LIMB SOUNDING OF THE MARTIAN ATMOSPHERIC COMPOSITION : O_2 AND H_2O

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ABSTRACT

The feasability of the observation of molecular oxygen and water vapor in the martian atmosphere has been studied for the case of an orbiting limb sounding absorption spectrometer, in the visible and near infrared parts of the spectrum. The resolution and signal to noise ratio requirements for this instrument are assessed as a function of the expected concentrations of the observed species and of the grazing altitude. Synthetic spectra, computed in the observational conditions, permit to check the sensitivity of the technique.

Keywords
MARS - OXYGEN - WATER VAPOR - INFRARED - VISIBLE - ATMOSPHERE.

Both water vapor and molecular oxygen present absorption lines in the visible and near infrared bands of the spectrum. It would be tempting to observe these using a limb sounding spectrometer. The purpose of this paper will be to define the specifications of a possible dedicated instrument. The visible and the near infrared present the advantadges, in solar absorption, of an important signal to noise ratio and to have access to other important phenomena, for example : molecular and aerosol scattering and ozone absorption.

The detection of absorption lines of H_2O and O_2 using a limb sounding technique would permit to deduce a vertical distribution of these constituents as demonstrated by numerous examples in the earth's atmosphere (Ref 1) however, as it will be shown here, this would necessitate severe resolution requirements for the instrument.

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The strongest water vapor lines catalogued in the AFGL file (Refs. 2,3) in this region are situated between 8650 and 8950 cm^{-1} (1110 nm); however, these lines are about 10 times weaker than the 1.4 μm bands used by Farmer et al (Ref. 4) for their nadir study of martian water vapor. The strongest oxygen lines are situated in the region between 13070 and 13175 cm^{-1} (765 nm). These last lines have been observed from the earth with a 0.026 cm^{-1} by Barker (ref. 5) who deduces a column of about 2.7 x 10^{20} molecules/cm^2 which, translated to a constant mixing ratio would be 1 x 10^{-3}. Incidentally, the observation is only possible from the earth in very isolated O_2 lines in which the Doppler shifted Martian line absorbs in the wings of the much stronger telluric line, using a spaceborne instrument, would on the contrary, allow the use of all available lines. The choice of a water vapor value, for evaluation purposes, is much more difficult because this constituent appear to be extremely variable, two extreme values were assumed : a low of 2 x 10^{-4} corresponding to the theoretical models and a high 10^{-2} compatible with the highest values observed by Farmer et al (ref. 4).

Synthetic spectra were computed, in the Martian conditions, using a 12 layers model based on the CO_2 pressure and temperature observed by the Viking 1 lander (Ref. 6). Tangent ray altitudes of 10 km for both O_2 and H_2O were considered while for O_2, computations were also performed for the 0 km altitude. In an occultation experiment, the ground grazing condition will probably rarely obtained in the Martian atmosphere, because possible clouds and dust winds, however it gives the threshold of detection of the gas.

The computer program, described by Maignan and Muller (ref. 7) takes into account the Voigt line shape and degrades the infinite resolution to the instrumental one. The computation step used is 0.005 cm^{-1}, a test performed with 0.002 cm^{-1} failed to produce any significant difference. This would seem paradoxal, knowing that the Doppler width of the lines is close to 0.003 cm^{-1} but it simply means that, to be observed with an instrument of 1 cm^{-1} or even 0.1 cm^{-1} resolution, the line center has to saturate and most

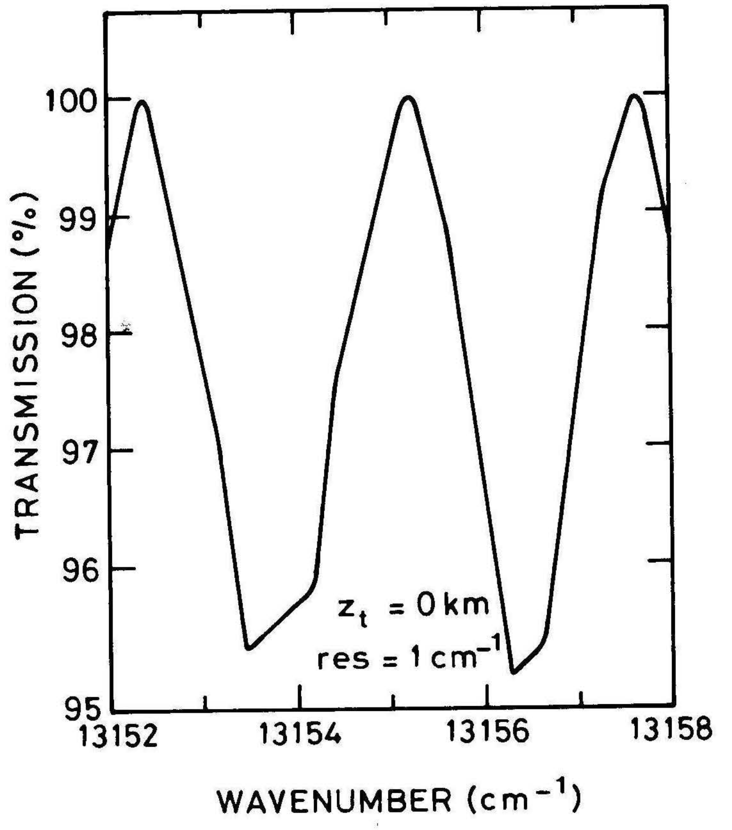

Figure 1 : Martian limb spectrum of molecular oxygen computed for a grazing altitude of 0 km and a resolution of 1 cm^{-1}.

