PHOTOCHEMICAL ESCAPE OF OXYGEN AT MARS:
A NON-THERMAL PROCESS OPERATING AT ALL LOW-MASS PLANETS

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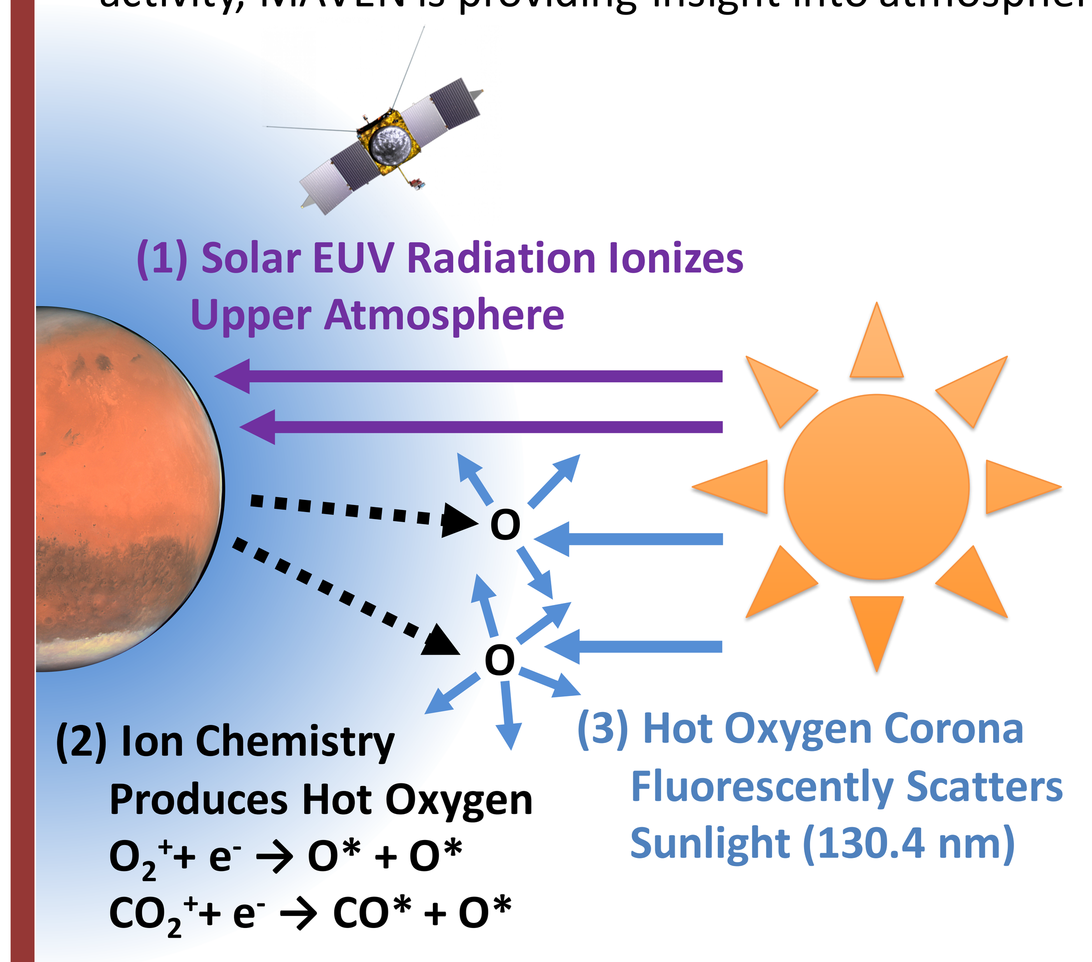
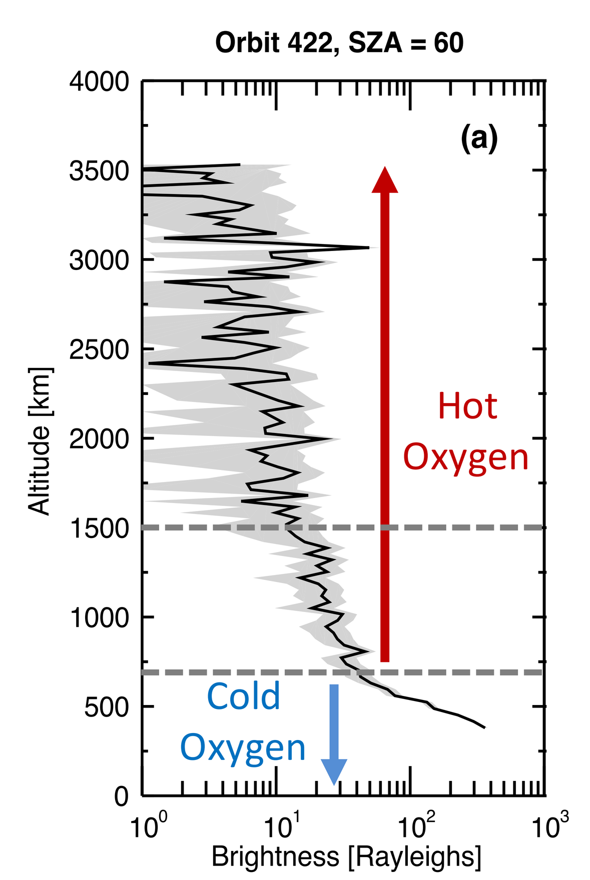
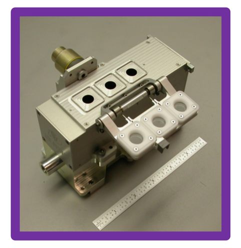
INTRODUCTION

