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Mars Express Observations of the Hydrogen Corona of Mars

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Abstract

Mars Express observations of hydrogen Lyman alpha are analyzed, yielding information about the temperature and density of the Martian exosphere and hydrogen escape rate. Using detailed radiative transfer calculations appropriate to the optically thick hydrogen corona of Mars, we obtain the temperature and density of hydrogen atoms at the exobase. From these data, we estimate the escape rate of hydrogen from the atmosphere of Mars, with important implications for water loss rates and the early habitability of the Martian surface. Results will be presented on the full range of data collected by the SPICAM instrument on Mars Express, with particular emphasis on the variation in escape rate as a function of solar zenith angle. Implications for the MAVEN mission's detection of the hydrogen corona will also be discussed.

1. Introduction

Analysis of the hydrogen corona of Mars has been performed by Chaufray et. al. (2008) [1], and Leblanc et. al. (2006) [2], using data gathered by the European Space Agency's Mars Express. Employing optically thick radiative transfer codes, they invert spacecraft data to obtain the density and temperature of exospheric hydrogen, and infer an escape rate of hydrogen, providing a constraint on water loss from Mars by this mechanism. In this work, similar analysis is performed on a Mars Express dataset four times larger than those previously studied. This abstract outlines the numerical techniques used and anticipates results to be presented at the conference.

2. Numerical Model

Because the corona of Mars is optically thick in Lyman alpha emission, density and temperature profiles are not directly measurable. This means that determining the density and temperature profiles of coronal hydrogen requires forward modeling. The physical atmosphere model is based on that of Krasnopolsky (2002) [3], incorporating production and diffusion of hydrogen through the background carbon dioxide atmosphere of Mars. Augmenting this description above the exobase is a classical Chamberlain exosphere without satellite particles [4]. In this region, the corona is observable in resonance scatted solar Lyman alpha.

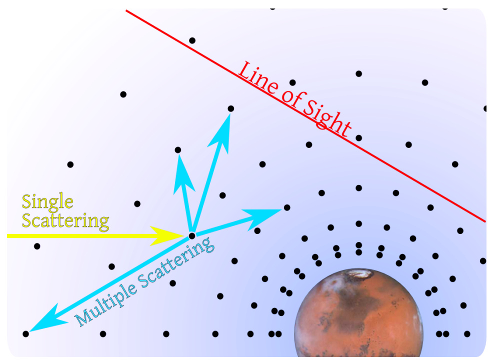

Figure 1: Geometry of the problem. Incoming light parallel to the Sun-Mars axis is scattered by hydrogen atoms in the upper atmosphere of Mars. Observations are made along a line of sight which terminates at the spacecraft (not shown). Here, the black dots indicate the grid points introduced to solve the problem numerically.

Because the hydrogen corona is relatively cold in comparison to the Sun, we assume that the solar line is flat over the Doppler width of Lyman alpha in the Martian atmosphere. This reduces the radiative transfer equation to an integral equation for a new object, the source function $S(\mathbf{r})$, which upon integration yields the specific intensity. Formally, we have

$$I(\mathbf{r},\mathbf{\Omega}) = \frac{g}{4\pi}\int S(\mathbf{r})T(\tau)e^{-\tau_{\mathrm{CO}_2}},$$

$$S(\mathbf{r}) = n(\mathbf{r})T(\tau_{\mathrm{sol}})e^{-\tau_{\mathrm{CO}_2}} + \sigma_0 n(\mathbf{r})\int_0^{2\pi}\int_0^{\pi}\int_0^{\infty} Q(\mathbf{r},\mathbf{\Omega})dsd\theta d\phi.$$

$$Q(\mathbf{r},\mathbf{\Omega}) = S(\mathbf{r}+s\mathbf{\Omega})G(\tau(\mathbf{r},\mathbf{r}+s\mathbf{\Omega}))e^{-\tau_{\mathrm{CO}_2}}$$

