Analyzing the Martian Atmosphere with the O 130.4 and 135.6 nm emissions observed by MAVEN/IUVS

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I. Non-thermal emission from atomic oxygen at 130.4 and 135.6 nm

Neutral atomic oxygen is produced by photodissociation of CO_2 and supersedes CO_2 as the **most abundant neutral species above 200 km** and up to the lower exosphere. It plays a major role in **the control of the thermal structure** of the Martian atmosphere and can then be used as an indicator of the thermospheric circulation. We focus on the **O(^{3}S)** and the **O(^{5}S)** excited states that emit line multiplets at **130.4 nm** and **135.6 nm**, respectively. The 130.4 nm emission is **optically thick** as it is mainly produced by resonance scattering from the solar oxygen 130.4 nm line. Both emissions are furthermore produced by **photoelectron impact on O** and to a small fraction also by **photoelectron impact on CO_2**. Other processes are negligible, but **absorption by CO_2 plays a major role** for the observed limb peak intensities and altitudes.

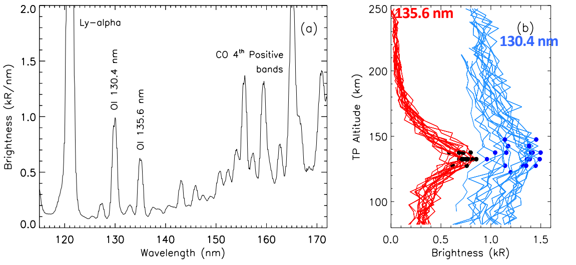


Figure 1: (a) IUVS FUV average spectrum, created from 19 individual limb scans recorded between 120 and 140 km tangent point altitude. (b) The corresponding limb scans at 130.4 nm (blue) and 135.6 nm (red). The dots indicate the maximum brightness of each scan that was used for further analysis.

Production processes

- $h\nu_{130.4}$ + O -> O(^{3}S)
- e^- + O -> O(^{3}S) + e^-
- e^- + CO_2 -> O(^{3}S) + e^-
- e^- + O -> O(^{5}S) + e^-
- e^- + CO_2 -> O(^{5}S) + e^-

II. Observations

The data has been collected during the last four years by the **Imaging Ultraviolet Spectrograph (IUVS)** [1] instrument on board the **Mars Atmosphere and Volatile EvolutioN mission (MAVEN)** spacecraft [2]. IUVS is capable of observing the Martian upper atmosphere within a total **spectral range of 115-340 nm** and operates in limb, coronal scan and disc mode. Up to now, the observations cover **two full Martian years** and provide an unprecedented dataset covering various **latitude and local time ranges per epoch**, which is available on the the NASA Planetary Data System (PDS). **Here, we consider dayglow limb observations with a solar zenith angle (SZA) < 70°**. It is the first time that the emissions at 130.4 and 135.6 nm are studied together since Mariner observations.

III. Influencing factors on peak brightness and altitude

We use Monte Carlo models [4,5] (for both emissions) and radiative transfer codes [6,7] (for 130.4 nm only) to investigate the dependence of the **peak line brightness B** and the **tangent point altitude of the peak Z** on the **O and CO_2** content, the solar zenith angle (**SZA**), the **temperature** of the atmosphere and the **solar flux** (Fig. 2) [8]

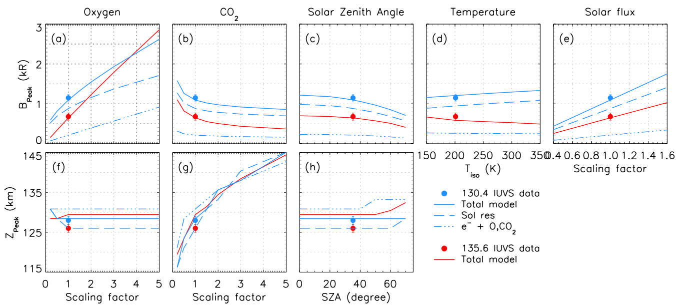


Figure 2: Peak brightness (top row) and peak altitude (bottom row) at 130.4 nm (blue) and at 135.6 nm (red) in dependence of the oxygen (a,f) and CO_2 (b,g) density, of the solar zenith angle (c,h), of isothermal temperature profiles (T_{iso}) (d,i), and of the peak brightness in dependence of the solar flux (e). The filled circles indicate the IUVS dataset taken in MY 32 (Fig. 3).

IV. Methodology

The data is binned into 'pixels' of of **5°L_s × 10°latitude** and **2h LT.** Mean profiles are created from individual scans (Fig. 3).

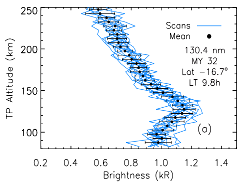


Figure 3: Creation of mean profiles from individual scans, for scans at 130.4 nm. The horizontal bars indicate the variation of the dataset.

