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J.T. Clarke, *Center for Space Physics, Boston University, Boston USA (jclarke@bu.edu),* **M. Mayyasi** *CSP / BU***, D. Bhattacharyya** *Univ of Illinois UC, Urbana USA***, J-Y Chaufray** *LATMOS France***, and the MAVEN IUVS team** *Univ. of Colorado Boulder USA*

Introduction: The history of water on Mars is of great interest to understand terrestrial planet evolution. The constituent atoms of water are known to escape the weak Martian gravity into space, while heavier water molecules remain in the atmosphere. A key indicator of water loss is the ratio of the isotopes deuterium to hydrogen. The lighter H escapes faster than D leading to a gradual increase in the D/H ratio of the remaining water. The present D/H ratio is proportional to the total water Mars has lost in its lifetime, but deriving the depth of a primordial Martian ocean requires understanding the physical processes that control escape today to accurately extrapolate back in time. Observations of UV resonance line emissions from H and D with the MAVEN and Hubble Space Telescope (HST) missions provide the key atomic H and D densities and escape rates.

Observations: H and D atoms in the Martian upper atmosphere are separately measured by resolving their UV Lyman-α emissions at high spectral resolution. H Lyman-α emission from Mars is produced by resonant scattering of solar photons by H and D atoms in the upper atmosphere. The incident sunlight penetrates to a depth where it is absorbed by CO_2, roughly 80-100 km altitude depending on the angle of incidence. Both D and H atoms in the Martian upper atmosphere scatter photons in the spectrally broad solar emission line, with a wavelength shift between the D and H lines corresponding to the small difference in energy levels in the isotopes. Relating the emission brightnesses to densities requires the application of a radiative transfer model that accounts for multiple scattering of photons in the atmosphere. This leads to complications involving a degeneracy between derived values of the atomic density and temperature, which have been carefully studied and reported. In this work we have made a fit to upper atmospheric temperature measurements by the MAVEN NGIMS instrument to remove the degeneracy. Another complication comes in relating local measurements to global average values to derive the total loss rates. In this report functional relationships for the variation in temperature and density with solar zenith angle are applied to the data. Measured values at each location on the planet have been converted to the values at the subsolar point, and then integrated across the Martian globe with the assumed functional relations for temperature and density with solar zenith angle to derive global escape fluxes. Observations will be presented from late MY 32 to mid MY 35.

Results: As previously reported there are strong repeated seasonal increases in the densities and escape fluxes of both H and D atoms each Martian year near perihelion, consistent with a strong upwelling of water tied to lower atmosphere dynamics needed to supply the atoms. Around perihelion there appear dramatic changes on time scales of a couple of weeks, providing a means to estimate the loss processes and fractions. A process in addition to thermal escape is required to explain the observed changes in D density, likely from superthermal processes that produce hot atoms. This implies that at present D and H escape at close to their ratio in water, providing strong evidence for the scenario of a warm, wet primordial Mars with a large depth of water on its surface. In addition the D/H ratio appears elevated compared with the ratio in Martian water, consistent with rapid escape of H atoms from the upper atmosphere. Changes in the atomic D/H ratio over each year result in changes in the fractionation factor that describes the ratio of D/H in the escaping atoms compared with the D/H ratio in Martian water. These results will be presented and the implications will be discussed.