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Numerical model for the acceleration of a dust cloud by the solar wind

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Abstract

In this study we investigate the behavior of two massive fluids: protons in the solar wind and charged dust. For simplification we temporarily ignore the charging process of dust particles. The mass of charged dust can be 10^3 amu to grams, but we only model the lighter ones because the behavior of grains more massive than 10^5 are similar. A multi-fluid MHD code is used to simulate the large scale structure formed around a dust cloud released into the solar wind, and its evolution. Dust clouds as we are simulating can be made by meteoroid-meteoroid collisions with size from 1 to 100 m in diameter. These are dangerous if they hit the Earth's atmosphere. Detecting them in space can help detect where such objects are in near Earth space.

1. Introduction

Charged dust has been found in many places in the space. The number density of such fine particles often well exceeds one per Debye sphere, thus, such interactions can be treated as a dusty plasma problem. The most common interaction in such dusty plasma is the evolution of a dust cloud in a plasma flow. Such a cloud can be produced by meteoroid collisions in space.

An interplanetary field enhancement (IFE) event was observed by 5 spacecraft simultaneously, and believed to be the result of such dust cloud accelerations. In this study, we investigate our 3-D field draping result and compare it with the field measured during the IFE.

2. The model

Protons, dust, and electrons are treated as an individual fluid, respectively. The multi-fluid MHD equations are used to simulate the conservation of mass, momentum, and energy, in perfectly conducting plasma. A dust cloud is sitting still at time zero, in a solar wind flow with nominal parameters at 1 AU. Dust particles get accelerated along the electric field, while the head of the cloud is accelerated downstream by the tension force. Figure 1 and 2 shows the dust structure and magnetic field perturbation about 4 hours after the release.

3. Figures

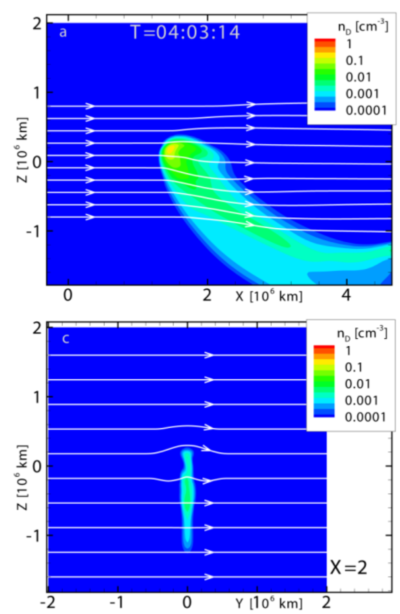

Figure 1. Acceleration of a dust cloud in the solar wind. Dust density contours are shown in two plane projections. White lines are proton stream lines.

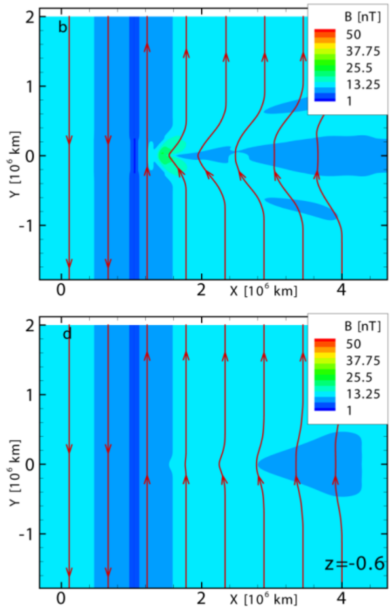

Figure 2. The magnetic field perturbation shown in colour contours projected into the z=0 and z=-0.6 planes. Red lines are magnetic field lines.

4. Summary

In this study we study the 3-D distribution of the dust cloud during its pickup process by the solar wind, generated by our 3-D multi-fluid model. The disturbed magnetic field is compared to the observed IFE field.