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Energetic particles population inside Ganymede magnetosphere

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Abstract

The case of Ganymede is unique in the solar system. It is the only moon to have its own intrinsic magnetic field. This field interacts strongly with the ambient Jovian plasma, creating a magnetosphere around the moon. The environment of Ganymede is composed of electrons and protons but also of heavier ions like sulphur and oxygen, due to the Io volcanic activity. Some of these ions reach energies of several MeV due to the strong Jovian magnetic field and consequently gyroradii comparable to the size Ganymede. These gyroradii effects create a complex flux distribution geometry at the vicinity of Ganymede, with asymmetries in pitch angles.
In order to study this complex environment, we have developed a code which compute the reversed particles movement for different energies, incidences and pitch angles. It allows us to describe a set of parameters physically realistic for energetic particles at each location, between 0 and 4 Ganymede Radii, and to draw maps of relative densities inside the magnetosphere. These maps show the relative reduction of electronic and ionic population compared to the Jovian undisturbed plasma. In particularly we can partly quantify the electron flux decreasing for the JGO orbiter trajectory and consequently evaluate the radiation shielding created by the moon during different phases of the mission. We can also investigate trapped particles distribution when the orbiter is passing through closed field line regions and the possibility for radiation belts to exist in such areas as much as possible influence on the Ganymede surface.

1. Introduction

In the context of the futur EJSM mission the complex environment of Ganymede and especially the distribution of energetic particles (ions and electrons) have to be investigated. Indeed they represent a key issue as much as for radiations matter than for science. Consequently we decided to developed a kinetic algorithm modeling the distribution of energetic ions and electrons inside Ganymede magnetosphere.

2. Method

In this paper we choose to use GphiO coordinates where X stands along co-rotational flow, Z along Ganymede's rotation axis and Y toward Jupiter. In this frame we use Kivelson [1] data to set a magnetic environment consistent with Galileo's flyby . An ambient field is superposed with a dipole field generated by a moment at equator derived from measurements. Our integration model is based on a kinetic algorithm known as the "Boris" algorithm, to compute the trajectory of the charged particles inside the magnetic field. This method has the advantage to conserved perfectly the kinetic energy of particles. The equation of movement integrated is the basic Laplace equation where we neglect gravity and electric field. At each location we describe of full set of parameters: energy, pitch angle (from 0 to 360°) and phase angle regarding the field lines, and run the simulation during an appropriate time to compute the "origin" of particles:

- If the particle comes from the surface of the planet we consider that parameters associated to this particle (pitch angle, energy,angle of incidence) are not observable at this location (literally we consider that this particle will not be able to exist because it will have to cross trough the planet to be present there).

– If the particle comes from Jovian plasma we consider that the set of parameters are accessible at this location and that a particle with these characteristics will be able to exist in the environment.

– The last case is the possibility for energetic particles to stay trapped. Our calculation made us considered the Jovian ambient plasma as the only source for incoming particles in Ganymede magnetosphere and consequently we neglect sputtering or sublimation from the surface

3. Results

Ions and electrons distribution shows asymmetries and geometrical distribution influenced by the intrinsic magnetic field (see figs). We observe the creation of trapped belt for particles below 300KeV as much as finite gyroradii effect, especially for MeV's oxygens ions. Moreover electrons flux computed along a potential JGO orbiter trajectory show a significative reduction of radiation dose (~50%) compared to an non magnetic moon-plasma interaction. We compared the simulated data with EPD measurements and tried to explain the differences observed

4. Figures

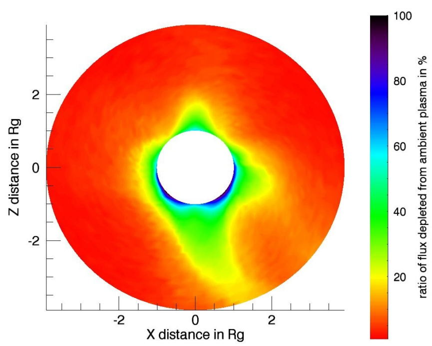

Fig 1: Oxygen ions relative flux depletion at 6MeV

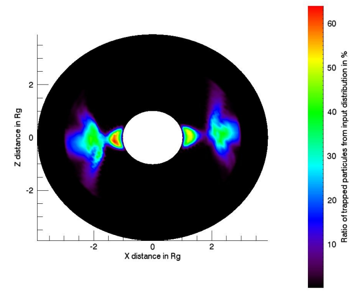

Fig 2: Oxygen ions trapped at 25KeV

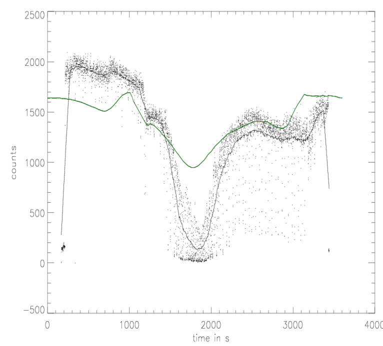

Fig 3: Electron simulated (green) and observed (black and dot) counts for chanel F2 of EPD instruments during the G2 flyby.

5. Conclusion

Our model helps to understand the interaction of energetic particles with the magnetic environment of Ganymede. If it has to be improve to fit better Galileo measurement, it already allows us to estimate the dose reduction for a potential orbiter as much as the energies of precipitating ions on the surface of Ganymede.

References

[1] M.G Kivelson, K. Khurana, M volverk et al., 2002, The permanent and inductive magnetic moment of Ganymede, Icarus, 157 507-522