MORE THAN BEFORE: INCREASE IN ESTIMATED OXYGEN PHOTOCHEMICAL ESCAPE RATES FROM EMM DATA AND UPDATED MODELING.

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Introduction

Atmospheric escape plays a major role in the climate history and evolution of Mars. Quantitative characterization of the current atmospheric loss rate is thus crucial to understanding the evolution of water and CO_2 inventories at Mars. During the present epoch, the photochemical escape of neutral atoms such as O, N, C and H is understood to be a major non-thermal escape mechanism. One of the critical but less certain parameter in computing the density of hot atoms in the corona (where most of the escape to space happens) and the resulting escape rate is the collision cross sections between nascent hot O atoms (that are primarily produced by the dissociative recombination of O_2^+ ions with electrons) and the major thermospheric neutral species, which is CO_2. The previous studies initially assumed an isotropic hard sphere approximation for all hot O collisions. Later, a more realistic quantum mechanical calculation of O + O collisions (Kharchenko et al. 2000) was applied to O collisions with different thermospheric species.

Estimation of hot oxygen escape flux

Recently, the new quantum mechanical calculations of doubly differential cross sections have been performed for O + CO_2 by Gacesa et al. (2020). The present study updates the existing three-dimensional Monte Carlo hot O transport simulations (Lillis et al. 2017) by adopting these new cross sections and their angular dependencies. In-situ observations from the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft during its Deep Dip campaign (when the periapsis altitude was lowered to $\sim$ 130 km) are used as input to the model. For each set of neutral density and electron and ion temperature profiles, we run the Monte Carlo model to calculate escape probabilities as a function of altitude. We assume that the atmosphere is spherically symmetric with the same altitude profile everywhere. Hot O atoms start at a set altitude and are given random directions and an initial energy drawn at random from the initial energy distribution for that altitude (Lillis et al. 2017). They are propagated through collisions with thermal neutrals, using the above mentioned collision cross sections.

In order to determine photochemical escape fluxes of hot oxygen from in-situ measurements, we must separately calculate two different quantities as a function of altitude: (1) the production rate of hot oxygen atoms from O_2^+ DR (Figure 1a), and (2) the probability that, once produced, a hot O atom will escape the atmosphere (Figure 1b). The hot O production rate, in number per cubic centimeter per second, is given by twice the DR rate, since each reaction produces two oppositely directed O atoms. The escaping production rate is then calculated by multiplying the total production rate with the ecsape probability (Figure 1c). The escaping flux is calculated by integrating the ecsaping production rate with altitude. The inclusion of new O + CO_2 cross sections is giving a factor of $\sim$ 6 enhancement in the oxygen escape flux as compared to the approach by Lillis et al. (2017) (Figure 1c).

Data–model comparison

Observations from the Emirates Mars Ultraviolet Spectrometer (EMUS; Holsclaw et al. 2021) instrument onboard Emirates Mars Mission (EMM; Amiri et al. 2022, AlMatroushi et al. 2021) spacecraft are used for validating the modeled coronal oxygen densities. EMUS is a high-sensitivity UV spectrometer, which measures emissions in the spectral range 100–170 nm. The FUV solar resonant fluorescence emission line of atomic oxygen at 130.4 nm in the corona is observed by EMUS up

