Altitude dependence of nightside Martian suprathermal electron depletions as revealed by MAVEN

Morgane Steckiewicz[1,2], C. Mazelle[1,2], P. Garnier[1,2], N. André[1,2], E. Penou[1], A. Beth[3], J.-A. Sauvaud[1,2], D. Toublanc[1,2], AMDA team[1,2], MAVEN team[4,5,6,7]

[1] CNRS, IRAP, Toulouse, France [2] Université Paul Sabatier, Toulouse, France [3] Department of Physics, Imperial College, London, UK [4]Space Science Laboratory, Berkeley, USA [5]Goddard Space Flight Center, Washington DC, USA [6]Laboratory for Atmospheric and Space Physics, Boulder, USA 7University of Iowa, Iowa City, USA

Abstract

MAVEN is providing new detailed observations of the Martian ionosphere thanks to its unique orbital coverage and instrument suite. On almost each periapsis in the nightside ionosphere suprathermal electron depletions were detected. A simple criterion was implemented to detect all the observed depletions and identified 1742 events from November 16 2014 to February 28 2015. A statistical analysis reveals that the main ion and electron populations within the depletions are surprisingly constant in time and altitude. The absorption by CO_2 is the main loss process for suprathermal electrons and thermal electrons strongly peaked around 6 eV result from this interaction. The observation of depletions appears however highly dependent on altitude. Above 170 km their observation appears strongly favored by the presence of crustal magnetic sources whereas the depletions observed for the first time below 170 km are globally scattered onto the Martian surface with no particular dependence on crustal fields.

Background

A typical suprathermal electron depletion similar to what has been previously observed by MGS and MEX above a strong crustal magnetic field anomaly

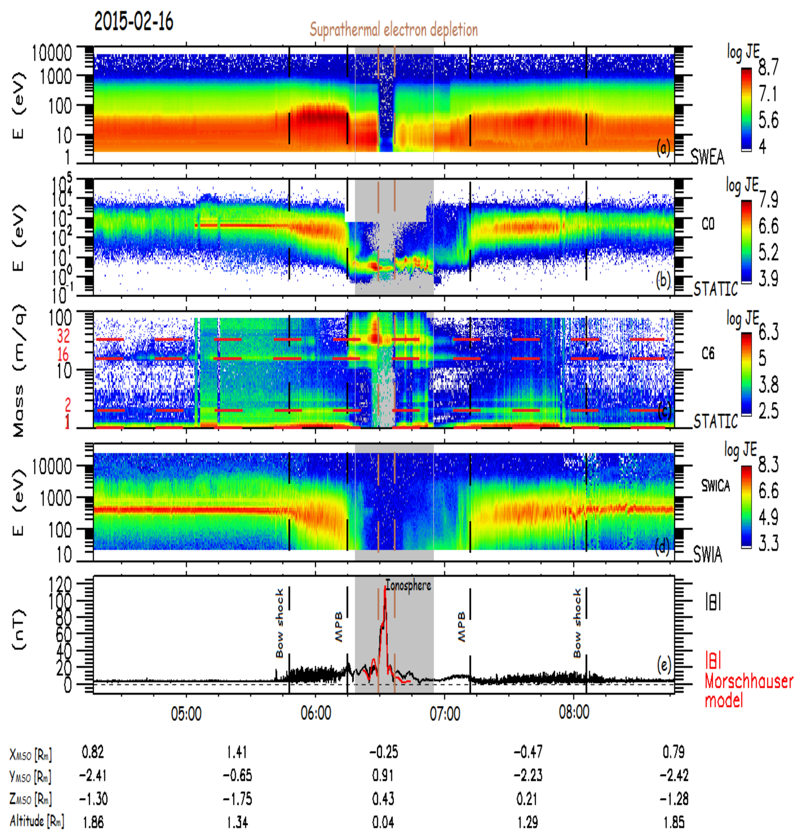

Figure 1. (a) SWEA energy-time spectrogram of electron flux (b) STATIC energy-time spectrogram of ion flux (c) STATIC mass-time spectrogram of ion flux (d) SWIA energy-time spectrogram of ion flux (e) Magnetic field intensity (measured by MAG in black and calculated from the spherical harmonic model of [Morschhauser et al., 2015] in red)

