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# Magnetic shadowing of high energy ions at Mars: Comparison of SLED/Phobos-2 observations and hybrid model simulations

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## Abstract

Energetic particle data recorded by the SLED instrument aboard Phobos-2 while in circular orbit about Mars in March, 1989 showed the presence of magnetic shadowing. A 3-D, self-consistent, hybrid model (HYB-Mars) supplemented by test particle simulations has been developed to study the response of the Martian plasma environment to the solar disturbances concerned and to interpret the SLED observations. During Extreme Solar Events, the magnetic and electric fields as well as the properties of high energy ions present at Mars can be derived from HYB-Mars. It has already been shown [1] that the hybrid modeling results in magnetic shadowing which is qualitatively similar to that recorded by SLED at Mars while demonstrating in addition that the size of the shadow decreases with the energy of the ions in the range analyzed (50 keV to 3.2 MeV). In this presentation the initial qualitative study outlined above has been extended to provide a more quantitative analysis by comparing the observed and the simulated fluxes of high energy ions at Mars during Extreme Flaring.

## 1. Introduction

In March, 1989 the Solar Low Energy Particle Detector (SLED) aboard the Phobos Mission to Mars and its Moons recorded the first in situ particle measurements at the planet in the energy range 30 keV to a few tens of MeV [1]. These data showed, during an extended (extreme) energetic particle event (6-26 March, 1989), significant depressions in flux in the particle counts due to magnetic shadowing (Fig. 1).

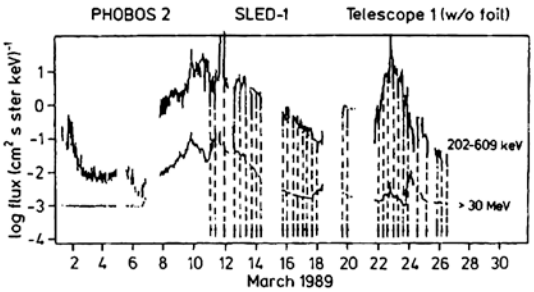


**Figure 1.** Enhanced particle fluxes recorded by SLED in two energy channels (202-609 keV and > 30 MeV) during March, 1989 in association with prolonged flaring. Significant depressions in flux due to magnetic shadowing as the spacecraft orbited Mars are indicated by dashed vertical lines. Following [1].

## 2. The Hybrid Model

A 3-D, self-consistent, hybrid model (HYB-Mars) supplemented by test particle simulations has been used to provide insight into the above observations. In the hybrid model the ions are modeled as particles while the electrons form a massless charge neutralizing fluid (see Fig. 2 for an example of an HYB-Mars run). During extreme solar events, the magnetic and electric fields present at Mars can be derived from HYB-Mars while the motions of associated high energy ion populations are analyzed in parallel using test particle simulations.

A variety of hybrid model runs were performed using different upstream parameters in various combinations (high velocity solar wind; high density solar wind; different values of interplanetary magnetic field strength/IMF and direction). This allowed the response of the Martian plasma environment as well as the motion of ambient high energy solar protons to be simulated under different interplanetary conditions. [2].

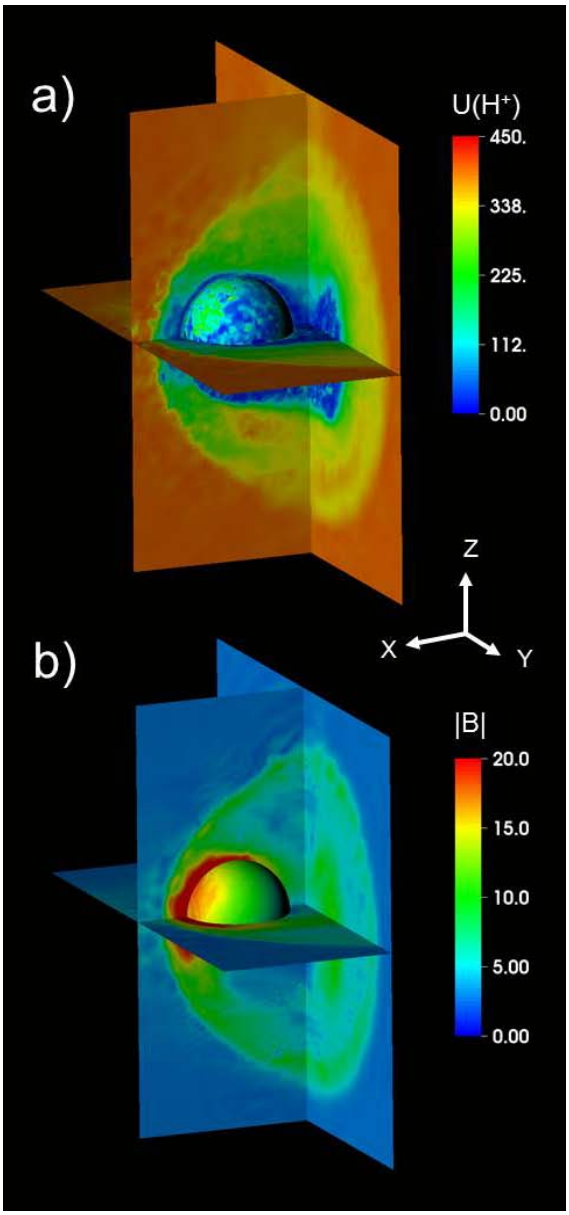


**Figure 2.** An example of an HYB-Mars run: (a) The velocity of the main (~1 keV) solar wind $H^+$ population and (b) the total magnetic field. Figure modified from [3].

## 3. Comparison of in situ observations with model predictions

The model predicted that, under certain extreme upstream conditions, a magnetic shadow can be formed at Mars that is (a) displaced to the nightside relative to the optical shadow; (b) decreases in size as the particles increase in energy in the keV to MeV range and (c) shows an asymmetry in the shadow along the direction of the convective electric field,

Although the properties of the high energy ions in the model runs displayed a qualitatively similar trend to the in situ data recorded by SLED, the quantitative results varied from one run to another. Thus, in order to fully understand the SLED data, it transpired to be necessary to know the actual upstream parameters that were present during the taking of the energetic particle measurements. It is currently planned to input to the HYB model plasma and magnetic field data that were contemporaneously measured aboard Phobos-2 when the particle data were recorded. It will thereby be possible to more realistically match the simulated results with the in situ observations.

## 4. Summary

Initial hybrid model simulations of magnetic shadowing recorded at Mars by the SLED instrument aboard Phobos-2 show encouraging results. In depth studies modeling the behavior of the particle measurements in response to changing, contemporaneously measured, plasma and magnetic field data are now ongoing.

## References

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