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Mars emissions from CO and CO_2^+: IUVS-MAVEN limb observations and model

J.-C. Gérard (1), L. Gkouvelis (1), B. Ritter (1), B. Hubert (1), S. Jain (2), N.M. Schneider (2), V.I. Shematovich (3) and D.V. Bisikalo (3)

(1) LPAP, Université de Liège, Belgium, (2) LASP, University of Colorado, Boulder, USA, (3) Institute of Astronomy, Moscow (jc.gerard@uliege.be)

Abstract

We analyzed limb observations of various dayglow emissions collected during about 3 years by the Imaging Ultraviolet Spectrograph (IUVS) instrument on board the Mars Atmosphere and Volatile Evolution mission (MAVEN) satellite orbiting Mars. These profiles have been analyzed in terms of latitude, season, local time, solar zenith angle and Martian year. They are compared with the altitude distribution and brightness expected by model simulations based on densities from Mars General Circulation models. To fit the observations scaling factors have to be applied to the GCM atmospheric densities. These are generally less then unity. In this study, we take advantage of the measurements by the EUV instrument on board MAVEN that allows monitoring of incoming solar flux reaching Mars every minute.

1. Introduction

Limb observation of airglow emissions is a standard technique to study the altitude profiles of the chemical elements in the Martian atmosphere and its thermal structure. Several previous missions have performed observations in the past (Mariners, Mars Express). Three years ago, the IUVS Ultraviolet spectrograph (McClintock et al. 2014) on board MAVEN started collecting thousands of airglow and auroral limb profiles in the range 120 to 340 nm. We now have analyzed more that three years of airglow observations and compared them to model simulations. The objective is to study the characteristics of the CO_2 and CO FUV emissions to describe the Martian upper atmospheric structure and its variations.

2. IUVS observations

The Imaging Ultraviolet Spectrometer is a remote sensing instrument on MAVEN, equipped with two ultraviolet channels: the MUV (middle ultraviolet) and FUV (far ultraviolet) detectors cover the 115-190 nm and 180-340 nm spectral ranges respectively. MAVEN has collected limb spectra over three years of airglow observations covering more than a full Martian year and various latitudes ranges per epoch.

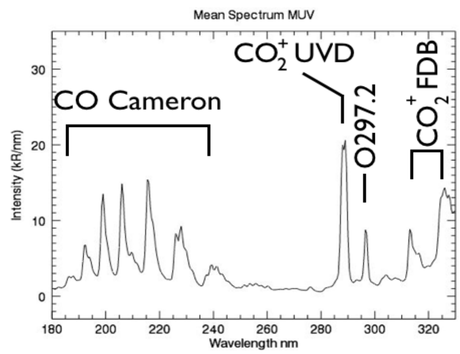

Figure 1: Sum of 210 FUV spectra collected between 110 and 130 km. The main dayglow emissions are identified between 180 and 330 nm. CO_2 is the main source constituent of all four emissions.

We have analyzed the data and generated mean altitudes profiles for many of the emission features, grouping them in epoch, seasonal and latitude ranges (Figure 2). An example of simultaneous limb scans of several emissions is shown in Figure 3. The limb brightness profile of each spectral feature was obtained by using a multiple linear regression method to fit each observed spectrum.

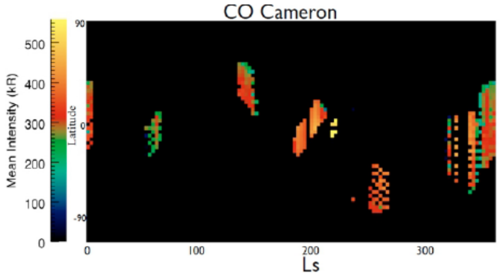

Figure 2: coverage of MAVEN dayglow observations during the first Martian year of the mission. The map shows the peak brightness of the CO Cameron emission in a 6°x6° bins.

3. Modelling

To model the dayglow emissions of the Martian atmosphere, we first construct neutral atmosphere distribution of the main constituents for different seasons, latitudes and local times based on the MCD model. Second, we use Monte Carlo simulations to calculate the photoelectron energy spectrum as a function of altitude for the latitude, solar longitude, local time and solar activity corresponding to the observations. Calculations of the collisional sources are based on the Direct Simulation Monte Carlo (DSMC) method that has been developed over the years (Shematovich et al. 2008; Gérard et al., 2008) to calculate the brightness profiles of emissions of the Earth, Jupiter, Saturn, Venus and Mars atmospheres. The energy spectrum of the photoelectrons calculated at fixed grid points is folded with relevant electron impact excitation cross sections to determine the corresponding collisional excitation rates. Finally, these sources are combined with directly solar-induced sources such as photodissociation to obtain the total volume production rates (Figure 3). In the case of the CO Cameron and CO_2^+ bands, the dominant sources are directly proportional to the CO_2 density. These emissions are therefore direct indicators of changes in thermospheric CO_2. To fit the observations, scaling factors have to be applied to the GCM atmospheric densities. These are generally less then unity.

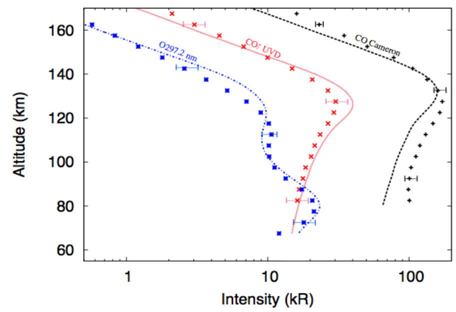

Figure 3: comparison between IUVS limb observations and model simulations for three airglow emissions. The best fit was obtained by scaling the CO_2 density by a factor of ~0.5.

4. Summary and Conclusions

A large number of limb profiles of CO and CO_2^+ dayglow emissions have been collected with the IUVS instrument on board MAVEN. They cover more than a Martian year and a wide range of latitudes, solar longitudes and local times. Comparisons with simulated limb profiles for conditions similar to the observations are presented. They provide information about the Martian atmospheric structure in a region that is difficult to probe with other techniques.

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