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Solar Wind interaction with Mercury's magnetosphere

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Abstract

First measurements from Messenger (NASA) shed new light into the basically unknown magnetic field of Mercury, confirming the existence of an Earth-like magnetosphere, which can be roughly modelled by a southward planetary moment of 230 to 290 nT R_M^3, tilted between 5° and 12° from the rotation axis [1]. The weak magnetic field of the planet and the increasing weight of the IMF B_X component at Mercury's orbit, introduce critical differences with respect to the Earth's case, such as a strong north–south asymmetry and a significant solar wind precipitation into the dayside magnetosphere even for non-negative IMF B_Z. We present an analysis of the interaction between the Solar Wind and Mercury's magnetosphere, the plasma entry, its circulation and interaction with the planetary surface.

Introduction

This study is based on an empirical–analytical magnetospheric model ad hoc developed for Mercury (e.g. [2]). As input values, the magnetosheath proton density, velocity and temperature along magnetopause boundary are derived from Spreiter's gasdynamic approximation [3]: their ratios with respect to the solar wind values, V / V_{SW}, N / N_{SW}, and T / T_{SW} are calculated as a function of: *i)* the distance from the subsolar point of the magnetopause, *ii)* the free-stream Mach number. T_{SW} is consistently computed as a function of the distance form the Sun [4]. The kinetic properties of the magnetosheath ions that cross the magnetopause are computed by assuming the existence of a *de-Hoffman-Teller* (HT) reference frame (e.g. [5]), that is taking into account the effect of the magnetic reconnection. The above mentioned key parameters were estimated over a 2° x 2° magnetopause grid, and then Monte Carlo simulations are computed by launching a number of test particles proportional to the H^+ density at the magnetopause, with an initial speed randomly chosen within a realistic *bi-Maxwellian distribution*. Particle tracking stops when H^+ ions hit the planet or exit from the simulation box (e.g. along the magnetotail).

• Simulation box (150 x 150 x 150)

$-4.0\ R_M < X < 2.0\ R_M$

$-3.0\ R_M < Y < 3.0\ R_M$

$-3.0\ R_M < Z < 3.0\ R_M$

by steps of 0.04 R_M (~100km)

• Surface impact data are stored into

a 180° x 360°, lat x long grid (1°x1°)

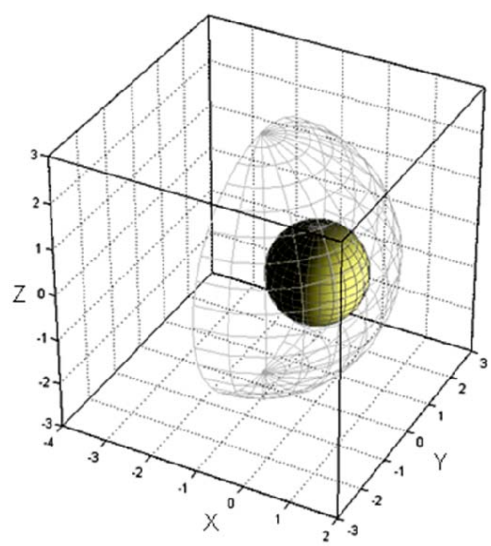

Figure 1: Simulation Box with the planet position and size, and the dayside magnetopause.

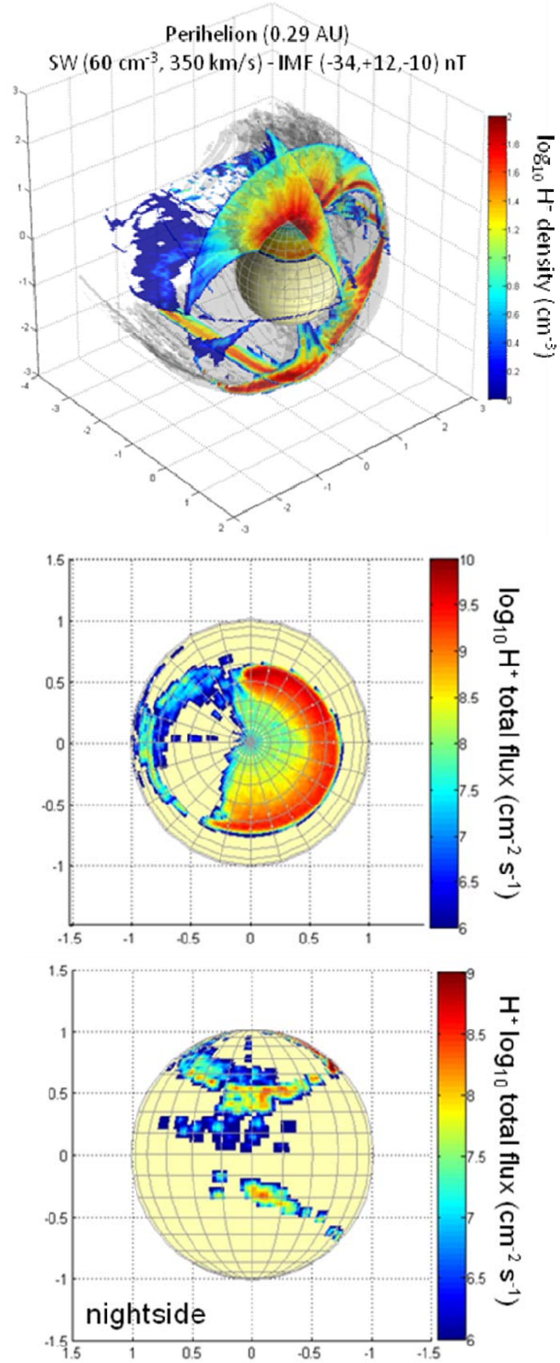

Figure 2: Monte Carlo simulation of the solar wind proton entry and circulation in the magnetosphere of planet Mercury, under “typical” solar wind and IMF conditions at perihelion: 3D H^+ density (upper panel), H^+ flux impacting on the northern hemisphere (middle panel), and on the nightside (lower panel).

Summary and Conclusions

Under typical interplanetary regimes, the Solar Wind is expected to widely penetrate into Mercury’s magnetosphere due to the strong coupling with the intense Interplanetary Magnetic Field (IMF). Extreme perturbations originating from the solar activity, would lead to even higher

• magnetospheric open regions grossly corresponding to those of the Earth, but extending over broader areas;

• IMF B_X (pos./neg.) causes strong hemispheric asymmetries, mostly in the dayside (cusp areas), but also on the nightside;

• SW - IMF different regimes at perihelion / aphelion causes different dayside solar wind proton precipitation, by about an order of magnitude ($\log_{10}$ H^+ flux 9-9.5 / 8.5 cm^{-2} s^{-1})

• SW precipitation on the dayside depends on both local B intensity and H^+ thermal speed in the magnetosheath (due to non-adiabatic effects).

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