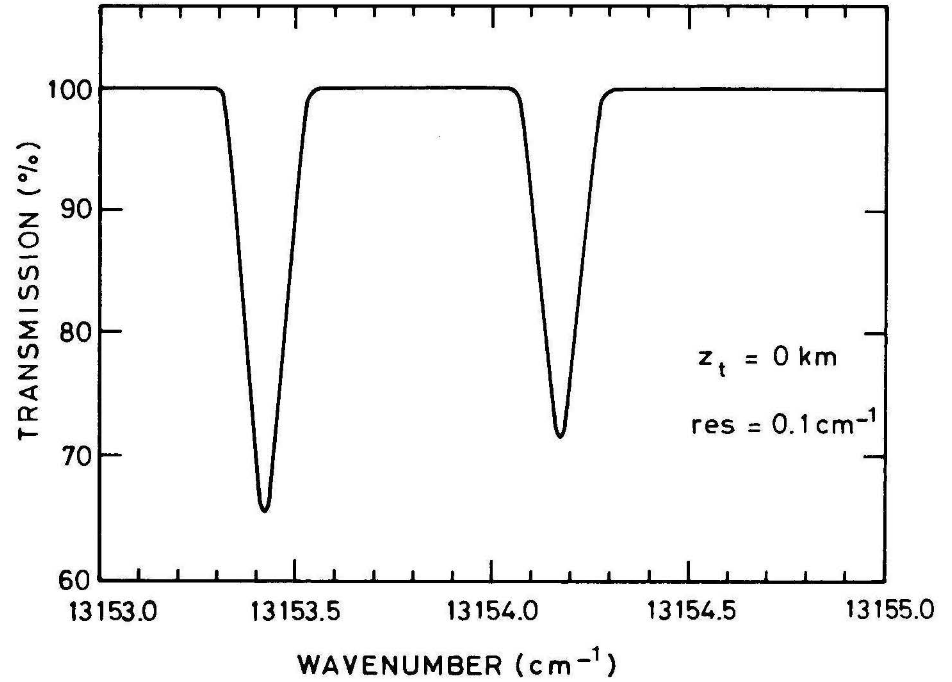

Figure 2 : Martian limb spectrum of molecular oxygen computed for a grazing altitude of 0 km and a resolution of 0.1 cm^{-1}.

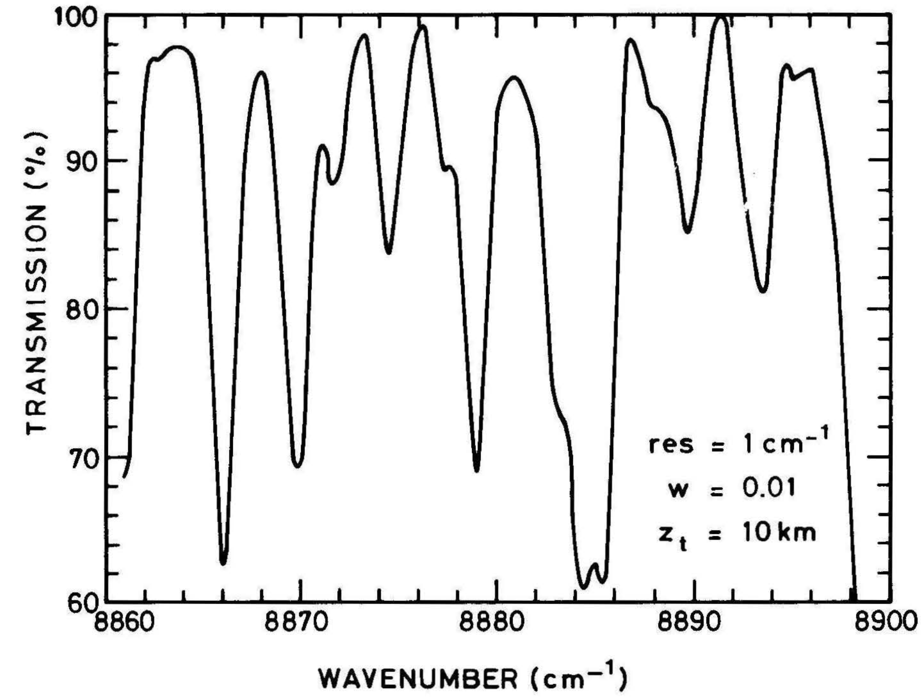

Figure 3 : Martian limb spectrum of water vapor computed for a grazing altitude of 10 km a water vapor mixing ratio of 1×10^{-2} and a resolution of 1 cm^{-1}.

