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Modelling of reflected hydrogen and protons signatures at Phobos' orbit

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Abstract

Following the discovery of a Solar Wind proton reflection process at the Moon and at Phobos, we study such process from the modelling point of view. We carry out simulations of the ejected of protons and neutral hydrogen atoms fluxes. Our calculations will help to interpret recent data from Mars Express/Aspera.

1. Introduction and Purpose of the Study

Solar Wind protons are reflected by the Lunar regolith in proportion 0.1% to 1%, as suggested by MAP-PACE measurements onboard SELENE [1]. A similar process seems to lead to a significant emission of neutralized hydrogen (up to 20% of the impinging protons flux), as evidenced by SARA instruments measurements onboard the Chandrayaan-1 spacecraft [2].

As in the case of the Moon, Phobos' surface is weathered by micrometeoroids impacts and Solar Wind ions bombardment. Since a significant part of Phobos' orbit is exposed to the shocked Solar Wind, downstream of the Martian Bow Shock, a SW protons reflection process similar to that observed at the Moon is likely to occur, and was indeed observed (S. Barabash, private communication) in 2008.

Following Phobos flybys by Mars Express in July 2008 and February 2010, the presence of reflected protons and neutral hydrogen populations can be investigated by instruments of the ASPERA3 package, namely IMA (Ion Mass Analyzer) and NPD (Neutral Particle Detector) sensors.

In the present study we use a 3D Test Particle model to simulate reflection of SW protons both as ionized and neutralized hydrogen, in order to derive signatures of those populations in the Martian Environment.

2. Simulation / Expected Results

Our numerical model has been described and used in [3] to investigate physical characteristics of a putative neutral gas torus at Phobos' orbit for low solar activity conditions.

In the present study we set up the electromagnetic field values in the vicinity of Phobos' orbit given by a Hybrid simulation performed in minimum solar activity [4], in order to infer characteristics of the reflected proton population. As a first step we take energy distributions of the reflected populations consistent with those measured at the Moon.

Since Phobos' surface potential and charge state may significantly influence the protons reflection process and the charge state of ejected atoms, we also introduce a boundary condition at Phobos' surface in the simulation.

Trajectories of ejected neutral hydrogen atoms on the one hand, and protons on the other hand, are followed around Mars, where particles are subject to the Martian gravity and to the solar radiation pressure for the former, and to the Lorentz force for the latter. Particles can be lost into the Martian thermosphere, escape the system, become ionized when originating as neutrals, or neutralized when originating as protons.

Specifically, we describe neutralization of reflected protons through charge exchange reactions with exospheric oxygen atoms leading to an ENA signature on the one hand, and ionization of ejected neutrals through charge exchange reactions with SW protons leading to a proton signature on the other hand.

We will therefore present the results of our simulations and describe the morphologies of the reflected fluxes and their dependence on the IMF characteristics at low solar activity, regarding: 1) a reflected proton population, 2) a reflected neutral hydrogen population, 3) a neutralized hydrogen (ENA) component, and 4) an ionized hydrogen component.

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