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Mars' "Magnetospheric" Response to Interplanetary Field Orientation: Inferences from Models for MAVEN Investigation

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Abstract

Planetary space weather at Mars has attracted much interest, but the focus is usually on the response to solar activity and its related disturbances in the solar wind. While this aspect is important and may be key to understanding Mars' atmosphere evolution, an additional consideration is based on the sensitivity of Earth's magnetospheric solar wind interaction to southward interplanetary magnetic fields. The study described here investigates whether Mars has its own specific interplanetary field orientation sensitivities that might be identified in the MAVEN data analyses.

1.Introduction

At Earth, the coupling of solar wind energy into geospace is extremely sensitive to the occurrence of southward interplanetary magnetic fields. This sensitivity is a consequence of the antiparallel orientation of the Earth's dipole field and the external field at the magnetopause. Under southward IMF circumstances, the magnetosphere has its maximum magnetic connection to the interplanetary field, and thus to convection electric fields in the solar wind that map down into large areas in the polar regions. The consequence for Earth is geomagnetic activity and its related atmospheric and ionospheric effects-including significant heating and momentum transfer.

Mars' more complex crustal magnetic fields at its solar wind obstacle boundary similarly allow reconnection with the draped external fields. However in this case the result is varying degrees of open field connection depending on both crustal field and interplanetary field orientations. Larger open field areas can presumably create stronger coupling.

2. Approach

We use BATS-R-US MHD simulations of the solar wind interaction with Mars [1] to explore some interplanetary field orientation effects on the solar wind coupling. To isolate these, a nominal solar wind density and velocity is assumed for all cases, while the orientation of the strong crustal fields of Mars and the interplanetary field are varied. We compare the areas and locations of open magnetic fields (those connecting Mars to interplanetary space) and the model ionospheric characteristics (e.g. velocities) for cases with the strongest Mars crustal fields at noon, dusk, midnight and dawn, and for interplanetary fields that are at nominal toward (Eastward) and away (Westward) Parker spiral orientations, or atypically northward or southward (relative to the Mars orbit plane). The results suggest coupling to the solar wind should be particularly strong for Southward interplanetary fields when the strong crustal fields are at dawn. While the IMF 'coupling function' at Mars is not as extreme as for Earth, the open field area in the ionosphere is 3-4X greater for that condition than for the other combinations.

MAVEN's comprehensive solar wind interaction and aeronomy measurements allow a search for times when the interplanetary conditions and crustal fields correspond to these 'best connected' conditions. However, major challenges come with this search. For one, strongly northward or southward interplanetary fields are rare and usually found in interplanetary coronal mass ejections (ICMEs)- that also include enhanced solar wind pressures and magnetic field strengths affecting solar wind response. For another, the crustal field location at dawn must coincide with the ICME passage, which typically lasts 1-2 days. While these requirements are restrictive at this relatively early stage of the mission, the current solar activity level continues to produce coronal mass ejections and thus opportunities.

References

[1] Ma, Y. et al. (2004), *JGR*, *109, doi:10.1029/2003JA010367*.