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The D/H Ratio in the Martian Upper Atmosphere

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Abstract

MAVEN IUVS echelle channel measurements of the H and D Lyman-alpha emissions from the upper atmosphere of Mars have been carried out since late 2014. Following a determination of the global scale patterns in temperature and atomic number density, and the application of a new asymmetric radiative transfer code, it is now possible to quote accurate values for the densities of H and D and the D/H ratio in the martian upper atmosphere. The densities of both atoms show a strong seasonal variation with a large increase during southern summer /perihelion. At this same time the D/H ratio also increases strongly compared with aphelion, when it is close to the value in lower atmospheric water. Initial thoughts on the processes responsible for this variation will be presented.

1. Introduction

Before the arrival of MAVEN at Mars in 2014 it was known from HST and Mars Express / SPICAM observations that the atomic hydrogen population in the upper atmosphere of Mars underwent seasonal changes corresponding to at least an order of magnitude increase in density and escape flux in southern summer, when Mars is closest to the Sun [1 and references therein]. Based on the detection of unexpectedly large amounts of water in the middle atmosphere in the same season [2], it was proposed that there was a short-term large flux of hydrogen into the upper atmosphere. Understanding this process, and its controlling factors, is critical to be able to extrapolate back in time to the escape of water into space when Mars was young.

2. New Work and the D/H Ratio

The orbital plane of MAVEN around Mars provides observations of specific regions on the planet that evolve over time as the orbit precesses. To determine changes with time, as opposed to variation with solar zenith angle or other location parameters, the time series of data from multiple instruments were used to establish the variation in density and thermospheric temperature from noon to midnight. Observations anywhere around the planet could then be related to conditions at the subsolar point for direct comparison [4]. In addition, the MAVEN echelle sensitivity is sufficient to detect the faint D Lyman-alpha emission during southern summer, but not around aphelion when it is much fainter. New and archived HST STIS spectra of the D and H emissions were used to establish the brightness of the D emission around aphelion. Finally, a new radiative transfer code that treats a non-spherically symmetric atmosphere was employed to obtain realistic values for density and escape flux for both H and D.

The combined data set and modelling indicate that around aphelion the thermospheric D/H ratio at Mars is consistent with the value in lower atmospheric water, which is 5-10 times that in standard mean ocean water [5]. However, closer to perihelion both the H and D densities increase sharply, and the D/H ratio is enhanced by a factor of 5-10 over the value around aphelion. This appears to be consistent with a strongly increased flux of atoms from middle atmospheric water, and the faster escape of H compared with D. On a longer time scale, the upper atmosphere equilibrates back to the conditions near aphelion, i.e. much lower atomic densities and lower D/H ratio.

3. Summary and Conclusions

Observations of both H and D populations in the upper atmosphere of Mars have been made with the MAVEN IUVS echelle channel around perihelion

and the HST/STIS around aphelion. Observations close in time in summer 2018 have shown consistent calibrations and emission brightnesses between the two instruments. Around aphelion the thermospheric D/H ratio at Mars is consistent with the value in lower atmospheric water, while closer to perihelion both the H and D densities increase sharply, and the D/H ratio is enhanced by a factor of 5-10 over the value at aphelion.

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