Mars is surrounded by a corona of hot atomic oxygen produced by ionospheric photochemistry. Some atoms in the corona are energetic enough to escape to space. By observing the structure of the corona and its response to solar activity, MAVEN is providing insight into atmospheric loss from Mars and analogous low-mass terrestrial exoplanets.

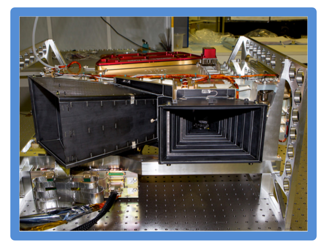




The Martian oxygen corona is dim. Here we average IUVS coronal scan profiles from 700-1500 km to track the brightness of the hot O corona. This is high enough to avoid the colder thermal oxygen, but still low enough that signal is good. MAVEN gathers coronal scans every four orbits, or roughly 18 hours.



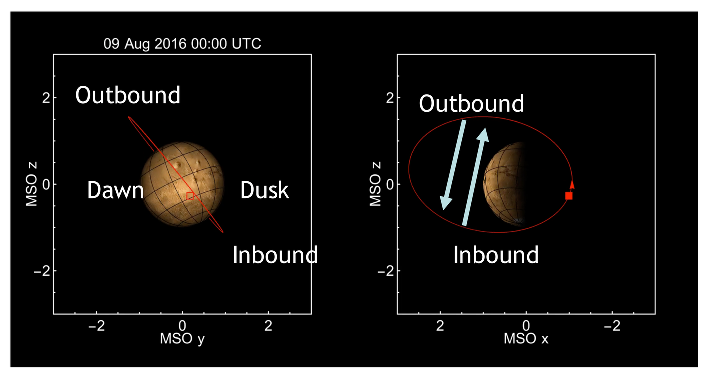
EUVM (Extreme Ultraviolet Monitor)
Solar Input Measurements:
- Ionizing solar radiation (process #1)
- FISM solar 130.4 nm (process #3)



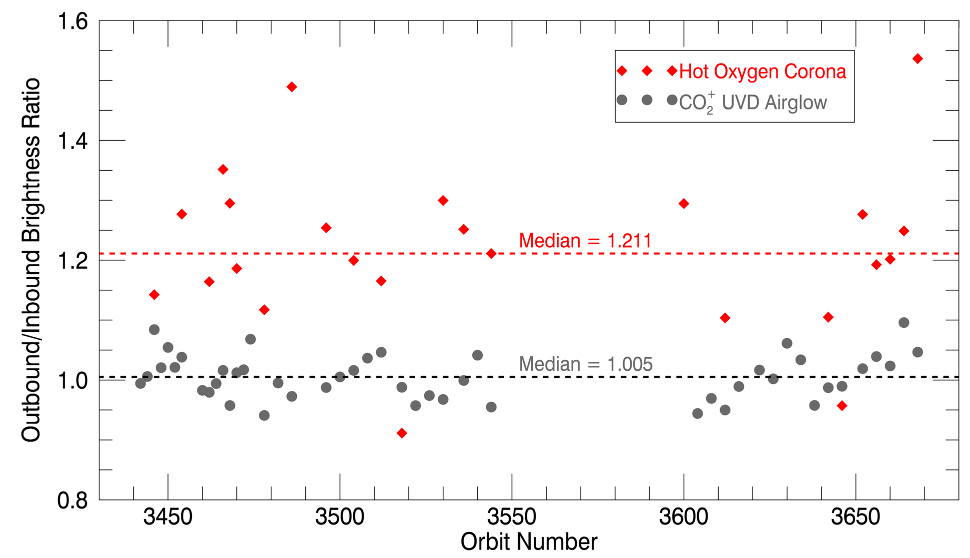
IUVS (Imaging Ultraviolet Spectrograph)
Martian Airglow Emission Measurements:
- Ionization rate (CO_2^+ UVD, process #1)
- O I 130.4 nm fluorescence (process #3)

