H ESCAPE AT THE PRESENT EPOCH Michael Chaffin[1], J.Y. Chaufray[2], J. Deighan[1], N.M. Schneider[1], W.E. McClintock[1], I.A. Stewart[1], J.T. Clarke[3], G.M. Holsclaw[1], B.M. Jakosky[1], and the IUVS team, [1]Laboratory for Atmospheric and Space Physics, Boulder, CO, USA, michael.chaffin@colorado.edu, [2]LATMOS/IPSL, Guyancourt, France, [3]Center for Space Physics, Boston University, Boston, MA, USA

Historical Measurements of H escape from Mars: Beginning with the observations of Anderson and Hord (1971), resonance scattering of 121.6 nm H Lyman alpha sunlight has been used to quantify the inventory of H atoms in the extended upper atmosphere of Mars and derive an escape rate of these atoms from the Martian atmosphere [1]. Because H in the upper atmosphere is ultimately derived from the breakdown of water in the lower atmosphere, H escape is an important loss process for the initial water inventory of Mars. H escape also provides a potential source of oxidizing power to the Martian atmosphere and surface, provided it is not balanced by the nonthermal escape of O from the atmosphere.

Historically, measurements of the Martian H corona have been intermittent, making it difficult to establish whether variability in the H escape rate exists and quantify its potential causes. Before Mariner 9, it was anticipated that seasonal variations in the H corona would manifest as a consequence of the changing lower atmospheric water inventory [2], but observations gathered in the winter of 1971/72 showed little variation in the brightness of the corona, despite a global dust storm and near daily coverage of the corona over a two month period [3]. Combined with the discovery of the lower atmospheric odd-hydrogen cycle in the same year, these observations led to the interpretation that exospheric H is sourced from molecular H_2, whose decades-long photochemical lifetime buffers short-term changes in the H escape rate [4, 5]. Later observations made by Mars 5, SPICAM on Mars Express, and ALICE on Rosetta did not challenge this interpretation, owing to a lack of high-cadence seasonal measurements, particularly during Mars Southern summer [6, 7, 8].

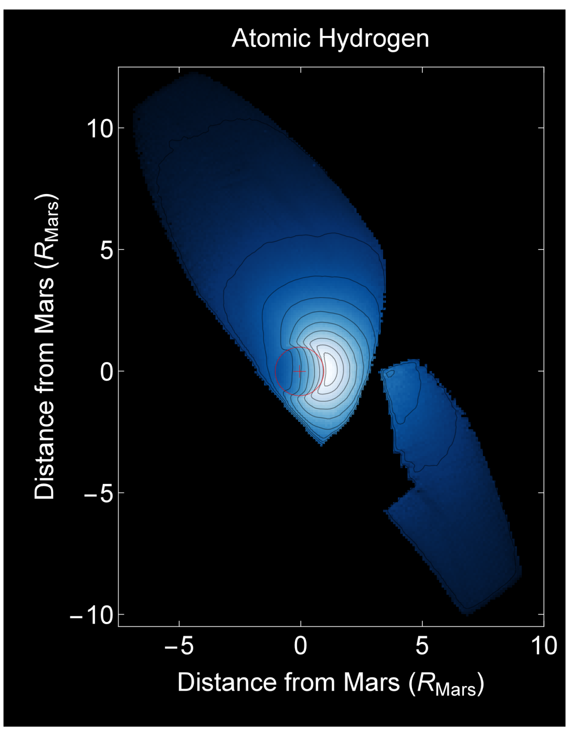

Figure 1: Insertion orbit composite map of the Mars H corona. Observations made during the high-altitude insertion orbit allow unprecedented high signal-to-noise maps of the H corona out to 10 Mars radii.

In late 2007, coordinated observations made using HST and SPICAM observed a factor of two change in the brightness of the H corona, well-correlated with the end of Southern summer and the perihelion egress of Mars, as well as the decline of the 2007 global dust storm [9, 10, 11]. More recent observations in a seasonal HST campaign have revealed a brightening of the Mars corona during Southern spring and perihelion ingress, consistent with a seasonal variation in the hydrogen inventory of the corona and the escape rate of H from Mars [12].

These observations indicate that H escape varies by more than an order of magnitude as a function of season, setting the stage for MAVEN measurements of the H escape rate over the course of its one-year primary mission. Observations made by MAVEN during its primary mission will cover the majority of southern summer on a 9 hour cadence, providing for the first time a uniform high-resolution database of the time-variation of the H corona at Mars.

Observations: MAVEN observes the H corona with its remote sensing platform, the Imaging UltraViolet Spectrograph (IUVS) [13]. IUVS simultaneously observes in the FUV and MUV, covering 115-330 nm in two separate channels. Lyman alpha is the brightest signal in the FUV airglow of Mars, and is ubiquitous in our observations. During MAVEN's 35-hour insertion orbit, special observations were made that allowed large scale high signal-to-noise mapping of the H corona to a distance of 10 r_{Mars}, as shown in Figure 1. For the 4.5hr primary science orbits, the instrument is pointed inertially across the elliptical spacecraft orbit during inbound and outbound legs. Spacecraft motion carries the instrument boresight across altitudes in the range 0-3000km; derived brightness profiles are shown in Figure 2.

