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Oxygen isotopic ratios in Martian water vapour: vertical profiles from ACS-MIR on ExoMars TGO

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Abstract

We report retrievals in the 2.51 – 2.64 µm spectral range using the Atmospheric Chemistry Suite onboard of ExoMars Trace Gas Orbiter, which allow the simultaneous measurement, for the first time, of vertical profiles of the oxygen isotope ratios in water vapour ($^{18}O/^{16}O$ and $^{17}O/^{16}O$). Large coverage of ACS-MIR solar occultation measurements allows the study of seasonal or spatial variability in these ratios.

1. Introduction

Isotopic ratios in C, O and H provide important clues to understand the history and evolution of volatiles on Mars. Enrichment of the D/H ratio by a factor of approximately 5.5 in atmospheric water vapour with respect to the Vienna Standard Mean Ocean Water [1] has often been understood as evidence of the substantial atmospheric escape into space.

On the other hand, oxygen isotope ratios in both water vapour and carbon dioxide do not show substantial enrichment of the heavier isotopes (e.g. [2],[3]). The lack of substantial fractionation therefore indicates the presence of a large reservoir of oxygen to exchange with the atmosphere [4].

In this work, we use solar occultation measurements made with the mid-infrared (MIR) channel of the Atmospheric Chemistry Suite (ACS), onboard ExoMars Trace Gas Orbiter (TGO) to measure the first-ever vertical profiles of oxygen isotopic ratios in water vapour ($^{18}O/^{16}O$ and $^{17}O/^{16}O$).

2. Measurements

ACS consists of a set of three infrared spectrometers covering a total wavelength range from 0.7 to 17 µm. The MIR channel, used in this study, is a cross-dispersion echelle spectrometer dedicated to solar occultation measurements in the 2.3-4.2 µm (2300-4400 cm^{-1}) range, with the main objective of measuring high resolution spectra ($\lambda/\Delta\lambda$~30000-50000) in a wide instantaneous spectral range (width 0.15-0.3 µm). In order to cover the full spectral range, MIR is equipped with a movable secondary grating that allows the selection of different diffraction orders [5].

In this work, we analyze MIR spectra in secondary grating position 5, which allows the simultaneous measurement of 12 diffraction orders from 2.57 to 2.64 µm (3790-4050 cm^{-1}). We select spectral windows in several diffraction orders, which show absorption lines of the three main oxygen isotopologues of water vapour ($H_2{}^{16}O$, $H_2{}^{18}O$, $H_2{}^{17}O$) and CO_2 (see Figure 1).

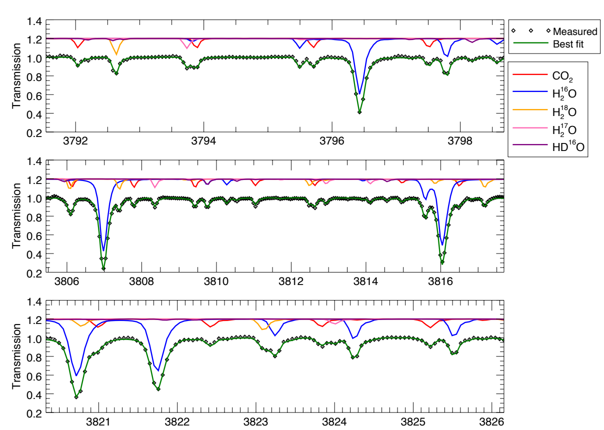

Figure 1: Examples of ACS-MIR spectral windows in diffraction orders 226, 227 and 228, measured at a tangent height of 16.8 km, used for the retrieval of the oxygen isotopic ratios in water vapour.

3. Radiative transfer analysis

The analysis of the spectra is performed using the NEMESIS code [6], which works under the optimal estimation framework [7]. In particular, for each solar occultation, we retrieve simultaneous vertical profiles of pressure, temperature and volume mixing ratio of the three main water isotopologues.

The pressure and temperature profiles can be constrained from the CO_2 absorption lines under the assumption of hydrostatic equilibrium and a given CO_2 volume mixing ratio profile, which we obtain from the Mars Climate Database [8]. In the case of the water vapour isotopologues, the volume mixing ratios can be constrained from the depth of the corresponding absorption lines.

4. Summary and Conclusions

Vertical profiles of the oxygen isotope ratios in the three main water vapour isotopologues ($^{18}O/^{16}O$ and $^{17}O/^{16}O$) are obtained for the first time in the Martian atmosphere. These profiles are obtained using solar occultation measurements by the Atmospheric Chemistry Suite onboard ExoMars Trace Gas Orbiter.

First analysis of the spectra yields results generally consistent with values measured by MSL on the Curiosity Rover [2]. The large number of observations being obtained by ACS will allow a more in-depth analysis of these ratios and a search for seasonal or spatial fractionation.

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