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MAVEN measurements of photochemical escape of oxygen from the Martian atmosphere

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1. Introduction

One of the primary goals of the Mars Atmosphere and Volatile Evolution Mission (MAVEN) mission is to characterize rates of atmospheric escape at the present epoch and relate those escape rates to solar drivers [1]. One of the major escape processes is known as photochemical escape, which is broadly defined as a process by which a) an exothermic reaction in the atmosphere/ionosphere results in an upward-traveling neutral particle whose velocity exceeds planetary escape velocity and b) the particle is not prevented from escaping through any subsequent collisions [2]. At Mars, photochemical escape of oxygen is expected to be a significant channel for atmospheric escape, particularly in the early solar system when extreme ultraviolet (EUV) fluxes were much higher [3]. Thus characterizing this escape process is central to understanding the role escape to space has played in Mars' climate evolution.

2. Approach

Because escaping hot atoms cannot easily be directly measured, models of production and transport (through the atmosphere) of such atoms must be used to constrain escape rates. These models require altitude profiles of neutral densities and electron and ion densities and temperatures, as well as compositional information.

All the relevant quantities upon which photochemical escape depends are measured by MAVEN at the relevant altitudes (130-300 km). The Langmuir Probe and Waves (LPW) instrument measures electron density and temperature [4], the Neutral Gas and Ion Mass Spectrometer (NGIMS) measures neutral and ion density [5]and the SupraThermal And Thermal Ion Composition (STATIC) instrument [6] measures ion density and temperature. Four separate calculations must be made for every inbound and outbound altitude profile [7]:

1. Profiles of O_2^+ dissociative recombination (DR) rates are calculated straightforwardly from electron temperature, electron density and O_2^+ density.
2. Profiles of rotational and vibrational distributions of O_2^+ ions are calculated from profiles of CO_2, O, O_2, O^+, CO_2^+ and CO^+ via a lookup table from an empirical model.
3. Profiles of energy distributions of hot O atoms are calculated from the results of step 2 and from profiles of electron and ion temperatures.
4. Profiles of all neutral densities are input into models of hot O transport in order to calculate photochemical escape fluxes from DR of O_2^+.

3. Preliminary results

We present photochemical escape fluxes as a function of all relevant factors, in particular solar zenith angle and EUV flux. The latter will change with solar activity, solar rotation and Mars heliocentric distance, while MAVEN will sample the former from ~10° to 150° as the periapsis location precesses over the first 5 months of the primary mission. Figure 1 shows an example of aphotochemical escape rate calculation from December 2014 at a solar zenith angle of 75°. Figure 2 shows calculated photochemical escape rates as a function of solar zenith angle for ~100 periapsis passes. At 60° solar zenith angle the calculated escape fluxes range from 0.1 to 5 x 10^7 cm^{-2} s^{-1} compared with modeled escape fluxes ranging from 1 to 40 x 10^7 cm^{-2} s^{-1}.

These results are still very preliminary and subject to change as calibrations evolve. Validated photochemical escape fluxes from the MAVEN primary mission, combined with further simulations with progressively higher EUV fluxes, will eventually enable a total integrated loss estimate over the course of Martian history and hence a determination of the impact of this loss process on the evolution of the Martian climate.

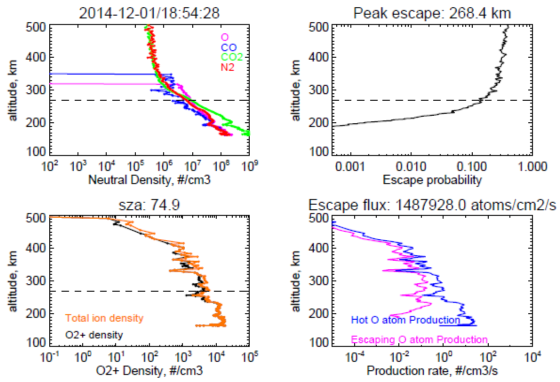

Figure 1: Example of photochemical escape rate calculation. Top left panel shows measured neutral densities. Top right panel shows average escape probability as a function of the altitude at which hot O atoms are produced via dissociative recombination. Bottom left panel shows measured ion densities. Bottom right panel shows of production rates of total and escaping hot O atoms.

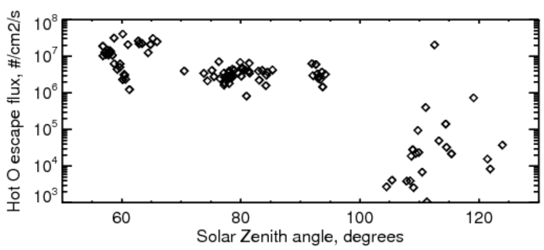

Figure 2: Hot oxygen escape fluxes calculated from periapsis passes in November and December 2014, shown as a function of solar Zenith angle.

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