The peak **brightness** and **altitudes** and **scale heights** are fitted and extracted.

Daily averaged In **situ solar flux measurements** from the Extreme UV Monitor (EUVM) [3] on board MAVEN are used to **normalize** the peak brightness by the solar flux [8].

Selected profiles are modeled using **solar flux measurements,** model atmospheres from the **Mars Climate Database** (MCD) and the as input (Fig. 4).

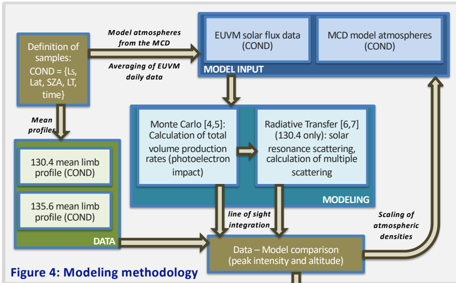


Figure 4: Modeling methodology

The model results (Fig. 5) are generally satisfying. Scale heights are not well reproduced, indicating a mismatch in the model atmosphere T profiles [8].
Finally, **[O/CO_2] mixing ratios** can be extracted.

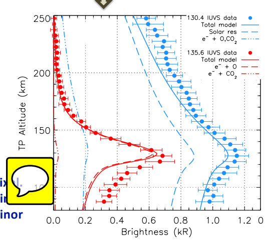


Figure 5: Modeling result (unscaled) for one pixel. The solid lines represent the total, the dashed lines the major and the dashed-dotted lines the minor contributor to the modeled brightness profile

V. Results: seasonal variations and mixing ratios

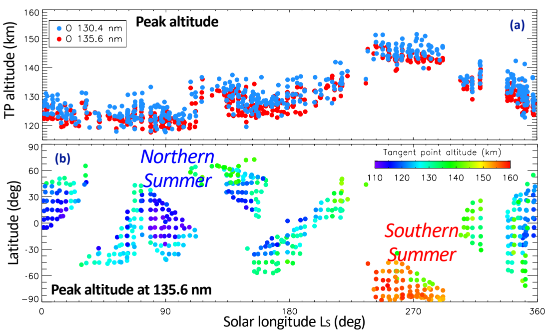
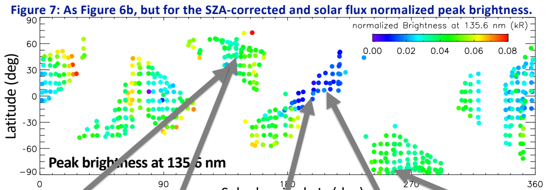


Figure 6: Merged data of 2 MY (Oct. 2014 – June 2018). (a) shows the (SZA-corrected) peak altitude at 130.4 and 135.6 nm, (b) shows a latitude-seasonal plot of the same data for 135.6 nm only.

Figure 7: As Figure 6b, but for the SZA-corrected and solar flux normalized peak brightness.



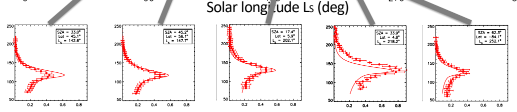


Figure 8: Randomly selected 135.6 nm profiles (unscaled profiles are shown) and extracted mixing ratios (after atmosphere scaling).

B and Z of the emissions at 130.4 and 135.6 nm are strongly correlated [8], but more difficult to interpret at 130.4 nm due the atmosphere's optical thickness. Hence, we focus on 135.6 nm emissions. The results of **2 Martian Years** (MY32-34) are shown and **normalized for solar flux and for the SZA of each pixel**. Each dot represents one mean profile.

The **peak altitude Z** (Fig. 6) shows the **expansion and contraction** of the atmosphere and corresponds to a **CO_2 overlying column density of about 2x10^{12} cm^{-2}** (preliminary result).

The seasonal variations due to Mars' elliptic orbit can be well seen. The expansion of the atmosphere during southern summer because of the melting polar cap are well known. **But also for the northern hemisphere this effect can be seen**, obviously not as strong as in the south.

The altitude, together with the peak brightness B (Fig. 7) gives hints on the local **[O/CO_2] mixing ratio.** The extraction of the mixing ratios to produce maps is ongoing work.

VI. Summary and outlook

- Model sensitivity tests show the influence of the atmospheric O density on the peak brightness and of the CO_2 density on the peak brightness and peak altitude. The altitude of the peak is an indicator for the overlying CO_2 column density.
- The models reproduce well the observations and with some iterations, [O/CO_2] mixing ratios can be derived [8]. A more general approach is under study.
- Normalization of the data by in situ measured solar flux and by SZA enables to prepare global maps helping to understand the seasonal and spatial variations of the atmosphere.
- The expansion of the Martian atmosphere during northern summer is observed, which is weaker than in the south, as expected.

References & Acknowledgements

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This work was partly funded by the Belgian Federal Science Policy Office.