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Atomic oxygen in the Martian thermosphere traced by the 130.4 and 135.6 nm emission lines with MAVEN/IUVS

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Abstract

We analyze limb observations of dayglow emissions from atomic oxygen in the upper Martian atmosphere. The data has been collected during the last almost four years by the Imaging Ultraviolet Spectrograph (IUVS) instrument on board the Mars Atmosphere and Volatile EvolutioN mission (MAVEN) spacecraft. Mean profiles for specific solar longitude, latitude and solar zenith angle ranges are created. We then use atmospheres from the Mars General Circulation models and in situ solar flux data from the MAVEN Extreme Ultraviolet Monitor (EUVM) to perform Monte Carlo and radiative transfer modeling for comparison with the observations. In order to match the results and to eventually retrieve oxygen densities, scaling factors are applied to the GCM atmospheric densities. We will present preliminary results of this analysis.

1. Introduction

Limb observation of airglow emissions is a standard technique to study the altitude profiles of the chemical elements in the Martian atmosphere and its thermal structure. Several previous missions have performed observations in the past (Mariners, Mars Express). In 2014, the Imaging Ultraviolet Spectrometer (IUVS, McClintock et al., 2014) on board MAVEN started collecting thousands of airglow and auroral limb profiles in the range 120 to 340 nm.

While below 200 km CO_2 is the dominating neutral species in the Martian atmosphere, above and up to lower exosphere atomic oxygen is more abundant. Atomic oxygen is produced by photodissociation of CO_2 and airglow transitions from the $O(^1S)$ (297.2 nm), $O(^3S)$ (130.2-4-6 nm triplet), and $O(^5S)$ (135.6-8 nm doublet) excited states fall into the spectral detection range of IUVS.

Resonance scattering from solar emission is by far the dominant source for the excitation of the 130.4 nm triplet and electron impact on atomic oxygen and CO_2 – resulting in dissociation of the molecule – contribute less than ten percent to the emission. Photodissociation of CO_2 can be neglected. This line triplet is optically thick, hence its intensity does not give direct indication of the oxygen abundance and radiative transfer codes are needed to understand the observations. Differently, the 135.6 nm doublet of atomic oxygen is an optically thin line emission and results mostly from electron impact on oxygen and on CO_2. Even though its intensity is therefore proportional to the oxygen density, interaction cross-sections leading to the $O(^5S)$ excited state are much less known than for the ones leading to the $O(^3S)$ excited state. Studying both emissions lines in parallel will therefore provide more robust results than treating these features separately.

We now have analyzed samples from more than three years of airglow observations and compared them to model simulations. The objective is to study the characteristics of the oxygen FUV emissions at 130.4 and 135.6 nm in order to describe the Martian upper atmospheric oxygen density.

2. Methodology

MAVEN observations

The Imaging Ultraviolet Spectrometer (IUVS) on board MAVEN is capable of observing the Martian upper atmosphere within a total spectral range of 115-340 nm. It operates in limb, coronal scan, and disc mode, respectively. By now the observations cover more than a full Martian year and provide an unprecedented data set, covering various latitude ranges per epoch. We analyze periapse limb observations of the Martian thermosphere with tangent point altitudes between 80 and 200 km. In order to do so, we use processed data provided by the NASA Planetary Data System (PDS) to generate mean altitude profiles for small ranges of season,

latitude and solar zenith angle.
Figure 1 shows an example of limb profiles of the 130.4 nm and the 135.6 nm lines.

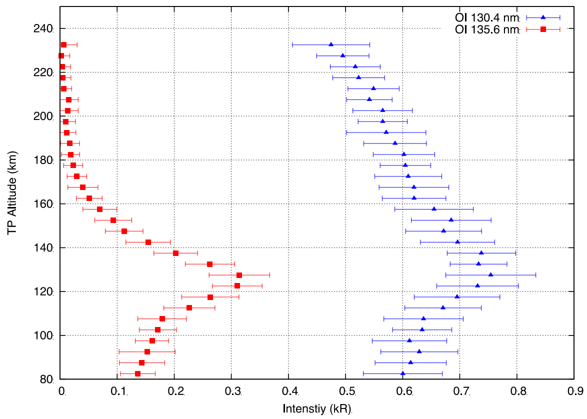

Figure 1: Averaged sum of more than 70 limb profiles in dependence of the tangent point (TP) altitude. Blue triangles show the 130.4 nm and red squares show 135.6 nm oxygen intensities. The horizontal bars indicate the 1-σ variability of the mean limb intensity at the respective altitude level.

The Extreme Ultraviolet Monitor (EUVM, Eparvier et al., 2015) on board MAVEN measures continuously the solar EUV flux. Data and extrapolated model data are available on the NASA PDS. We generate an average solar flux spectrum corresponding to the selected limb profiles as input for the models.

Modelling

We use model neutral atmospheres provided by Mars Climate Database that provide the respective altitude distribution of the main neutral constituents in dependence of season, local time, latitude and solar activity. Using the EUVM data as the solar driver, we employ Monte Carlo simulation for the calculation of the photoelectron spectrum as a function of altitude. Calculations of the collisional sources are based on the Direct Simulation Monte Carlo (DSMC) method that has been developed over the years (Shematovich et al. 2008; Gérard et al., 2008) to calculate the brightness profiles of emissions of the Earth, Jupiter, Saturn, Venus and Mars atmospheres. Collisional (photoelectron impact) (as well as photodissociation) excitation rates are calculated to provide the total volume production rates. For the 130.4 nm triplet we combine these results additionally with calculations for the resonance scattering of the solar 130.4 nm triplet. The solar line intensity is again taken from the EUVM and its line shape from Gladstone (1992). We employ the REDISTER radiative transfer code from Gladstone (1985) to calculate the effects of multiple scattering including frequency redistribution, which allows photons to escape an optically thick atmosphere by scattering in frequency from the core of the line into the optically thin line wings. Additionally, absorption due to CO_2 is taken into account, which influences not only the observed 130.4 nm intensity, but also the altitude of the intensity peak in the limb profile.

3. Summary

We present preliminary results of a parallel study of the 130.4 nm and 135.6 nm atomic oxygen dayglow emissions from the Martian thermosphere. We use MAVEN/IUVS limb profile observations, in situ solar flux measurements by MAVEN/EUVM, and Monte Carlo and radiative transfer modelling on neutral model atmospheres whose composition distribution matches the respective season, latitude, solar zenith angel and solar activity of the observational samples.

Acknowledgements

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