SPATIAL VARIABILITY

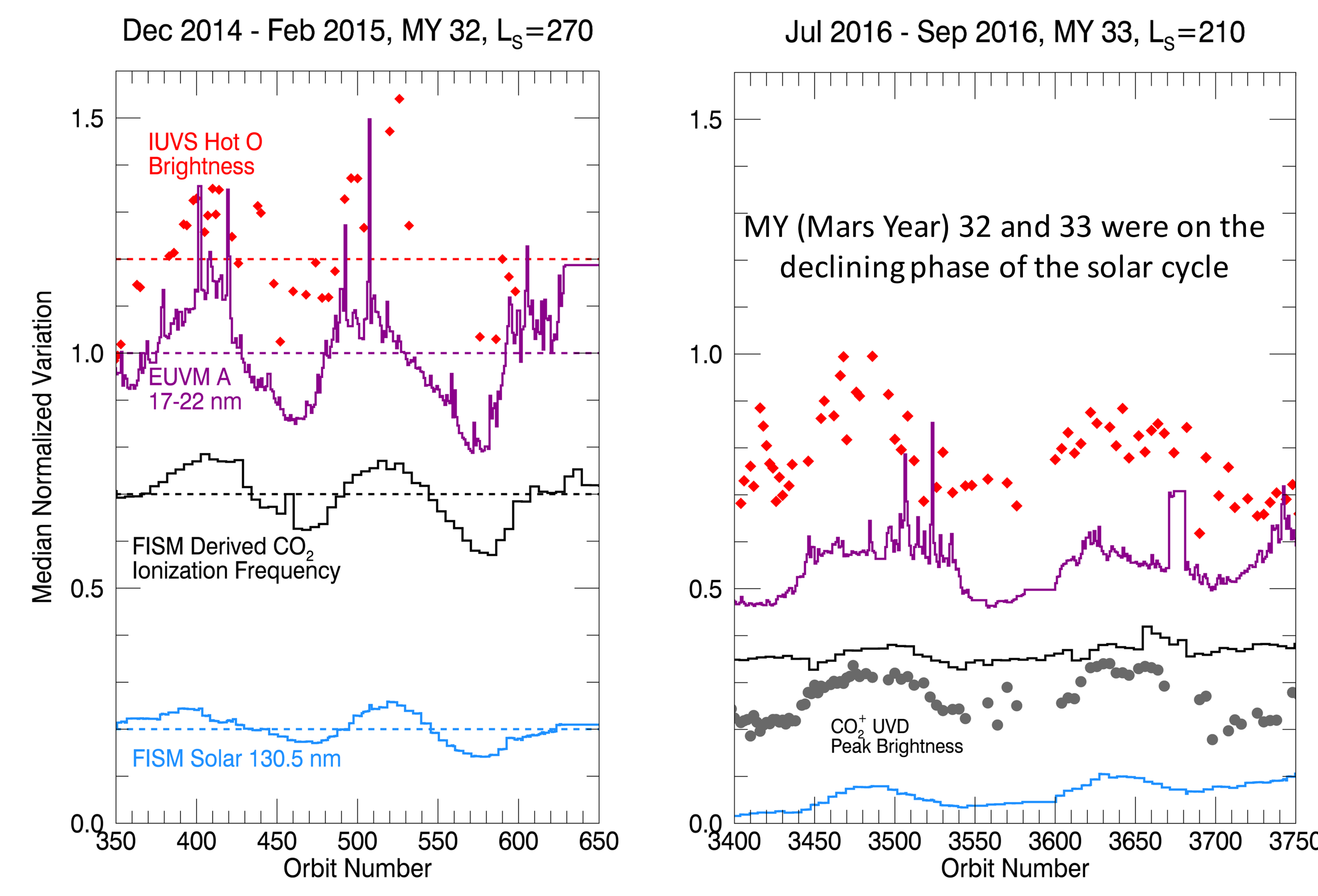
In summer 2016, MAVEN IUVS acquired coronal scan pairs with anti-parallel lines of sight on each side of the orbit. The outbound/inbound ratio of CO2+ UVD airglow brightness was unity, indicating globally consistent ionization frequencies, but there was an asymmetry in the dayside hot oxygen corona. Orientation was not well constrained.



