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Interaction between Mars' induced magnetosphere and the comet Siding Spring

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Abstract

On 19 October 2014 the comet C/2013 A1 (Siding Spring) flew by Mars. This was a unique opportunity to study the interaction between a cometary and a planetary magnetosphere. Here we model the magnetosphere of the comet using a hybrid plasma solver (ions as particles, electrons as a fluid). The undisturbed upstream solar wind conditions are estimated from ion observations by ASPERA-3/IMA on Mars Express, and from magnetic field observations by MAVEN. It is found that Mars probably passed through a solar wind that was disturbed by the comet during the flyby.

1. Introduction

We want to answer two questions. (1) Was the solar wind that Mars encountered disturbed by the comet? (2) What was the precipitation of cometary ions on Mars?

2. Model

To model the interaction of the comet with the solar wind we use a hybrid plasma model. The production rate of ions are analytically computed from a spherical symmetric neutral Haser model [1]. We also need the undisturbed upstream solar wind conditions. The solar wind density, velocity and temperature are estimated from observations by ASPERA-3/IMA on Mars Express [2]. The magnetic field is estimated from MAVEN observations [3].

2.1. Hybrid Model

In the hybrid approximation, ions are treated as particles, and electrons as a massless fluid. The trajectory of the ions is computed from the Lorentz force, given the electric and the magnetic fields. The electric field is

$$\mathbf{E} = \frac{1}{\rho_I}\left(-\mathbf{J}_I \times \mathbf{B} + \mathbf{J} \times \mathbf{B} - \nabla p_e\right) + \eta \mathbf{J}, \qquad (1)$$

where ρ_I is the ion charge density, $\mathbf{J}_I$ is the ion current density, p_e is the electron pressure, and η is the resistivity. The current is computed from, $\mathbf{J} = \mu_0^{-1}\nabla \times \mathbf{B}$, where $\mu_0 = 4\pi \cdot 10^{-7}$ is the magnetic constant.

Then Faraday's law is used to advance the magnetic field in time,

$$\frac{\partial \mathbf{B}}{\partial t} = -\nabla \times \mathbf{E}.$$

Further details on the hybrid model used here, the discretization, and the handling of vacuum regions can be found in [4].

2.2. Comet Model

The dominant neutral specie produced at the comet is water. For water, the most important loss process is the photodissociation, $H_2O \rightarrow OH+H$.

The water ion production as a function of distance from the origin, r, is

$$q_i(r) = \frac{\nu_i Q}{4\pi r^2 u} e^{-\nu_d r/u} \quad [\mathrm{m}^{-3}\mathrm{s}^{-1}],$$

where the release rate of water molecules is Q at a radial velocity of u. The water is photoionized at a rate of ν_i and the destruction rate is ν_d (including photoionization).

Here we use a water production rate of $Q = 1.1 \pm 0.5 \cdot 10^{28}$ molecules per second [5].

3. Results

As can be seen in Figure 1, a bow shock is formed upstream of the comet. The trajectory of Mars passes through the shock, as seen in the plot of the magnetic field in Figure 2. Mars does however not pass near the region of high density of water ions. Due to the relatively high production rate of the comet, the escape of water ions is mainly not as pick-up ions, but is more fluid like.

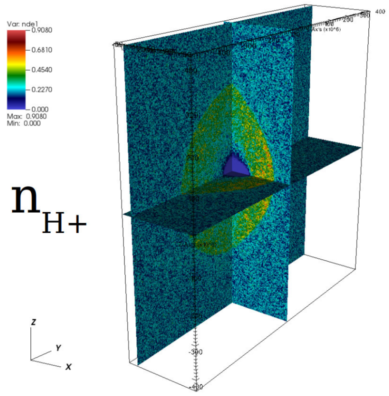

Figure 1: Preliminary simulation results. Solar wind proton number density. The solar wind flows along the $-x$ axis.

4. Summary and Conclusions

We have studied the interaction of the comet Siding Spring with the solar wind on 19 October 2014 using a hybrid plasma model. We conclude that most likely Mars passed through a shocked solar wind that was disturbed by the comet during the flyby. There are uncertainties in the model parameters, but the solar wind interacting with Mars was disturbed for all parameter sets tested. The uncertainty derives from that the size of the disturbed solar wind region in the comet simulation is sensitive to the assumed upstream solar wind conditions, especially the solar wind proton density. The amount of cometary ions precipitating on the planet is small (compared to the solar wind, and to the neutral influx).

Possible further studies are (1) Comparing the model predictions with plasma observations by Mars Express and MAVEN, and (2) Modeling the effects of the time dependent distubed upstream solar wind on Mars.

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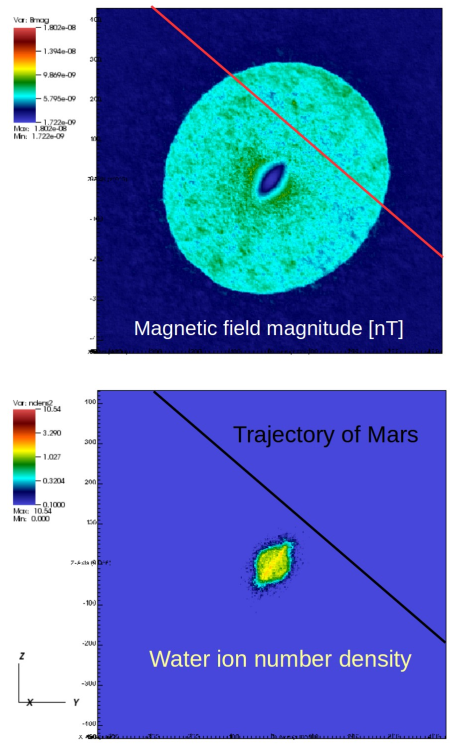

Figure 2: Preliminary simulation results. Magnetic field magnitude (top) and water ion number density (bottom) in a cut at 46 320 km downstream of the nucleus of comet Siding Spring. The lines show the trajectory of Mars (downward). The width and height of the cut is 864 000 km.

References

[1] Haser, L., Distribution d'intensité dans la tête d'une comète, Bulletin de la Class des Sciences de l'Académie Royale de Belgique, 43, 740-750, 1957.

[2] Barabash, S., et al., The Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) for the Mars Express Mission, Space Science Reviews, 126(1–4):113–164, 2006.

[3] Espley, J. R., et al., A comet engulfs Mars: MAVEN observations of comet Siding Spring's influence on the Martian magnetosphere, Geophys. Res. Lett., 42, 2015.

[4] Holmström, M., Handling vacuum regions in a hybrid plasma solver, *Numerical modeling of space plasma flows (ASTRONUM-2012)*, ASP conference series, 474, 202–207, 2013. ArXiv:1010.3291

[5] Crismani, Matteo M.J., et al., Ultraviolet observations of the hydrogen coma of comet C/2013 A1 (Siding Spring) by MAVEN/IUVS, *Geophys. Res. Lett., 42*, 8803-8809, 2015.