

Comet Siding Spring's effect on Mars' plasma environment

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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. A topic that may have implications for the evolution of planets in early stellar systems, where such encounters are more common.

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. The amount of cometary ions precipitating into Mars' atmosphere is small compared to the amount of neutrals and dust. However, the energy deposited by the precipitating ions is significant.

1. Introduction

We want to answer the following questions. (1) What was the undisturbed upstream solar wind conditions during the flyby of Mars by comet Siding Spring? (2) Was the solar wind that Mars encountered disturbed by the comet? (3) 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 upstream 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 computed from the particles and the magnetic field. Then Faraday's law is used to advance the magnetic field in time. 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, $\text{H}_2\text{O} \rightarrow \text{OH}+\text{H}$.

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

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

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 $Q = 1.1 \cdot 10^{28}$ 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 not pass near the region of highest density of water ions. Due to the relatively high production rate of the comet, the outflow of water ions is not as pick-up ions, but is more fluid like.

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

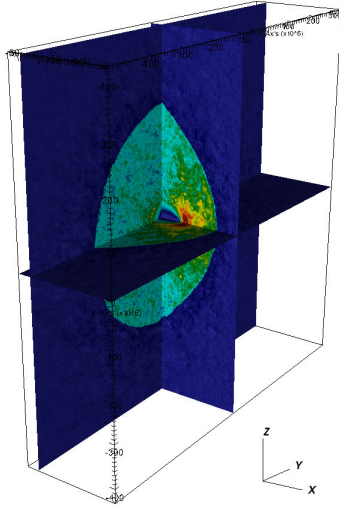


Figure 1: Preliminary simulation results. Solar wind magnetic field magnitude. The solar wind flows along the $-x$ axis.

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 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, and it is also sensitive to the assumed production rate. The amount of cometary ions precipitating on the planet is small (compared to the dust and the neutral influx), but the energy deposition into Mars' atmosphere is significant.

A possible further study is to investigate the effects of the time dependent disturbed upstream solar wind on Mars' induced magnetosphere.

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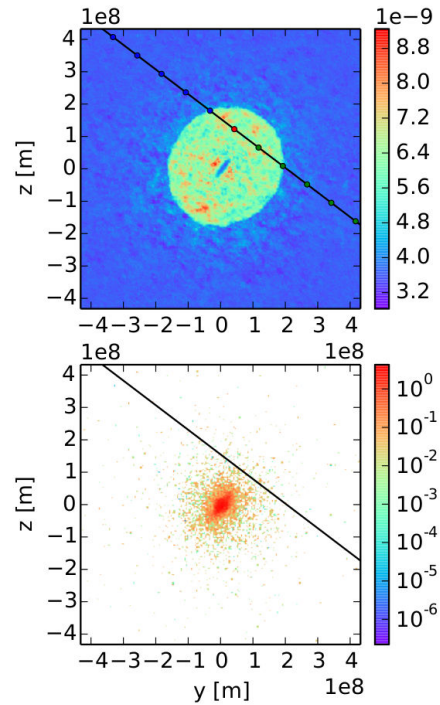


Figure 2: Preliminary simulation results. Magnetic field magnitude [T] (top) and water ion number density [m^{-3}] (bottom) in a cut downstream of the nucleus of comet Siding Spring, in a comet centered reference frame. The lines show the trajectory of Mars (downward).

References

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