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MAVEN in situ measurements of photochemical escape of oxygen from Mars

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One of the primary goals of the MAVEN mission is to characterize rates of atmospheric escape from Mars at the present epoch and relate those escape rates to solar drivers. One of the known escape processes is photochemical escape, where a) an exothermic chemical reaction in the atmosphere results in an upward-traveling neutral particle whose velocity exceeds planetary escape velocity and b) the particle is not prevented from escaping through subsequent collisions. 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. Thus characterizing this escape process and its variability with solar drivers is central to understanding the role escape to space has played in Mars' climate evolution.

We use near-periapsis (<400 km altitude) data from three MAVEN instruments: the Langmuir Probe and Waves (LPW) instrument measures electron density and temperature, the Suprathermal And Thermal Ion Composition (STATIC) experiment measures ion temperature and the Neutral Gas and Ion Mass Spectrometer (NGIMS) measures neutral and ion densities.

For each profile of in situ measurements, we make several calculations, each as a function of altitude. The first uses electron and temperatures and simulates the dissociative recombination of both O_2+ and CO_2+ to calculate the probability distribution for the initial energies of the resulting hot oxygen atoms. The second is a Monte Carlo hot atom transport model that takes that distribution of initial O energies and the measured neutral density profiles and calculates the probability that a hot atom born at that altitude will escape. The third takes the measured electron and ion densities and electron temperatures and calculates the production rate of hot O atoms. We then multiply together the profiles of hot atom production and escape probability to get profiles of the production rate of escaping atoms. We integrate with respect to altitude to give us the escape flux of hot oxygen atoms for that periapsis pass.

We have sufficient coverage in solar zenith angle (SZA) to estimate total escape rates for two intervals with the obvious assumption that escape rates are the same at all points with the same SZA. We estimate total escape rates of 3.5-5.8 x 1025 s-1 for Ls = 289° to 319° and 1.6-2.6 x 1025 s-1 for Ls = 326° to 348°. The latter is the most directly comparable to previous model-based estimates and is roughly in line with several of them.

Total photochemical loss over Mars history is not very useful to calculate from such escape fluxes derived over a limited area and under limited conditions. A thicker atmosphere and much higher solar EUV in the past may change the dynamics of escape dramatically. In the future, we intend to use 3-D Monte Carlo models of global atmospheric escape, in concert with our in situ and remote measurements, to fully characterize photochemical escape under current conditions and carefully extrapolate back in time using further simulations with new boundary conditions.