark current was negligible. The measured equivalent widths are 30.6, 24.1, 28.3, 35.2, 28.7, 25.6, 32.1, 25.2, and 22.1 mÅ for $J = 8$ to 24 and 21.8 mÅ for the solar line.
6. C. B. Leovy, B. A. Smith, A. T. Young, R. B. Leighton, *J. Geophys. Res.* **76**, 297 (1971).
7. Kitt Peak National Observatory is operated by the Association of Universities for Research in Astronomy, Inc., under contract with NSF.

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