See Fig. 1 for a diagram of the geometry. Here, I is the intensity at point $\mathbf{r}$ along a line of sight $\mathbf{\Omega}$ through the atmosphere. $S(\mathbf{r})$, the source function, is defined at all points of the atmosphere and is composed of two parts: single scattering, defined by the first term, which is proportional to the number of hydrogen atoms $n(\mathbf{r})$ at that point multiplied by the probability of absorbing a solar photon, and multiple scattering, which is a convolution of the source function at all other points in the atmosphere with a kernel describing the probability of scattering between the two points. All terms are diminished by CO_2 absorption, which dominates at points deep inside the atmosphere. In this context, $T(\tau)$ and $G(\tau)$ are the Holstein T and G functions, σ_0 is the cross section for absorption at the center of the Lyman alpha line, and g is the frequency of Lyman alpha scattering [5].

Once the source function is obtained, numerical integration yields the intensity observed by the spacecraft. The source function as computed is compared with the data obtained on site, and the density and temperature of the model are adjusted until the calculation and observations match. In the Chamberlain model adopted here, the exospheric hydrogen density and escape flux are functions of the temperature and density of the exobase only, enabling the immediate calculation of the escape flux once these parameters are known. By examining the entirety of the Mars Express dataset, constraints will be placed on the escape flux of hydrogen, and thus the time-integrated loss of water over the course of Martian history.

3. Observations

Shown in Fig. 2 are observations taken on orbit by SPICAM on Mars express. Observations are expressed as intensity of observed Lyman alpha intensity as a function of the minimum altitude along the spacecraft line of sight. These observations demonstrate the variability of coronal airglow as a function of solar illumination, indicating that hydrogen escape is highly dependent on the intensity of the impinging sunlight.

4. Future Applications

This work will present the results of applying the radiative transfer model described above to the entirety of the coronal airglow data gathered by Mars Express. This analysis is particularly important in light of the upcoming MAVEN mission, which will extend the observations of Mars Express to a broader set of solar input conditions and allow for the measurement of Deuterium as well as hydrogen.

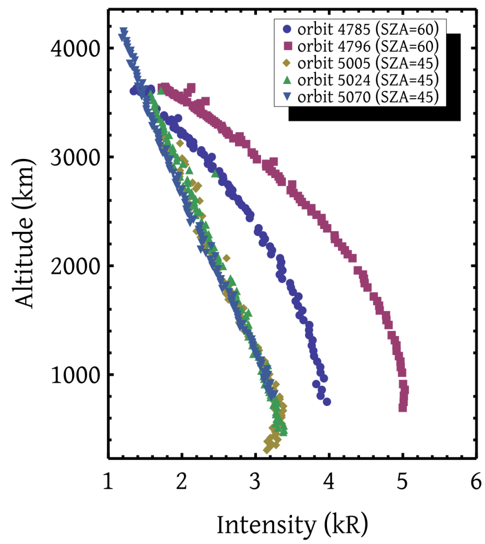

Figure 2: Observed Lyman alpha intensity as a function of spacecraft pointing altitude. Note the dramatic variability of the altitude profile as a function of illumination conditions.

References

[1] Chaufray, et. al.: Observation of the hydrogen corona with SPICAM on Mars Express, Icarus, Vol. 195, pp. 598-613, 2008.

[2] Leblanc, F., et. al.: The martian dayglow as seen by SPICAM UV spectrometer on Mars Express, J. Geophys. Res., Vol. 111, 2006.

[3] Krasnopolsky, V.A.: Mars upper atmosphere and ionosphere at low, medium and high solar activities: Implications for evolution of water, J. Geophys. Res., Vol. 107, pp. 28-51, 2002.

[4] Chamberlain, J.W.: Planetary coronae and atmospheric evaporation, Planet. Space Sci., Vol. 11, pp. 901-960, 1963.

[5] Holstein, T.: Imprisonment of Resonance Radiation in Gases, Phys. Rev., Vol. 72, pp. 1212-1233, 1947.