A common suprathermal electron depletion observed by MAVEN above region without significant crustal magnetic field anomaly

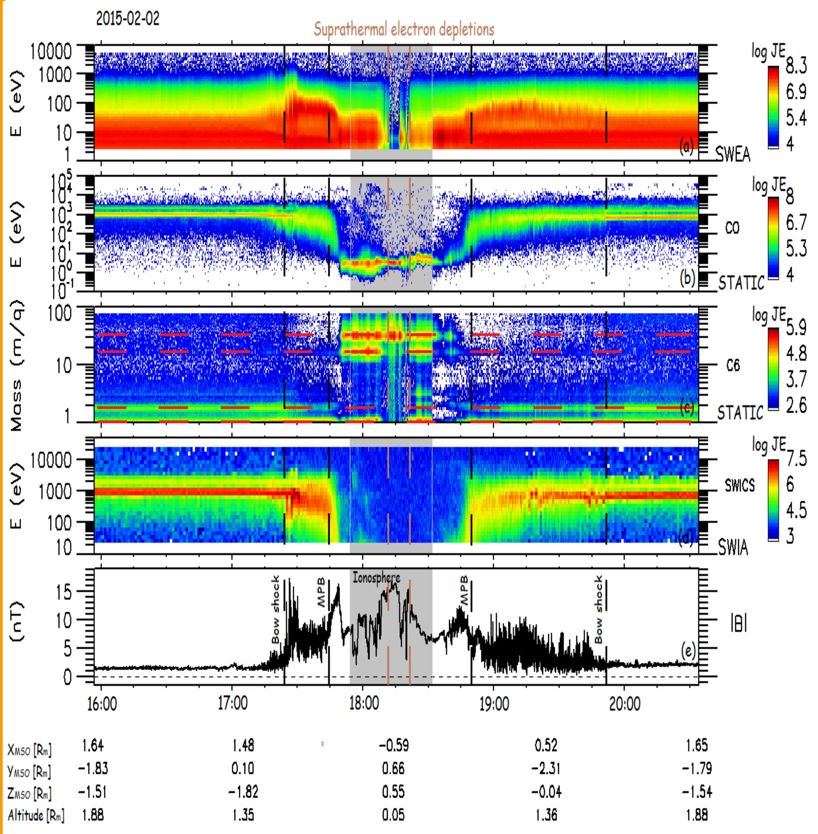

Figure 2. (a) SWEA energy-time spectrogram of electron flux (b) STATIC energy-time spectrogram of ion flux (c) STATIC mass-time spectrogram of ion flux (d) SWIA energy-time spectrogram of ion flux (e) Magnetic field intensity measured by MAG

Crustal magnetic fields can not be the unique source of electron depletions

Ion and electron populations

A simple but robust criterion was implemented in order to detect electron depletions in MAVEN data. Application of this criterion to data obtained between November 16 2014 and February 28 2015 resulted in a dataset of 1742 electron depletions identified on 457 orbits among the 494 where data are available. During the 37 others no electron depletion satisfying our criteria was found.

Figure 3 provides the measurements of SWEA (electron) and STATIC (ion) obtained within the depletions. We superimposed CO_2 cross section to the electron spectrogram. The local time distribution of our dataset covers the whole nightside sector and the Solar Zenith Angle (SZA) distribution covers a 60° sector, varying from 95° to 155°.

