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Response of the Martian ionosphere to a coronal mass ejection as detected by Mars Express radar sounding

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Abstract

We report here the detection of a coronal mass ejection by the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) on board the Mars Express spacecraft. The CME was detected at Earth and at Mars.

1. Introduction

After a drought of approximately four years, solar activity has been increasing in the first half of 2011. Among the events observed during this time was a coronal mass ejection (CME) late on 7 March 2011. The effects of this CME were apparent at both Earth and Mars. The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) on board the Mars-orbiting spacecraft Mars Express (MEX) obtained several full periapsis passes during the occurrence of the CME, providing us with an opportunity to study the effect of an isolated CME on the Martian ionosphere using all of the MARSIS data sets available, along with other applicable data sets.

2. Signatures of CME particles

We see the particle signature of the CME in background counts from the HEND neutron detector on board the Mars-orbiting Odyssey spacecraft in Figure 1. The enhancement is seen to begin at approximately 01:00 UTC on 8 March 2011, peak approximately an hour later, and decrease to near background level by the start of 10 March 2011. Note that an X-class solar flare observed near 00:00 UTC 10 March is completely invisible in these data.

In Figure 2 we show an echogram from the MARSIS Active Ionospheric Sounder (AIS), averaging frequencies between 1 and 2 MHz for all of MEX orbit 9172. Between UTS 05:25 and 06:00, where the instrument samples the nightside and terminator regions of Mars, the surface reflection of the sounding wave is clearly visible. As the spacecraft gets deeper into the dayside, the signal disappears, which is typical behavior. However, in Figure 3, which samples data taken at the height of the HEND particle enhancement, the nightside surface reflection has completely disappeared. Figure 4 shows a full periapsis pass somewhat later in the event. It is seen that the nightside surface reflection is still invisible. Finally, in Figure 5, at about the time that the particle enhancement has subsided, the surface reflection has returned.

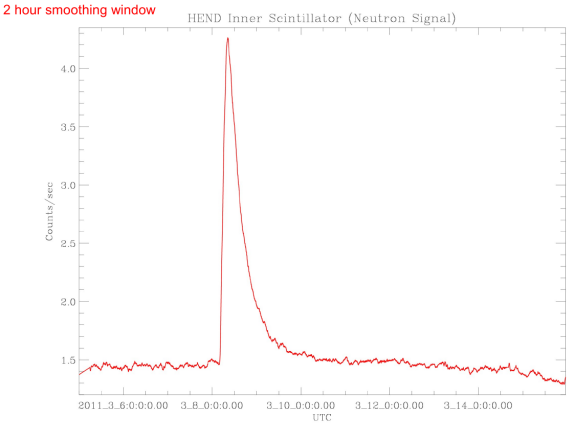

Figure 1: Odyssey HEND neutron detector background enhancement associated with CME of 7 March 2011.

3. Summary and Conclusions

We have shown in this abstract that energetic particles from a CME can affect the Martian ionosphere in a way readily detectable by the MARSIS AIS topside

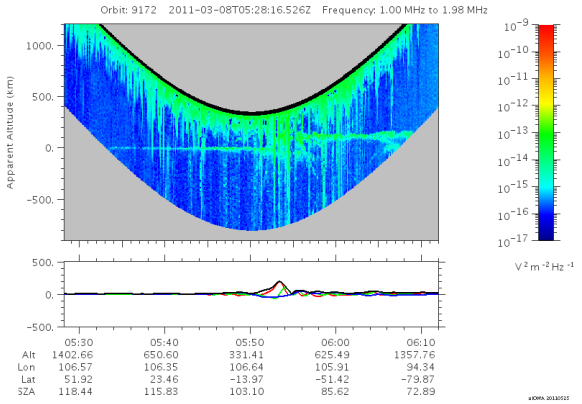

Figure 2: Echogram of orbit 9172, showing the surface reflection at 0 km altitude before the HENS event.

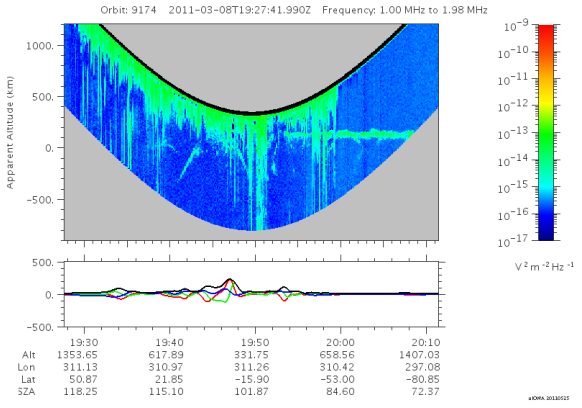

Figure 3: Echogram of MARSIS orbit 9174 showing disappearance of surface reflection near onset of the particle enhancement seen by Odyssey HEND.

sounder. The disappearance of the surface reflection has been explained by [1] as the result of increased collision damping due to an excess of electrons in the ionosphere. More sophisticated methods of analyzing radio wave absorption in the ionosphere of Mars have since become available, *e. g.,* those of [2]. In our presentation, we shall make use of some of these methods. As well, we shall bring to bear the full array of MARSIS measurements, including the ionospheric trace, local plasma oscillations, and electron cyclotron echoes, as well as applicable particle data from MEX ASPERA-3 and distortion effects in the MARSIS subsurface radargrams, to give as complete a picture as possible of this isolated CME event at Mars.

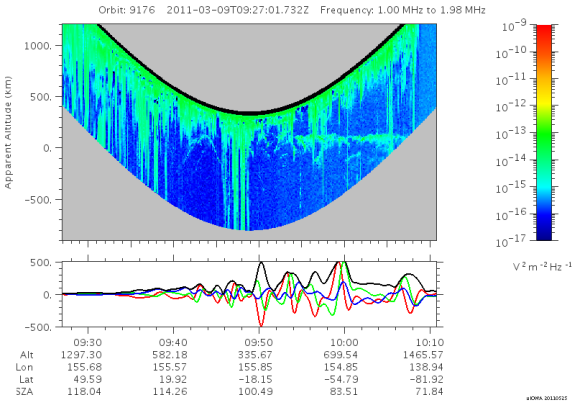

Figure 4: Echogram of MARSIS orbit 9176, during particle enhancement observed by HEND. Note the continued absence of the surface reflection.

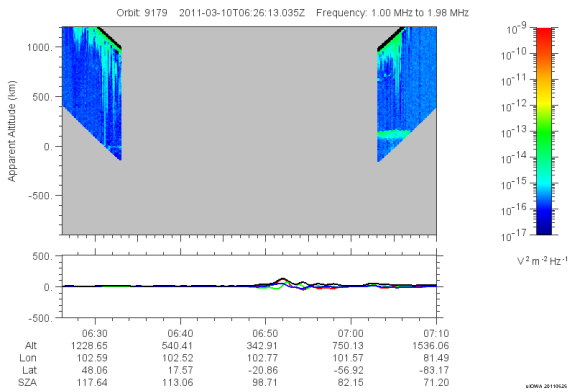

Figure 5: Echogram of MARSIS orbit 9179, at the end of the HEND particle event.

References

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[2] Withers, P.: Attenuation of radio signals by the ionosphere of Mars: theoretical development and application to MARSIS observations,*Radio Sci.,46,* RS2004, doi: 10.1029/2010RS004450, 2011.