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Multi-fluid MHD model for Sun-grazing comets

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Abstract

Sun-grazing comets are comets that dive into the lower corona. Recent advances in spacecraft capabilities have enabled us to observe these comets with high resolution both in time and space. These comets exhibit rich tail activity, even multiple tails. This study investigates a collection of these activities, models the cometary plasma with model-generated coronal conditions.

1. Introduction

Extreme Ultraviolet (EUV) emission from two recent sun-grazing comets, C/2011 N3 and C/2011 W3 (Lovejoy), has been observed in the solar corona for the first time by the SDO/AIA and STEREO/EUVI instruments [*Schrijver et al*. 2012, *Bryans & Pesnell*, 2012]. These observations provided a unique opportunity to investigate the interaction of the cometary material with the solar corona and probe their physical conditions.

2. Model

The parameters and scales of Sun-grazing comets is very different, compared with the conventional models of comet-solar wind interactions [*Gombosi et al*., 1996]. We adopt a multi-fluid version of the University of Michigan BATS-R-US MHD code to treat the interaction between the coronal medium and cometary plasma that contains massive ejecta.

In a multi-fluid model we treat each group of particles with a certain range of mass/charge ratio as a fluid unit, except for the electrons. We neglect the inertia of electrons. The electron parameters are calculated by combining all other fluid parameters, assuming charge neutrality.

We model the ionization processes from neutral to ions with high charge state. The solar wind protons are lost by charge exchange with cometary neutrals. The charged dust particles are sublimated and dissociated. The neutral density of each species in the coma can be estimated as a spherical expanding atmosphere with ionization loss.

Figure 1 shows a model of comet Lovejoy based on nominal solar corona conditions and reaction rates provided by *Bryans & Pesnell*, [2012]. The corona proton density decreases because of charge exchange with cometary oxygen. A shock is formed, because the comet is moving in a supersonic speed relative to the corona plasma. With a gas production rate of $10^{30}s^{-1}$, the peak O^{6+} number density reaches 5 times the background proton density, while the Fe^{9+} peak density is about 10 times smaller, or half the background density.

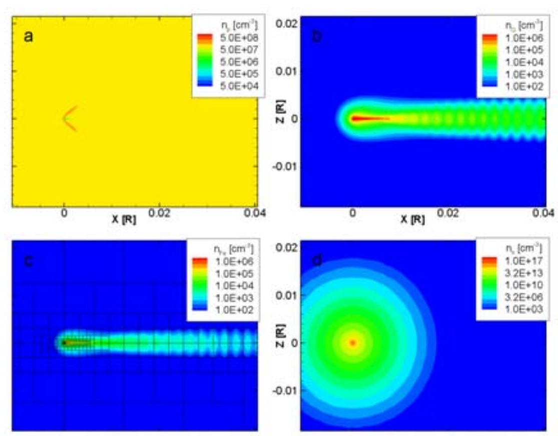

Figure 1. The density contour of a steady-state Sun-grazing comet. Number density contours of proton, Oxygen ions, and Fe ions are shown in panels a, b and c, respectively. Panel d shows the assumed density profile of the neutral coma. Panel c shows the multi-stage grid structure of this model. Unit R measures 1 million kilometers.