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THE MARTIAN PHOTOELECTRON BOUNDARY AS SEEN BY MAVEN

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Abstract

Photoelectron peaks in the 20-30 eV energy range, produced by the intense photoionization from solar 30.4 nm photons, are commonly observed in planetary atmospheres. At Mars, these photoelectrons are known to escape the planet down its tail (Frahm et al., 2006), making them tracers for the atmospheric escape. Furthermore, their presence or absence allow to define the so-called martian PhotoElectron Boundary (PEB), that separates the photoelectron dominated ionosphere from the external environment. We provide here a detailed statistical analysis of the location, drivers and properties of the PEB based on the Mars Atmosphere and Volatile Evolution (MAVEN) Solar Wind Electron Analyzer (SWEA) data obtained from September 2014 until May 2016.

1. Introduction

The photoelectron boundary was discovered by Mars Global Surveyor, but it remains poorly understood. Its nature with respect to the so-called ionopause (or other boundaries based on specific parameters) was in particular long a matter of debate.

The MAVEN spacecraft orbits around Mars since autumn 2014, and hosts a complete suite of plasma and fields instruments that allows to characterize in details the nature, properties, and variability of the PEB. We used in particular the data obtained by the Solar Wind Electron Analyzer (SWEA) instrument which is an electrostatic analyzer designed to measure the energy and angular distributions of electrons within an energy range of 3 to 4600 eV, with an energy resolution of 17%.

We analyzed the SWEA data from September 2014 to May 2016 and identified 3022 crossings where the photoelectron line appeared or disappeared. Among these 3022 crossings, 1696 correspond unambiguously to dayside PEB crossings, the others being edges of nightside suprathermal electron depletions, detached escaping photoelectrons, etc.

2. Results

The location of PEB crossings reveals an almost circular boundary with a highly variable altitude. The reorganization of the PEB crossings in the MSE coordinates system reveals a strong influence of the clock angle of the interplanetary magnetic field (IMF), and thus of the orientation of the IMF draping.

The analysis of the various drivers (Fig. 1) reveals that the altitude of the PEB is mostly driven by a pressure balance between the solar wind dynamic pressure (that pushes the boundary towards low altitudes) and the crustal magnetic field pressure (that pushes towards higher altitudes). This balance, partly influenced by the solar extreme ultraviolet fluxes or the exact geographical location (solar zenith angle, local time) thus determines the location where the upward moving photoelectrons will encounter the open draped field lines to get eventually convected toward the tail.

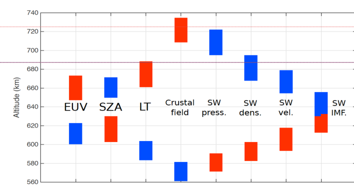

Fig 1 : Influence of several parameters on the PEB altitude: extreme ultraviolet (EUV) fluxes, solar zenith angle (SZA), local time (LT), crustal magnetic field, solar wind (SW) dynamic pressure, density, velocity and magnetic field (IMF). Each set of parameters was separated into low (below the median, blue color) and high (above the median, red color) subsets of data.

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Moreover, we show how the increase of the PEB altitude on the dayside, due to several drivers, will allow the access of photoelectrons to high altitudes until the terminator and beyond and thus affect their transport along draped field lines toward the tail and strongly modify (up to 50%) the tail cross section to be considered for deriving escape rates of photoelectrons (and associated ions assuming neutrality).

Finally, we provide a detailed analysis of the average plasma and magnetic field characteristics around the PEB, in order to provide a complete description of the boundary properties and of the processes taking place around it.

References

[1] R.A. Frahm et al. (2006), Space Science Reviews, 126, 389–402.

[2] D. Mitchell et al. (2016), Space Science Reviews, 200, 495–528.