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Mars Express observations of cold plasma structures in the Martian magnetotail

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Abstract

We investigate the variability of plasma structures in the Martian tail using Mars Express (MEX) measurements. We focus on five non-consecutive orbits from September 2016, namely 16130, 16133, 16136, 16144 and 16148 during which MEX passed through the induced magnetotail. These were specifically chosen as special operations of MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) on MEX were made only on these orbits. Operated in Active Ionospheric Sounding (AIS) mode, MARSIS functions as a local sounder allowing us to determine the local plasma density in the upper ionosphere, as the sounder excites oscillations at the plasma frequency and its higher harmonics. We show that the electron density well above the ionospheric peak is highly variable and patchy thermal plasma is present deep in the tail, transported from day to night. MAVEN Solar wind data are used as well to help us evaluate a possible correlation between the observed plasma structures and Solar wind variations, taking into account the time delay due to the ionospheric response time. The crustal magnetic fields are also studied, as an additional factor that affects the day-to-night transport process through the terminator and modifies the flow and behaviour of the nightside ionospheric plasma. Relatively few studies have fully exploited the presence of simultaneous measurements from two spacecraft at Mars for the purposes of making short time-scale comparisons between Solar wind variations and changes in the induced magnetosphere and ionosphere. With this study we aim to show that the varied nature of the nightside plasma structures is not controlled by any simple parameter, even given the best possible knowledge of the upstream Solar wind.

1. Observations

The MARSIS instrument is a low frequency radar on board MEX, which measures the propagation time delay of a transmitted pulse from the spacecraft to the Martian ionosphere where it is reflected as it enters the dense plasma. Simultaneously, interactions with the tenuous plasma in the vicinity of the spacecraft yield the local electron plasma frequency[1]. The determination of the altitude and structure of the ionospheric peak is feasible when MARSIS operates in AIS mode for altitudes below 1200 km[1].

2. Results

In Fig. 1 one of the five MEX orbits studied (16136) and the corresponding MAVEN one are shown in MSO coordinates. As MEX enters in the shadow, MARSIS starts to run in AIS mode (black part on the red orbit) and MAVEN is located in the Solar wind for the greater part of it. The trajectories of the rest of the orbits are roughly the same, however MAVEN Solar wind data coincide with MARSIS measurements only in one more case.

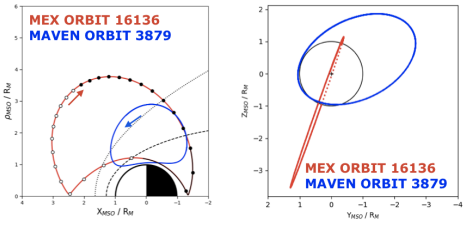

Figure 1: MEX and MAVEN orbits in red and blue respectively, presented in MSO coordinates.

In Fig. 2 data from the MEX orbit 16136 (four upper panels) and the corresponding MAVEN one (five bottom panels) are presented. First, (a) MARSIS frequency measurements, (b) electron density, (c) local magnetic field and (d) the position of MEX are shown. In the rest of the panels MAVEN observations are presented for the same period MARSIS was operated in AIS mode for the aforementioned MEX orbit:

(e) energy spectrum from SWIA, (f) electron (LPW) and proton (SWIA) densities, (g) velocity (SWIA), (h) magnetic field (MAG) and (i) MAVEN position. Patchy thermal plasma even when MEX was deep in the tail and IMF rotations can be observed in panels (b) and (h) respectively.

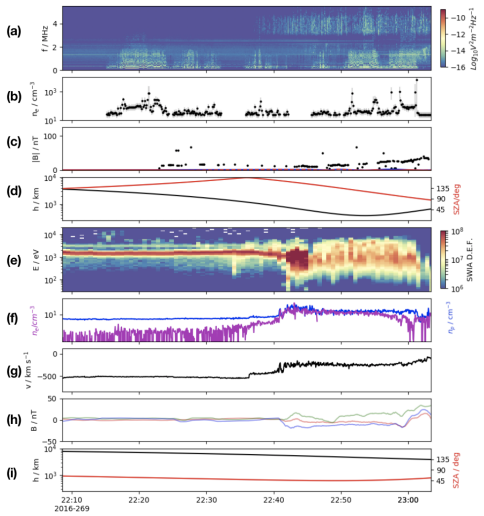

Figure 2: MARSIS and MAVEN data for MEX orbit 16136. From top to bottom we show time series of (a) MARSIS frequency measurements, (b) electron density and (c) local magnetic field inferred from MARSIS, (d) position of MEX, (e) SWIA energy spectrum, (f) electron and proton densities (from LPW and SWIA respectively), (g) velocity (SWIA), (h) magnetic field magnitude (MAG) and (i) MAVEN altitude and Solar Zenith Angle.

3. Conclusions

MEX and MAVEN measurements combined allow us to perform a thorough study of the plasma transport processes through the Martian terminator and to the nightside. The MARSIS soundings of the five orbits of interest, obtained at altitudes much higher than the nominal operations, and the complementary Solar wind MAVEN data shed some light upon the day-to-night transport process through the terminator, to the description of which the investigation of the effects of the crustal fields also contributed.

Acknowledgements

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References

[1] Gurnett D. A. et al. (2005), Radar soundings of the ionosphere of Mars, Science, 310(5756):1929-33.