AN ATTEMPT TO DETECT WATER-VAPOR AND OXYGEN LINES IN THE SPECTRUM OF MARS WITH THE REGISTERING MICROPHOTOMETER[1]

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ABSTRACT

Observation of water-vapor and oxygen in the spectra of Mars and the sky.—If these gases are present in the atmosphere of Mars, the motion of the planet with reference to the earth should produce a relative displacement of the lines due to these gases in the two spectra.

Material.—Spectrograms of Mars and the sky were made with a 6-prism spectrograph, the scale being 1 mm = 7.3 A at D; graphs were drawn by a registering microphotometer on a scale of 1 mm = 0.12 A.

Method of measurement.—The lines of water-vapor and oxygen in the graphs of the two spectra were superposed; the relative displacements of the solar lines were then read directly from the curves.

Results.—The water-vapor lines in the spectrum of Mars were displaced 0.03 ± 0.01 A, and the oxygen lines 0.09 ± 0.03 A to the red, with respect to their positions in the sky spectrum. On taking account of the Doppler displacement, the length of path in the two atmospheres, and the amounts of water-vapor and oxygen above Mount Wilson, the quantity of water-vapor in the atmosphere of Mars, area for area, was found to be approximately 3 per cent of that over Pasadena, and the quantity of oxygen two-thirds of that above Mount Everest.

Before red-sensitive photographic plates were available, observations of the oxygen and water-vapor lines in the spectrum of Mars were necessarily visual. The first spectrograms covering the B-band of oxygen and the *a*-band of water-vapor[2] were made by V. M. Slipher in 1908.

Professor Very made photometric measurements of the relative intensity of the bands on Slipher's spectrograms and concluded that the atmosphere of Mars contained 1.75 times as much water-vapor as the atmosphere of the earth above Flagstaff and that the *B*-band of oxygen was 15 per cent stronger than in the spectrum of the moon at the same altitude.[3]

Campbell, from the equality of the *a*-band in spectrograms of Mars and the moon taken on Mount Whitney, came to the conclusion that the quantity of water-vapor in the atmosphere of Mars

[1] *Contributions from the Mount Wilson Observatory*, No. 307.

[2] *Astrophysical Journal*, **28**, 397, 1908.

[3] *Lowell Observatory Bulletins*, Nos. 36 and 41, 1909.

at the time of his observations was too small to be detected by the spectroscopic methods then available.[1]

The Doppler-Fizeau principle was applied by Lowell and Slipher with low dispersion in an attempt to detect lines originating in the atmosphere of Mars from their displacement with respect to similar lines originating in the atmosphere of the earth. They concluded that their measures neither proved nor disproved a displacement due to the motion of Mars relative to the earth.[2]

Campbell and Albrecht employed much higher dispersion and found for water-vapor lines near D a displacement of 19.2 km/sec. and for the α-band of oxygen 18.1 km/sec., the displacement due to relative motion being 19.1 km/sec. They concluded that the water-vapor in the atmosphere of Mars was less than one-fifth that above Mount Hamilton and that the quantity of oxygen was small compared to that in the earth's atmosphere.[3]

The primary purpose of our observations was to test the applicability of the Doppler-Fizeau principle to this problem by the use of a spectrograph of higher dispersion and the registering microphotometer. The spectrograms of Mars and of the sky were taken with a 6-prism wooden spectrograph placed on a pier in the constant temperature room at the coudé focus of the 60-inch reflector. The scale of the original spectrograms was 1 mm = 7.3 A at D and 11.4 A at λ 6300. The scale of the graphs drawn by the registering microphotometer was 1 mm = 0.12 A at D and 0.19 A at λ 6300. The spectrograms were made on February 2, 1925, at a time when the relative velocity of Mars and the earth was considerable.

Mars.....$5^h\ 35^m$–$9^h\ 20^m$ P.S.T.	Exp. 225 min.
Sky.....$3^h\ 10^m$ P.S.T.	Exp. 30 sec.
Slit width.....	0.075 mm
Length of path in atmosphere of Mars (sec z).	2.2
Length of path in atmosphere of Earth (sec z).	1.4
Relative velocity.....	+17.80 km/sec.
Velocity displacement at D.....	0.35 A
Velocity displacement at λ 6300.....	0.37 A

[1] *Lick Observatory Bulletins*, No. 169, 1909.

[2] *Lowell Observatory Bulletins*, No. 17, 1905.

[3] *Lick Observatory Bulletins*, No. 180, 1909.

