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Simulated Interaction of Ganymede's Magnetosphere with the Jovian Plasma

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Abstract

Ganymede is the only magnetized moon in the solar system embedded in its large parent's planet magnetosphere. Its internal magnetic field interacts strongly with the Jovian magnetospheric plasma and makes unique this interaction. Thermal magnetospheric ions co-rotate at about 180km/s and are mainly composed of oxygen ions and protons. Few MHD models [1],[2] succeeded in describing accurately the global shape of the magnetosphere and reproduce most of the signatures observed by Galileo but they are unable to take in consideration high gyroradius effects or multiple ions dynamic. Therefore we developed a 3D parallel multi-species hybrid model based on a CAM-CL algorithm [3] which has been largely used for other magnetized or unmagnetized body such as Mars, Titan or Mercury.

1. Introduction

In the scope of the EJSM/JGO mission preparation, new modeling developments have been done to simulate the Jovian plasma interaction with Ganymede's magnetosphere.

Our simulation model uses a classic hybrid description which aims to fulfill the gap between MHD code and purely kinetic method. This model uses the same hybrid approximation than the model developed by Travnicek et al ([4]). At Ganymede, the Larmor radius of magnetospheric ions are small enough, with respect to the radius of the jovian moon, to consider a fluid approximation but it is large enough to have a significant kinetic effects.

Indeed MHD models are very efficient to describe global magnetospheric structure [1], but they cannot take in consideration gyroradius effects and are limited in the number of ion fluids that they can describe [2]. On the other hand, fully kinetic models provide a complete description of the plasma behavior but they cannot be used on a magnetospheric scale at Ganymede due to computational limitations. Therefore an intermediate approach seems to be a good compromise. We developed a 3D parallel hybrid multi-species model. This model, still under developments is adapted for various environments [5],[6].

2. Simulation model

In the hybrid approximation, ions have a kinetic description while electrons are represented as an inertialess fluid which ensure the neutrality of the plasma and contribute to the total current and electronic pressure. Maxwell's equations are solved to compute the temporal evolution of electromagnetic field.

The Jovian magnetospheric plasma described in this model is composed of O^+ and H^+. The plasma parameters used in these simulations are listed in Tab.1 and are typical values of the Jovian plasma at Ganymede's orbit [7]. The intrinsic Ganymede's magnetic field is implemented at initialization as a dipolar field with a magnetic moment taken from Kivelson et al ([8]).

The planetary plasma included in the simulation is composed of ionospheric O^+ and H^+. In a first attempt, the ionospheric plasma is loaded at the initialization of the simulation with a total density at the surface of 5200 cm-3, a ratio between O^+ and H^+ of 4:1 and a scale height of 125 km in agreement with Paty and Winglee ([2]). In addition, neutral corona of atomic hydrogen and water group atoms is included in the simulation. This neutral environment is partly ionized by solar photons, electron impacts and charge exchange reactions between the magnetospheric ions and the neutral coronae.

Alfven Speed	377 km/s
Plasma Bulk Flow	180km/s

Incident Jovian field	120 nT
H^+ temperature	22,5eV
O^+ temperature	360eV
H^+ density	0,74cm^{-3}
O^+ density	2,96cm^{-3}

Table 1 : Jovian plasma parameters at Ganymede's orbit used in the simulations

3. Simulation results

Simulations are perfomed on a Cartesian grid with a spatial resolution of 0.5 $c/w_p(O^+)$~250 km. The size of the grid is about 200×400×600 with about 12 particles per cell in the undisturbed magnetospheric plasma region and about 600 millions particles are present in the simulation box. The time step is taken sufficiently small to represent correctly the gyration of H^+ (20 values per gyroperiod) and therefore about 20000 time steps are required to reach a quasi-stationary solution. This simulation has been run on 48 CPUs for about 2 weeks which correspond to more than 16000h CPU elapsed time.

We present simulation results of magnetic field morphology in the vicinity of Ganymede, the current system, the plasma distribution and the plasma bulk speed near Ganymede (Fig 1). The simulation reproduces the main features of the ganymede's interaction such as the Alfven wings, the ionospheric region, the mini-magnetosphere,etc...The dynamic of each ion species will also be presented.

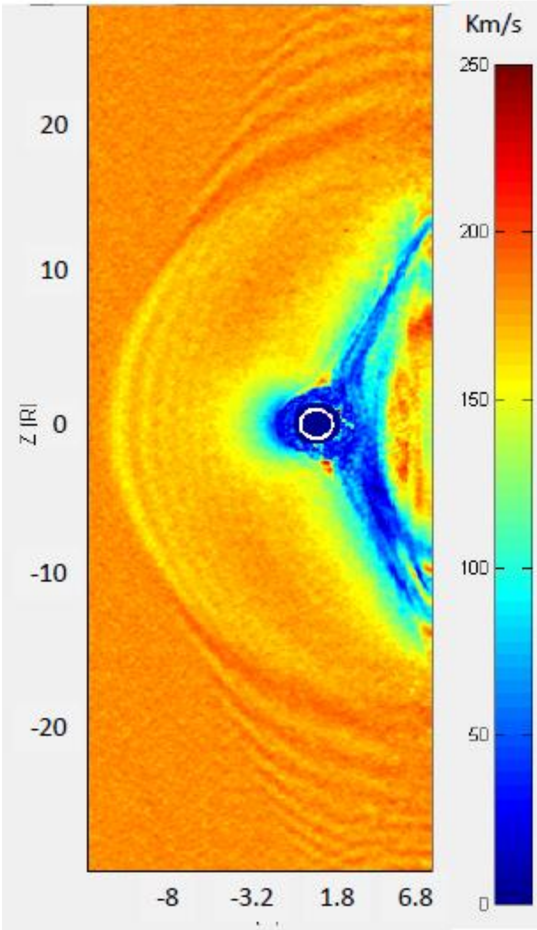

Figure 1: Bulk speed in the XZ plane

The influence of energetic particles, present in the Jovian magnetosphere, on the Ganymede's interaction region is planned to be investigated.

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