Because these observations are optically thick, their interpretation requires forward modeling and radiative

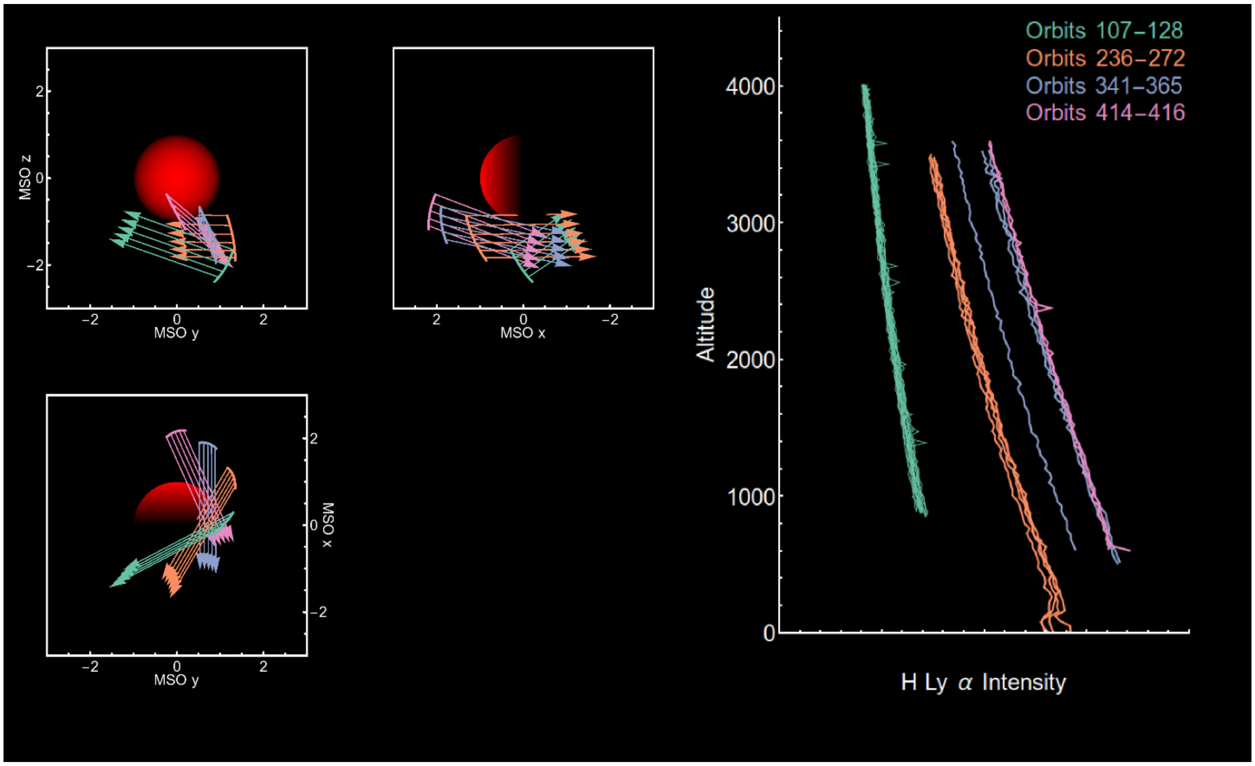

Figure 2: H Lyman alpha coronal scans obtained by MAVEN's IUVS. At left, orbit geometry and look direction over the first three months of the mission. At right, intensity of Lyman alpha as a function of pointing altitude. Units are unspecified as the instrument is still being calibrated.

transfer [14, 15], which has been integrated into the MAVEN data processing pipeline. Initial results from this processing and the escape rates derived will be presented and placed in context with prior observations described above.

Implications for Water Loss History: MAVEN's driving goal is to understand the history of atmosphere and volatile loss to space over the past 4.5 Billion years. Such an understanding is only possible through a comprehensive characterization of the processes at work in the atmosphere today, so that these processes can be projected into the past. Thermal H escape may be the dominant mechanism removing water from the Martian atmosphere today, but determining the total amount of H removed by this process over Martian history is likely to be complicated by many factors, including the climate and solar forcing history of the atmosphere.

H escape today exhibits a strong seasonal dependence, which is likely derived from seasonal variations in the amount of water vapor at high altitude [16]. Percent level changes in the total column due to detached upper atmospheric water layers can drive order of magnitude changes in H escape on a timescale of months, providing a convenient connection between lower atmospheric dynamics and H escape in the corona of Mars.

In order to understand the impact of the altitude distribution of water vapor on the H escape rate, simultaneous observations of coronal H and the altitude profile of lower and middle atmospheric water are required.

References: [1] D. E. Anderson, Jr., et al. (1971) *J Geophys Res* 76:6666. [2] C. W. Hord, et al. (1970) *Icarus* 12:63. [3] C. A. Barth, et al. (1972) *Icarus* 17:457. [4] M. B. McElroy, et al. (1972) *Science* 177:986. [5] T. D. Parkinson, et al. (1972) *J Atmos Sci* 29:1380. [6] S. B. Dostovalov, et al. (1973) *Kosmicheskie Issledovaniia* 11:767. [7] J. Y. Chaufray, et al. (2008) *Icarus* 195:598. [8] P. D. Feldman, et al. (2011) *Icarus* 214:394. [9] J. T. Clarke, et al. (2009) in *AAS/Division for Planetary Sciences Meeting Abstracts* vol. 41 #49.11. [10] M. S. Chaffin, et al. (2014) *Geophys Res Lett* 41:314. [11] J. T. Clarke, et al. (2014) *Geophys Res Lett* 41:8013. [12] J. T. Clarke, et al. (2014) in *AAS/Division for Planetary Sciences Meeting Abstracts* vol. 46 #412.08. [13] W. E. McClintock, et al. (2014) *Sp Sci Rev*. [14] D. E. Anderson, Jr., et al. (1977) *Plan Sp Sci* 25:563. [15] B. C. Bush, et al. (1995) *J Geophys Res* 100:19627. [16] M. S. Chaffin, et al. (2014) *LPI Contributions* 1791:1039.