OBSERVATIONS AND SIMULATIONS OF COLLISIONAL STRUCTURES IN THE SOLAR WIND  
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Introduction: At 1AU, the typical collisional speed between asteroids and meteoroids is 20km/s. At such speeds, impactors will totally disrupt their targets if the mass ratio is less than 10⁶. Clouds of fine dust released in the collisions become charged and are picked up by the solar wind via electromagnetic forces. Large interplanetary magnetic field structures called interplanetary field enhancements (IFEs) are generated in the interactions between solar wind and dust clouds. The magnetic signatures of these collisions record the passages of small interplanetary objects upstream of the spacecraft and can be used to identify the otherwise ‘invisible’ interplanetary objects, whose diameters are tens of meters [1].

To estimate the mass of interplanetary bodies disrupted in the collisions, we need a good measurement of the dimensions of, and the force on, the IFEs. In addition, we need to know how the magnetic structure forms and evolves. The first task can be performed with multi-spacecraft simultaneous observations. Figure 1 shows such an IFE detected by five spacecraft. During this event, the trajectories of the spacecraft were well spaced in all three dimensions in the structure and the 3D magnetic field geometry can be reconstructed (Figure 2). Field lines are seen draping around in the upstream region and rotating in the convection electric field direction in the downstream region. Both signatures support the hypothesis that IFEs are formed while the solar wind is accelerating the dust clouds: the draped field lines enable the dust-solar-wind momentum exchange, while the shear in the magnetic field at 0735UT is a typical signature of dusty plasma pickup [2]. With the reconstructed geometry, the radial length of the IFE is about four times the cross-flow radius and the force that caused this momentum exchange is approximately 10³N.

To estimate the mass, the only unknown is the acceleration of the IFE. We use multi-fluid MHD simulations to estimate this acceleration. In our dust cloud-plasma flow interaction code, a cloud of charged dust is placed in a plasma flow with a small velocity difference between the two populations. Figure 3 shows the results of a case study. The 4 top panels show the magnetic and plasma perturbations from the solar wind interacting with a cloud of dust of mass 3×10⁶amu/electron charge, moving at a speed of 40km/s relative to the solar wind. The dust cloud is located around the origin, where the field lines (white lines) drape around the dust. The bottom panel shows the three components and magnitude of the magnetic field along the black vertical line in top right panel. A rotation is shown in the BZ component. The field enhancement, field draping and rotation are similar to IFEs.

In this study, we adjust the dust cloud parameters, e.g., the particle mass and the shape of the dust cloud to reproduce IFEs in simulations. By comparing the modeled results with the observations, the mass of the dust cloud can be estimated. With the knowledge of the model of debris distributions [3], we can infer the mass of the asteroids before collisions.

Figures:

Figure 1. Magnetic-field profiles of an IFE detected by five spacecraft in a VB coordinate system. Here X is the solar-wind flow direction, ambient IMF lies in the X-Y plane and Z completes the right-handed coordinate system. The time delay has been adjusted so the BZ changes directions at the same time. We use the Geotail time series as the reference.
Figure 2. Magnetic-field projections in X-Y and X-Z plane in VB coordinate system. The filled circles represent the spacecraft locations while the solid lines indicate the magnetic-field directions and strengths. The coordinate in X direction is the product of time interval and solar wind speed. The intervals between two adjacent points are about five minutes except the one between the two points near the central peak of the IFE. The scale in X direction is the same as the one in Y and Z direction.

Figure 3. (Top 4 panels projected into 2-D planes): Plasma and dust density and magnetic field contours produced by a dust cloud of mass 3×10⁶amu. (Bottom panel): Magnetic field components extracted along the vertical line in the top right panel.

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