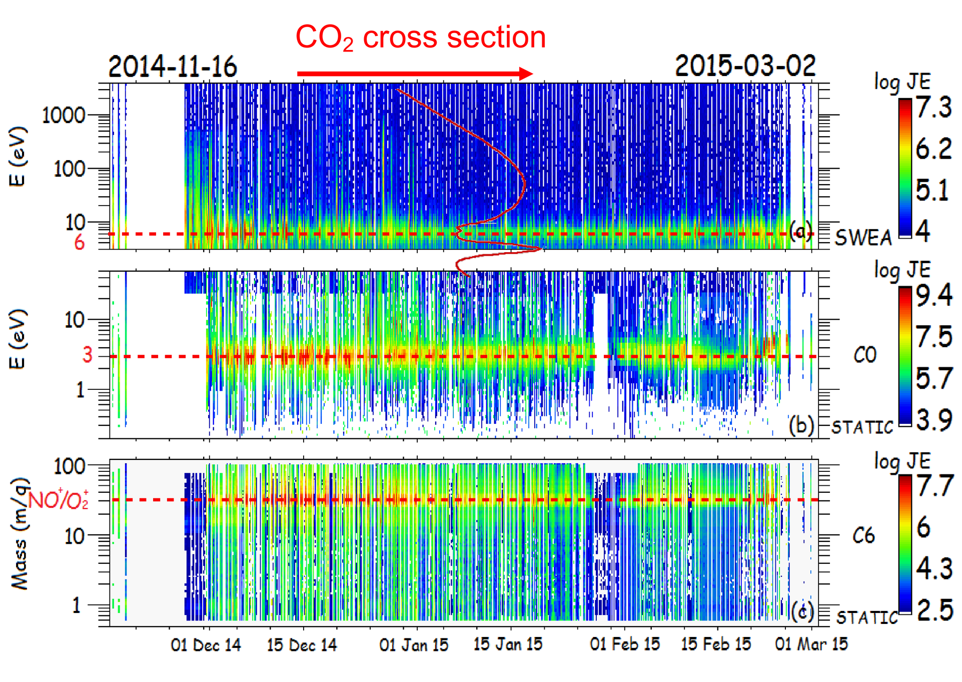

Figure 3. Concatenation of all the time intervals where electron depletions have been obtained based on the criterion given by equation (1) (a) SWEA energy-time spectrogram of electron flux (b) STATIC energy-time spectrogram of ion flux (c) STATIC mass-time spectrogram of ions flux

Inside the depletion:

- **The disappearance of electron populations with energy > 10 eV & the remaining electron population at 6 eV are due to impact with CO_2**
- **O_2^+ is the main ion species at 3 eV (ram effect)**

Altitude distribution

In order to investigate the altitude distribution of electron depletions we binned our data with constant bins of 2 km altitude. For each bin we determined the ratio between the number of electron depletions and the number of MAVEN's passages contained therein during the time period under study in order to remove any orbital bias. The percentage of electron depletions per MAVEN passage is then provided on **Figure 4**.

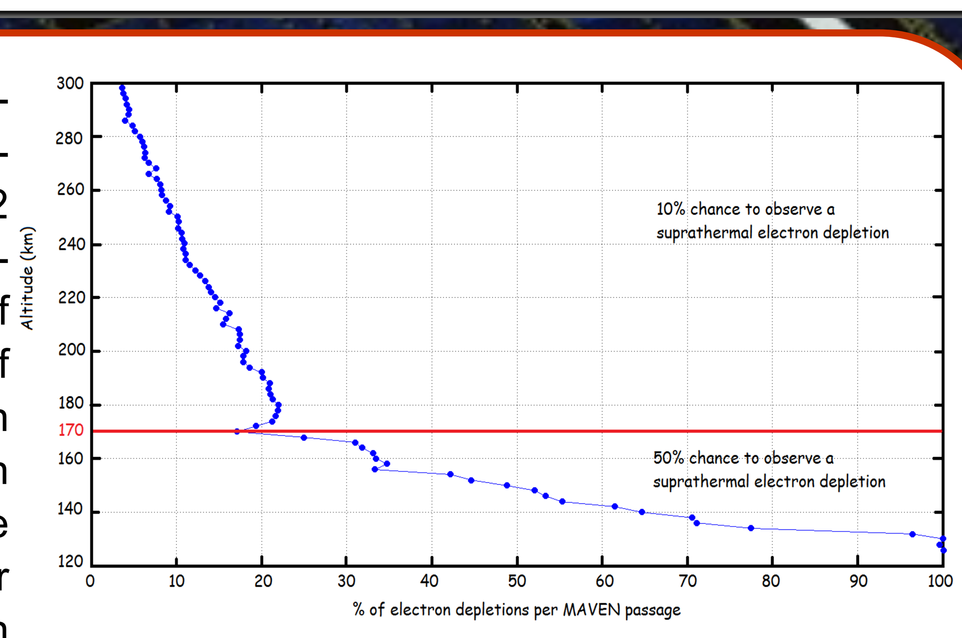

Figure 4. Percentage of electron depletions detected by our criterion per MAVEN passage in relation to altitude. The horizontal red line highlights the abrupt change in slope observed around 170km.

