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Martian CO_2 and O_2 abundances obtained from MAVEN/IUVS stellar occultations

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Abstract

We present CO_2 and O_2 density profiles from stellar occultations by the IUVS instrument onboard MAVEN. The first occultation by MAVEN was of α Cru on February 8, 2015 and the first campaign of stellar occultations with 60 more observations of 11 different stars was executed from March 24, 2015 to March 26, 2015. To increase the longitudinal coverage, each star, except λ Sco, was observed 5 times; λ Sco was targeted 10 times. Density profiles from the first occultation are determined in the altitude range between 100 and 140 km. The derived O_2 mixing ratio in this region is 1.6×10^{-3}, in agreement with previous measurements.

1. Introduction

The stability of the Martian atmosphere is connected not only to the main constituent CO_2 but also to minor species like O_2 which are produced photochemically. A better understanding of the CO_2 and O_2 distribution is important for constraining models for the current state and the evolution of the Martian atmosphere.

UV occultations have proved to be a powerful technique for the study of upper atmospheric structure and composition. Sandel et al. (2015) recently presented CO_2 and O_2 abundance profiles in the Martian atmosphere obtained from UV stellar occultations observed by SPICAM onboard Mars Express [5]. The obtained O_2 mole fractions within 90 and 120 km vary from 1×10^{-3} to 5×10^{-3}. Seasonal variations of CO_2 densities and temperatures at various latitude and longitude over one Martian year was shown by Forget et al. (2009) using retrievals of 616 stellar occultations from SPICAM/MEX [1]. In the past, Viking mass spectrometer measurements were used to determine the CO_2 and O_2 densities and the corresponding O_2 mole fractions between 120 and 160 km [3].

The MAVEN IUVS instrument will measure numerous occultations through the course of the mission to increase the geographic and seasonal coverage and therefor the understanding of the CO_2 and O_2 abundance on Mars. Because they sample the region below MAVEN's periapse altitude, occultations provide a link between the middle and upper atmosphere. At the time of writing a single α Cru occultation observation and the first occultation campaign have been executed. The obtained CO_2 and O_2 number densities and their corresponding O_2 mole fractions are presented below.

2. IUVS Stellar Occultations

The FUV channel of the IUVS spectrograph onboard Maven covers the spectral range from 110 to 190 nm with an intrinsic spectral resolution of 0.6 nm [2]. For the α Cru occultation 3 spectral pixels and for the first occultation campaign 4 spectral pixels are binned resulting in spectral bin sizes of 0.24 and 0.33 nm, respectively.

The α Cru occultation observation begins below the limb and extends up to 500 km. With the cadence time of 2 s, including an integration time of 1.6 s, the resulting altitude resolution is around 5.5 km. Atmospheric absorption is evident below 150 km and occultation starlight is completely extinguished below 90 km.

Above 150 km the line of sight to the star is unattenuated and thus the unabsorbed reference spectrum from the star is measured. As the spacecraft moves along its trajectory the line of sight penetrates the atmosphere and the star spectrum attenuated by the atmosphere is measured. The transmission is obtained by dividing the attenuated spectrum by the unabsorbed spectrum. This method has the advantage that no absolute calibration of the spectograph is needed.

We fit the measured transmission spectra at each altitude assuming absorption by CO_2 and O_2 and using the Levenberg-Marquardt algorithm to retrieve the best fit column densities. We invert the column density profiles to obtain local densities by using the Tikhonov regularization method [4, 5].

3. Results and Discussions

The altitude dependence of the transmission spectra for this occultation is illustrated in Figure 1 for 7 different altitudes. The region between 200 and 500 km is used to characterized the unattenuated star spectrum.

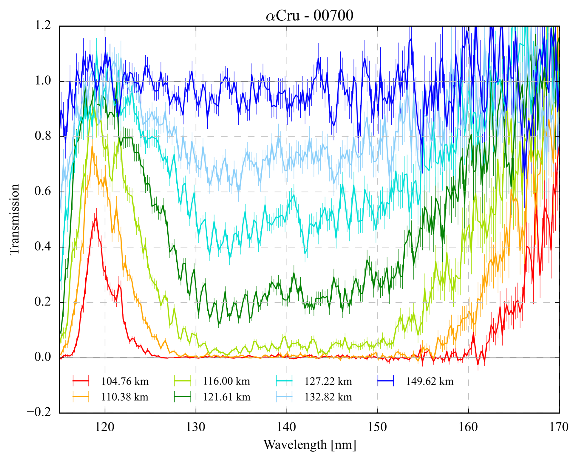

Figure 1: Transmission spectra of the α Cru occultation for 7 different altitudes including the 1σ-uncertainties.

The CO_2 and O_2 densities including the 1σ-uncertainties for the α Cru occultation are shown in Figure 2. The CO_2 and O_2 densities measured from Viking 1 and 2 as well as 6 different occultations from SPICAM on Mars Express for three stars (ζ Pup, β Cen, and γ Ori) with two different occultations each [5] are also shown. Both the CO_2 and O_2 densities inferred from the IUVS instrument are in good agreement with Viking and SPICAM/MEX occultations. The mean value of the mole fraction obtained from the MAVEN α Cru occultation is 1.6×10^{-3}. This value is in agreement with observations from SPICAM/MEX and Viking measurements.

Acknowledgements

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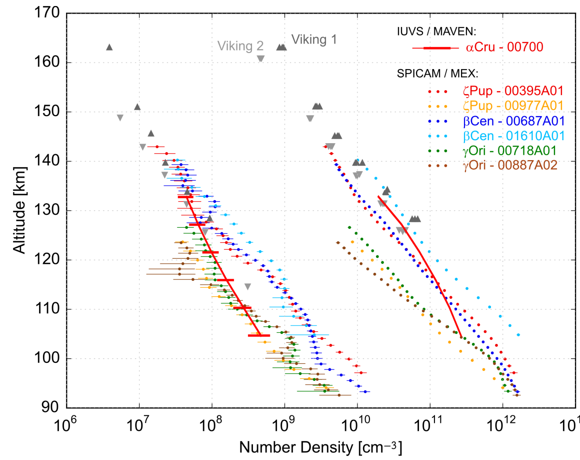

Figure 2: CO_2 and O_2 abundances including the 1σ-uncertainties for the α Cru occultation from the IUVS and for the SPICAM occultations of three different stars (ζ Pup, β Cen, and γ Ori) with two different occultations each (colored circles) as well as for the measurements from Viking 1 (gray upward pointing triangles) and Viking 2 (gray downward pointing triangles).

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