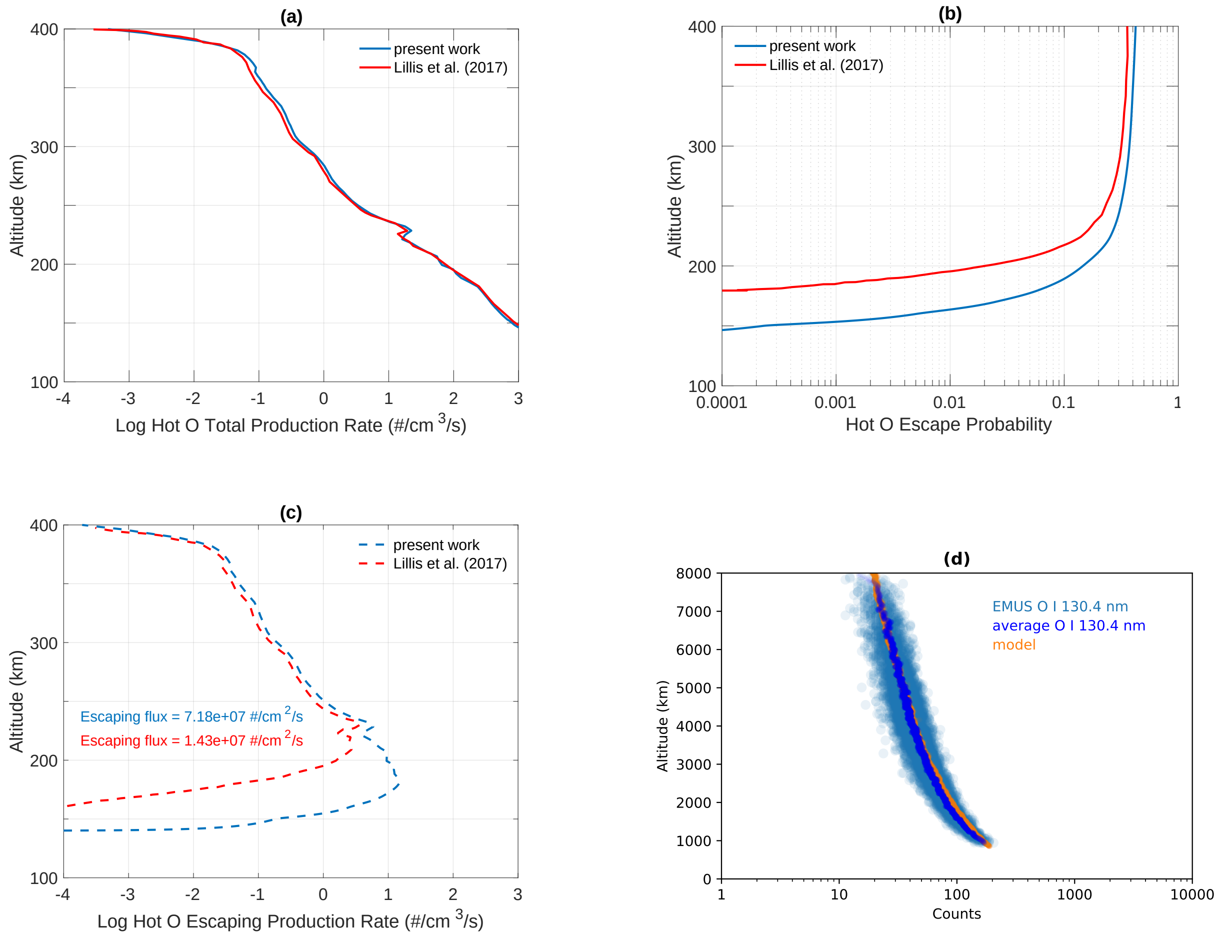

Figure 1: (a) Total production rate of hot oxygen, (b) escape probability of hot oxygen, (c) escaping production rate and escape flux of hot oxygen, and (d) comparison of EMM/EMUS hot oxygen corona observations with the Monte Carlo model.

to several Mars radii (> 6 R_M). Observing this tenuous hot oxygen corona is challenging (Deighan et al. 2015), and such high-altitude observations are made for the first time. The oxygen coronal brightnesses are obtained using the long exposure time EMUS observation strategy, termed as U-OS4.

The U-OS4 provides long exposure times for the mid and outer exosphere and will occur while the spacecraft is charging in a near-inertial orientation (Holsclaw et al. 2021). There are two scenarios for this observation: U-OS4a and U-OS4b. The U-OS4a is a cross-exosphere observation that is targeting the coronal oxygen emission at 130.4 nm with the instrument boresight vector in the plane of the spacecraft orbit, perpendicular to both the Mars-Sun line and orbit normal, while U-OS4b targets the interplanetary background. A typical such U-OS4a observation taken on February 13, 2022 (EMM orbit number 172) is compared with the Monte Carlo hot O model (Figure 1d). The comparison shows a gross match between the modeled and observed profiles.

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