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Searching for signatures of water vapor transport on Mars during the 2019 regional C dust storm

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Abstract

Recent work [1, 2, 5] has shown that martian dust storms transport water vapor to the middle and upper atmosphere, where it can photodissociate, driving H escape and catalyzing the recombination of CO_2 from CO and O. Understanding the time evolution of H escape is critical to estimating how much atmosphere and water Mars has lost over its history; thus, quantifying the effects of seasonal dust storms is also critical. We use data from the MAVEN (Mars Atmosphere and Volatile EvolutioN mission) IUVS (Imaging UltraViolet Spectrograph) instrument to study changes to emission lines of CO 4PG (4th positive group), O 135.6 nm, and Lyman α before and after the 2019 regional C dust storm in a non-parametric way. Initial results confirm expectations of decreases in CO 4PG and O 135.6 emissions, while differing viewing geometry shows either an increase or decrease in Lyman α.

1. Dust, chemistry, and escape

Dust storms are important drivers of atmospheric chemistry and photochemistry on Mars. Recent work [1, 2, 5] has shown that dust storms transport water vapor to the middle and upper atmosphere, where it photodissociates, producing atomic H and other odd hydrogen species (of the form HO_x), leading to two important effects. First, atomic H can escape to space via Jeans escape, driving atmospheric loss. Second, odd hydrogen species catalyze the otherwise slow recombination reaction CO + O $\rightarrow$ CO_2, leading to a decrease in CO and O densities.

Understanding H escape is important because it is the primary vector by which martian water and atmosphere are lost to space, as water vapor is the main reservoir of H on Mars [4]. Thus, understanding the effects of dust storms is also critical, and can be studied by examining differences in pre-storm and post-storm spectra. Here, we study the effects of the 2019 regional C dust storm on the CO 4PG, O 135.6 nm, and Lyman α bands by performing a non-parametric analysis of FUV (far ultraviolet) martian airglow.

Date (2019)	L_s	Orbit no.	Event
8 Jan	320.5	8344	Storm begins
16-23 Jan	325-329	8388-8426	Storm peak
6 Feb	336.7	8506	Storm ends

Table 1: Key dates and orbit numbers.

Due to the chemical behavior described above, we expect to see decreases in CO 4PG and O 135.6 emissions, which tracks increases in odd hydrogen, and an increase in Lyman α emission, which tracks increased production of atomic H.

Key dust storm dates are provided in Table 1. Wavelengths studied (in nm) are as follows: HI, 121.567; OI, 135.6; CO 4PG band, 139.2, 141.8, 144.6, 147.8, 151.0, 154.3, 159.6, 165.3, 171.1, and 177.5.

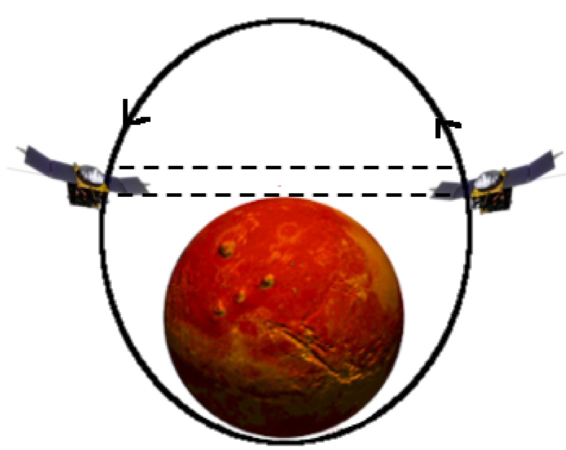

Figure 1: IUVS side segment limb scanning geometry, not to scale. Dashed lines represent observation direction. Outbound trajectories on the right, inbound on the left. Observation altitudes range from 0-500 km.

2. Data set scope

We use FUV data from the IUVS instrument onboard the MAVEN mission. Data are collected during inbound and outbound side segment limb scans of Mars (see Figure 1 for geometry). IUVS observes Mars through a 1024-pixel slit, which is binned onboard to 7 bins, each of which collects a spectrum from 107-343 nm (FUV to MUV). Each spectrum is collected at some observation altitude above the surface, ranging from 0 to 500 km.

For this project, we co-add spectra from orbits 8130 to 8630 (December 2018 to March 2019), binning by altitude in 5 km bins, and do not bin by solar zenith angle (SZA). The result is a rough global mean picture of dayglow emission by wavelength and altitude before and after the dust storm.

3. Preliminary results

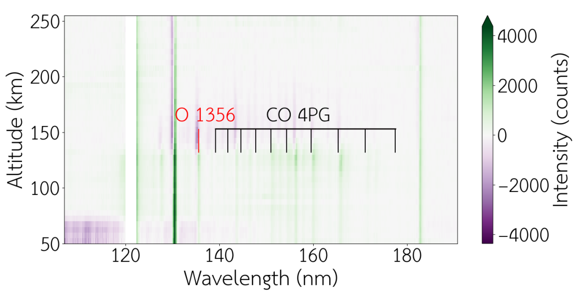

Figure 2: Inbound limb emission changes due to the dust storm, represented as either an increase or decrease in intensity. Ly α is masked to bring out details in O 135.6 and CO 4PG, which all show an increase just below the homopause (125 km) and a decrease above. The decreased intensity below 75 km and shortward of 120 nm is stray MUV light.

Preliminary results showing the change in FUV dayglow emission over the time of the dust storm for the inbound limb scans and outbound limb scans are shown in Figures 2 and 3. The outbound limb data shows the overall decrease in CO 4PG and O 135.6 that we expect, while the inbound limb data shows a decrease above 125 km and an increase below. This altitude-dependent behavior could be capturing the downwelling behavior of CO and O, known to occur in dusty periods. The outbound limb data show an overall intensity decrease of the spectral lines in Figure 3.

In both figures, Lyman α was masked out as it saturates the detector compared to the fainter O 135.6 and CO 4PG lines. Without masking, the inbound limb data Lyman α line shows an overall increase during the dust storm as expected, but the outbound limb data shows an overall decrease. Understanding this anomaly will require additional analysis.

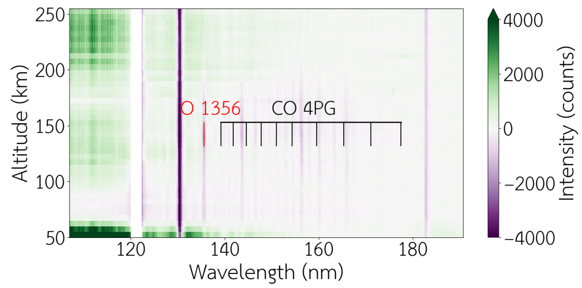

Figure 3: Same as Figure 2 for outlimb data. O 135.6 and the CO 4PG bands all show an overall decrease. The smeared out increase in emission below 60 km and shortward of 120 nm is again stray MUV light.

Future work will include implementing non-negative matrix factorization for a full non-parametric study, which will be compared with parametric studies of co-authors [3]. Additional improvements will be to delineate the contributions of observation altitudes and locations, bin by solar zenith angle, and to convert recovered intensities to densities.

Acknowledgements

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References

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