Outbound scans preferentially sampled South/Dusk
Inbound scans preferentially sampled North/Dawn



TEMPORAL VARIABILITY

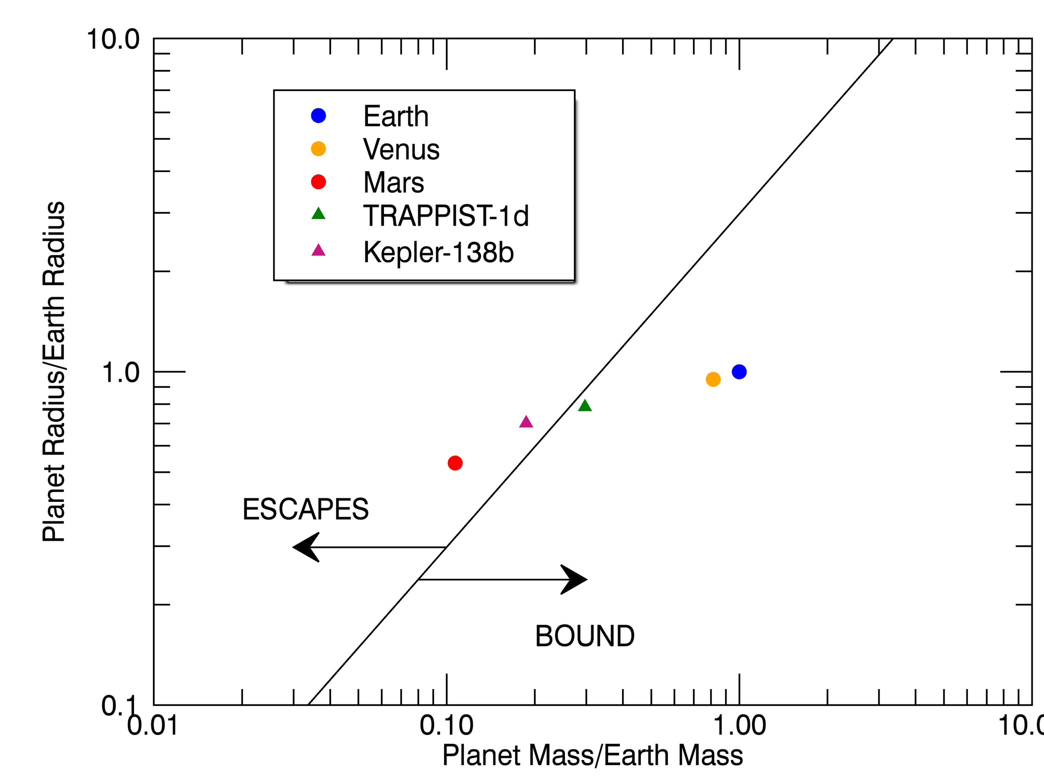


Two major sources of solar variability are the 27 day solar rotation period and 11 year solar magnetic activity cycle. MAVEN data from two Martian years has measured the effect of solar variation on the hot oxygen corona.

Values are normalized to their respective median for the MY 32 season. The position of unity on the ordinate for each variable is offset for clarity (indicated by dashes).

As expected, hot oxygen corona brightness is correlated with the flux of solar ionizing radiation.

LOW-MASS EXOPLANETS



Photochemically produced hot atomic oxygen has discrete energies determined by quantum mechanics. For an O_2^+ source, the fastest atoms move at 6.5 km/s. If the escape velocity at a planet is less than this, photochemistry can drive atmospheric escape.

Earth and Venus are stable against such photochemical loss, while Mars' atmosphere is escaping. The exoplanets TRAPPIST-1d and Kepler-138b fall just on either side of the threshold for photochemical oxygen escape. The rate of loss depends on the EUV output of the parent star.

CONCLUSIONS

- Measurements by MAVEN show that the brightness of the hot oxygen corona surrounding Mars linearly correlates to changes in ionizing solar EUV, as expected for a photochemical oxygen source. The coronal brightness variation is larger than the variation in the solar 130.4 nm line that illuminates the oxygen, indicating real density changes.
- The dayside hot oxygen corona is asymmetric, being thicker in the southern/dusk hemisphere by 20%. The asymmetry may be due to morning/afternoon differences in photochemistry, or an ionospheric effect of the southern crustal magnetic fields.
- The observations presented here provide useful constraints for modelers estimating the escape rate of oxygen from Mars and other low-mass planets. Reproduction of the variations would increase confidence in estimates of past Martian loss rates and exoplanets at the current epoch.

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