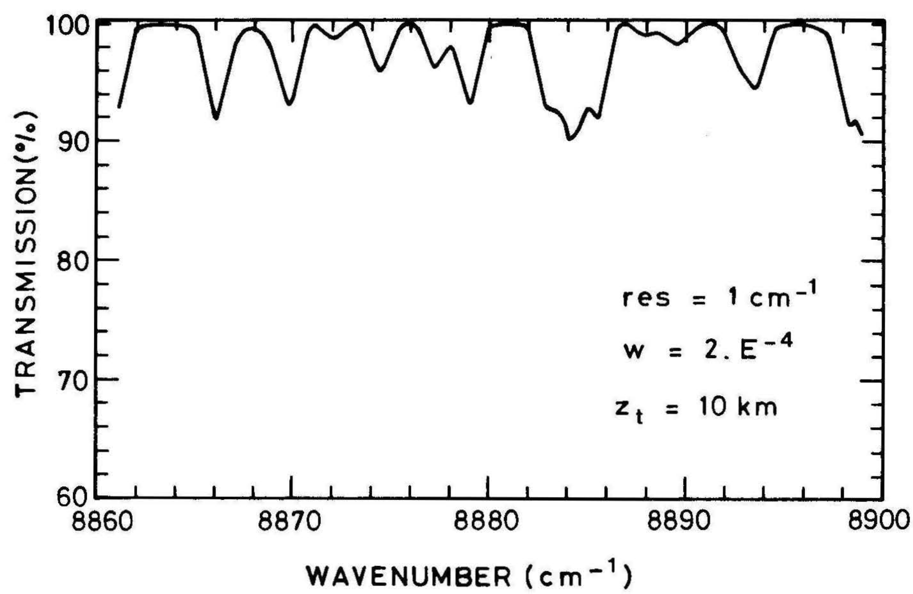

Figure 4 : Martian limb spectrum of water vapor computed for a grazing altitude of 10 km a water vapor mixing ratio of 2×10^{-4} and a resolution of 1 cm^{-1}.

of the sensitivity of the spectrum to change in concentration comes from the lorentzian wings of the line (1 cm^{-1} resolution corresponds to about 0.01 nm in the 1 μm range).

In the molecular oxygen case, the computation confirms the results of ref.5, except that with a factor of about 50 times in the airmass, using limb sounding, an absorption of about 5% is observed at 0 km grazing altitude for the 1 cm^{-1} resolution (fig. 1); at the higher resolution of 0.1 cm^{-1} (fig. 2), it is easy to see that the apparently asymmetric lines were in fact blends of 2 O_2 lines. This 5% absorption reduces to 2% at the altitude of 10 km. The constraints posed by the observation of a 2% dip would make the O_2 measurement marginal for a general purpose instrument, however a specific Fabry-Perot interferometer tuned to one of the O_2 lines would yeld a vertical distribution, as would also a heterodyne spectrometer.

In the case of water vapor, the computations, performed at the 10 km altitude promise much more, the high and the low values give respectively (fig. 4 and 5) absorptions of 40% and 10% at the resolution of 1 cm^{-1} and the numerous features present in the spectrum point to the use of a scanning spectrometer which would yeld not only values of H_2O but also a vertical distribution of temperature based on a study of the relative intensities of the observed lines. It would however be an error to base a water vapor experiment on an instrument whose resolution would be worse than 1 cm^{-1} because saturated lines could not be separated from weaker lines still in near linear regions of the curve of growth. This low resolution spectrum would lose its characteristic aspect and appear like a dip in a continuum, possibly difficult to separate from an instrumental shift. A specific high resolution instrument tuned on a single water vapor line would be difficult to operate on the whole range of altitudes and water vapor concentrations, because on one case the absorption would be negligible while, in an other one, it would saturate completely. This leaves, as only possibility, a medium to high resolution scanning spectrometer.

In conclusion for both the H_2O and O_2 cases, the 1 cm^{-1} resolution permits to isolate features which could be unambiguously interpreted in term of vertical distribution of these constituents. A lower resolution (10 cm^{-1}) would make the detection of O_2 by limb sounding impossible. Data on H_2O could still be obtained provided the instrument is able to detect a 1% variation on the continuum but, a vertical distribution obtained by this technique might not be unambiguously derived. A higher resolution (0.1 cm^{-1}) would permit to resolve lines of both constituents and would lead to an accurate determination of the vertical distribution. On the basis of the computation performed, the altitude range for the 0.1 cm^{-1} resolution would be 0-60 km when for the 1 cm^{-1} resolution it would be 0-30 km. Above these altitudes, O_2 cannot be detected anymore, and, in the low value case, the H_2O spectrum tends to flatten to less than a 2% absorption which places signal to noise requirements rarely met by a spaceborne instrument.

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