There is a strong change of slope at 170 km

Geographical distribution

In order to further investigate the altitude dependence of electron depletions we binned the Martian surface with constant bin size of 5° longitude per 5° latitude and then estimated the percentage of electron depletions per MAVEN passage above each bin. We superimposed on the resulting map contour lines for the intensity of the magnetic field calculated from the model of Morschhauser et al. [2015] at an altitude of 170 km.

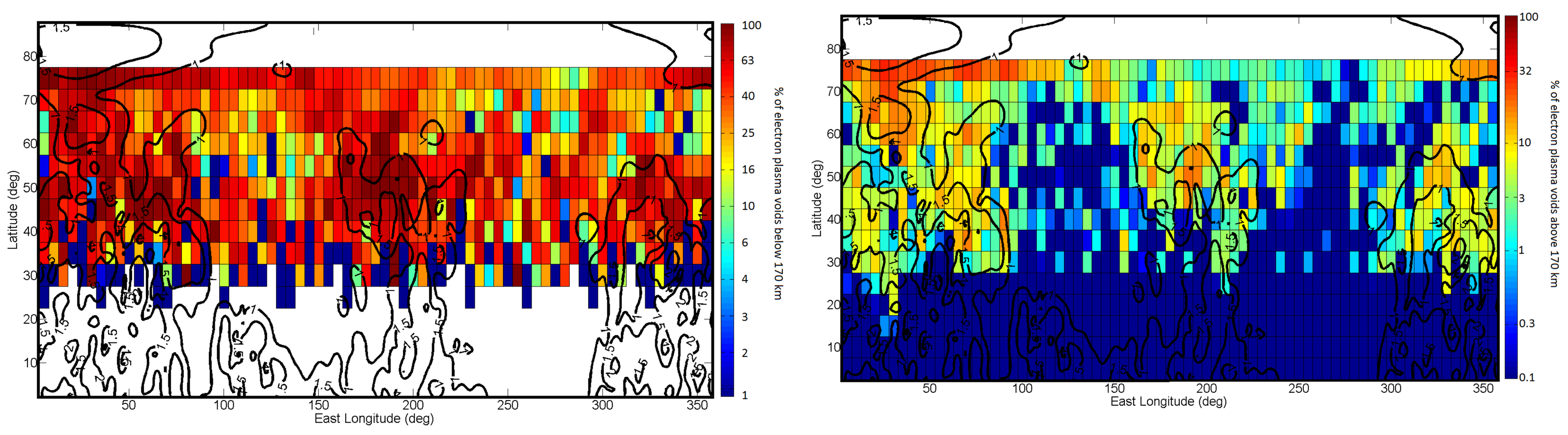

Figure 5. Percentage of electron depletions detected by our criterion per MAVEN passage superimposed on a geographic map of the Martian surface with constant bin size of 5x5 degrees. The black lines correspond to contour lines for the magnetic field intensity (in logarithmic scale) calculated from the model of Morschhauser et al. [2015] at an altitude of 170 km. Distribution of depletions observed (left) below 170 km, (right) above 170 km.

Suprathermal electron depletions are homogeneously scattered above the Northern hemisphere below 170 km but are mainly located above strong crustal sources above 170 km

Conclusions

We showed that the main ionic and electronic composition of electron depletions appears surprisingly constant with time and altitude. Electron absorption by CO_2 seems to be the best candidate to explain their origin. Our statistical analysis reveals that the presence of electron depletions in the nightside ionosphere is highly dependent on altitude: their observation above 170 km is strongly favored by the presence of crustal magnetic fields whereas they are globally scattered are onto the surface of the planet below 170 km.

References

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