Water-vapor.—The measurements were made by superposing successively the 6 water-vapor lines

λ 5879.820		λ 5887.560
5879.945	λ 5886.193	5887.620
		5887.905
λ 5887.445		
5887.880	λ 5919.860	λ 5920.776

in graphs of the spectra of Mars and the sky over millimeter cross-section paper and reading with a magnifier the distances between the lines of solar origin, λλ 5884, 5893, 5905, 5914, and 5922, on the two graphs. The means of the two observers were 2.6±0.13 mm and 2.7±0.10 mm, respectively, the final weighted mean being 2.67±0.08 mm, equivalent to 0.32±0.01 A.

The displacement of 0.35 A, due to relative motion, *minus* the measured displacement 0.32 A, is 0.03 A and represents the displacement to the red of the water-vapor lines in the combined Mars-sky spectrum due to water-vapor in the atmosphere of Mars. When the displacement is small compared with the width of the lines, as was the case on these graphs, the approximate relation

$$\Delta\lambda = (1 + K_1/K_2)\delta$$

is applicable, where K_1 and K_2 are the intensities of the lines in the atmospheres of the earth and Mars, respectively. When $\Delta\lambda$ is 0.35 A and δ is 0.03 A, K_2 is 0.09 K_1.

The component of the water-vapor lines due to Mars in the Mars-sky spectrum at the time of observation was 9 per cent as strong as the component due to the water-vapor in the earth's atmosphere. The precipitable water above Mount Wilson at 5 P.M. on the day of observation was 0.73 cu. cm, for the preceding day 0.74 cu. cm, and for the following 0.75 cu. cm, or one-half that over Pasadena at noon for the same days. Taking into consideration the paths traversed in the two atmospheres, we find that the quantity of water-vapor in the atmosphere of Mars, area for area, was 6 per cent of that over Mount Wilson and 3 per cent of that over Pasadena. This indicates extreme desert conditions over the greater portion of the Martian hemisphere toward us at the time, which was

near the beginning of the Martian spring, or about 2.5 Martian months after the solstice.

Oxygen.—Similar measurements were made with the oxygen lines.

λ 6276.815	λ 6277.513	λ 6279.084	λ 6295.389
6277.021	6277.634	6279.308	6296.170
	6277.701		6310.101
	6277.837		

The mean displacement of the solar lines λλ 6265, 6270, 6298, 6301–2, 6322, and 6339, referred to the oxygen lines in the Mars-sky

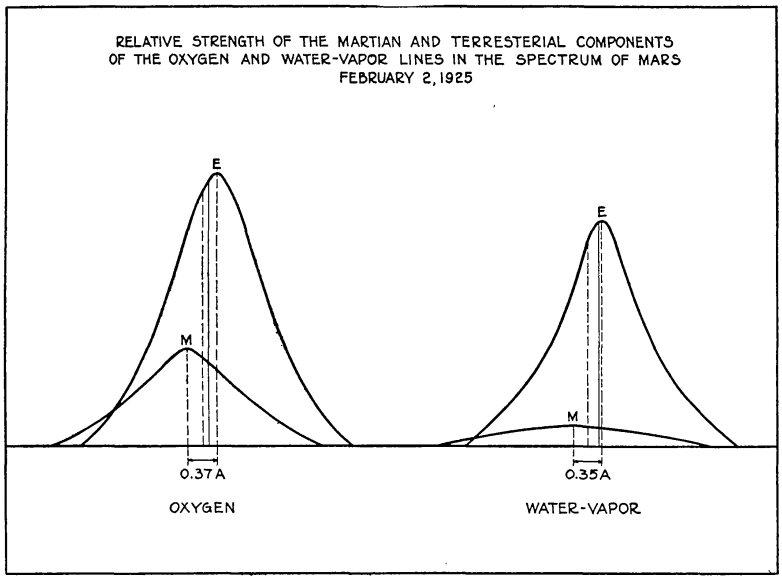

FIG. 1

spectrum, was 1.46±0.17 mm, equivalent to 0.28±0.03 A. The displacement due to relative velocity was 0.37 A. Applying the formula as above, we find that the Martian component of the oxygen line in the Mars-sky spectrum was 33 per cent of the earth's component.

On taking account of length of path and the elevation of the observing station, the oxygen in the atmosphere of Mars was found to be 16 per cent, area for area, of that over Mount Wilson, or about two-thirds of that in the earth's atmosphere above Mount Everest.

The heights of the curves *M* and *E* in Figure 1 indicate the relative intensities of the Martian and terrestrial components of the

oxygen and water-vapor lines on the Mars-sky spectrogram. The Martian components are displaced to the red—to the left in the diagram—by the amount of the Doppler effect. For components of equal intensity the compound line in the spectrum of Mars would have been displaced by one-half the Doppler effect. The measured displacement, which is much less, is indicated by the position of the solid vertical line.

We wish to express our appreciation of the skill and experience of Miss Ware in the production, and her assistance in the measurements, of the microphotometer graphs.

MOUNT WILSON OBSERVATORY
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