EPSC Abstracts
Vol. 13, EPSC-DPS2019-1764-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Simulations of JUICE spacecraft charging and its impact on particle measurements in Europa's ionosphere and the Jovian magnetosphere

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Abstract

We present Spacecraft Plasma Interaction Software (SPIS) simulations performed to estimate spacecraft charging and ion wake structure formation for the future Jupiter Icy Moons Explorer (JUICE) mission. This study is focused on how different environments in the Jovian system, including the ionosphere of Europa, will affect the charging and how this will impact the future particle measurements. Our simulation results shows a large ion wake structure forming behind the spacecraft for all the studied environments, that the spacecraft will be charged negatively in the inner magnetosphere and in the ionosphere of Europa, where the plasma density is high, and positively further out in the magnetosphere. In addition, for all studied environments dense photoelectron and secondary electron sheaths will further complicate the particle measurements.

1. Introduction

To do accurate data analyses of plasma measurements from any spacecraft it is imperative to understand how the measurements are disturbed by the spacecraft itself. The interaction between the plasma and the spacecraft will charge the spacecraft to a potential decided by the spacecraft materials, design, and the surrounding space environment. The spacecraft potential will affect the energy distribution of the particles that are able to reach the particle instruments. Spacecraft charging can therefore give erroneous measurements and incorrect scientific results. For most space plasma environments there will also be a wake forming behind the spacecraft, which will for example affect in-situ measurements of the ion properties. To study this impact the open-source software SPIS is commonly used.

The main objectives of the JUICE mission are to study the Jovian magnetosphere and the Galilean moons, especially the habitability of the moons. JUICE will study the plumes of Europa, the aurora of Ganymede, and the possible subsurface ocean of Callisto. In order to do so it is imperative to have an accurate understanding of how the measurements are disturbed by the spacecraft.

2. Simulation results

We study four different magnetospheric environments: the centrifugal equator, i.e. the densest part of the plasma disk around Jupiter, at 9.5, 15, and 26.3 R$_J$, and the ionosphere of Europa at ∼400 km (closest approach for JUICE). The environments are based on measurements from several missions that have visited the Jovian system, Galileo, Voyager 1 and 2, Ulysses, Pioneer 10 and 11, and on models.

The simulations of each environment provides the surface charging, the ion wake structure, the disturbance on the ambient electron population, the spacecraft potential, as well as the photoelectron and secondary electron sheaths around the spacecraft. The photoelectrons and secondary electrons are electrons that are emitted from the spacecraft itself due to the interaction with solar radiation and the ambient plasma environment. These particles can create potential barriers, as can be seen in Figure 1, which will add to the potential structure of the charged spacecraft and prevent low energy ambient electrons to reach the spacecraft and its particle instruments. Figure 1 shows that the surface potential of the spacecraft reaches -4 V while the surrounding photoelectron and secondary electrons will create a potential structure that reaches down to -6 V on the wake side of the spacecraft, for the environment at 9.5 R_J from Jupiter.

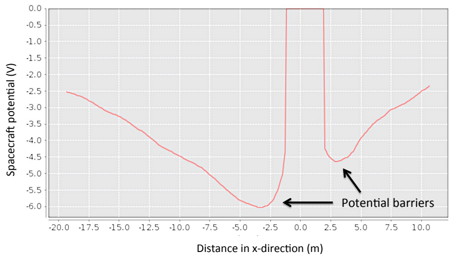

Figure 1: The JUICE spacecraft potential in x-direction for the centrifugal equator and at 9.5 R_J.

Figure 2 shows an example of the ion wake structure that can be formed behind the spacecraft. Figure 2 illustrates the large depletion of ions and the disturbed plasma environment behind the spacecraft.

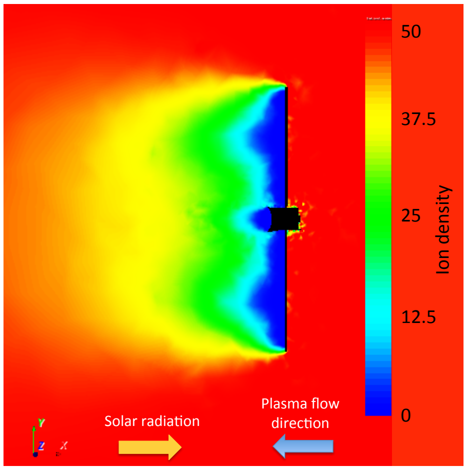

Figure 2: The JUICE ion wake formation in the centrifugal equator and at 9.5 R_J.

Our simulations also shows that the choice of white thermal control paint is important for the charging of the spacecraft. Figure 3 shows an example of the spacecraft surface charging at 26.3 R_J, using the white paint Z93C55 which shows relatively good conductive properties. Despite this the spacecraft charges up to around 5 V differential charging. This shows that the conductivity of the spacecraft material is important, not only to assess the risks of electrostatic discharges harmful to electronics but also to understand the disturbed potential structure around the spacecraft and its effect on the measurements.

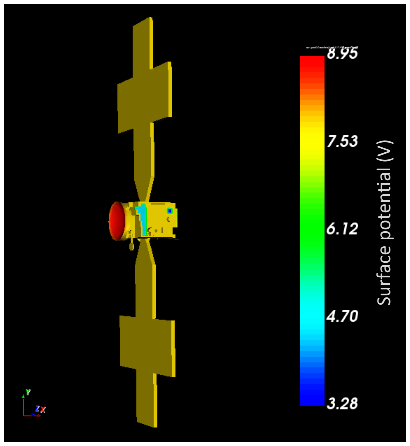

Figure 3: The JUICE surface potential in the centrifugal equator and at 26.3 R_J.

3. Summary and Conclusions

To correctly understand the Jovian system and its many icy moons we need to understand the impact the spacecraft itself will have on its surrounding and how this can affect our measurements. Several recent studies have sparked new life in the discussion on the existence of a plume/plumes of Europa (for example [1], [2] and [3]). JUICE will study Europa in detail and might even be able to measure the plumes in situ. This study shows that several perturbations caused by the spacecraft space environment interaction needs to be taken into account in order to perform accurate data analyses, regardless if it concerns plume or other magnetospheric measurements. Relevant corrections should be made, taking into account surface charging, the ion wake structure, the disturbance on the ambient electron population, the spacecraft potential, as well as the photoelectron and secondary electron sheaths around the spacecraft.

References

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