JUICE spacecraft charging in the variable Jovian magneto-sphere, plumes of Europa and the auroral zone of Ganymede: Implications for future particle and fields measurements

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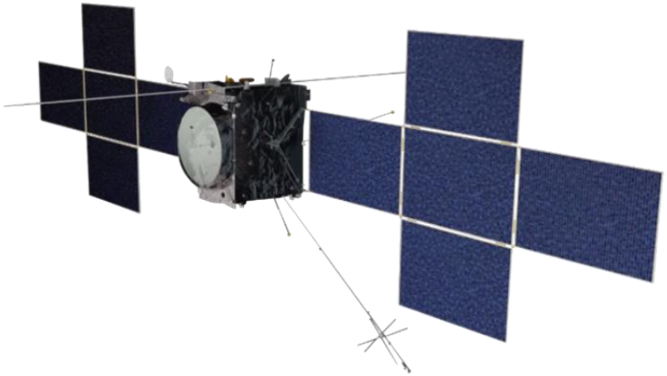


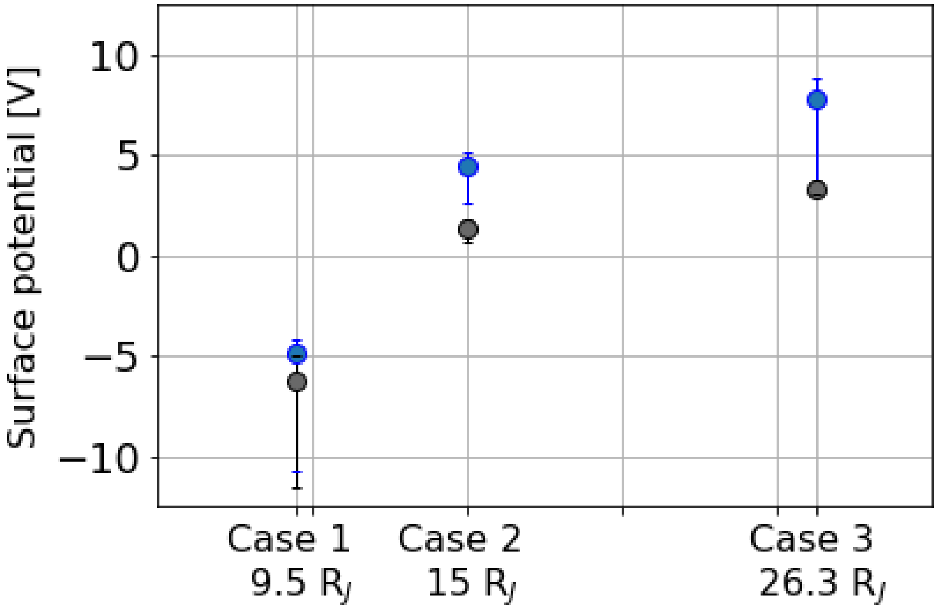
Introduction – JUICE in the Jovian magnetosphere

- In preparation for the ESA mission Jupiter Icy Moons Explorer (JUICE)(1), we use Spacecraft Plasma Interaction Software (SPIS)(2) simulations to study how the spacecraft will charge up in a number of typical and atypical environments found in the Jovian magnetosphere. We want to know:

Will spacecraft charging impact the particle and field measurements of JUICE?

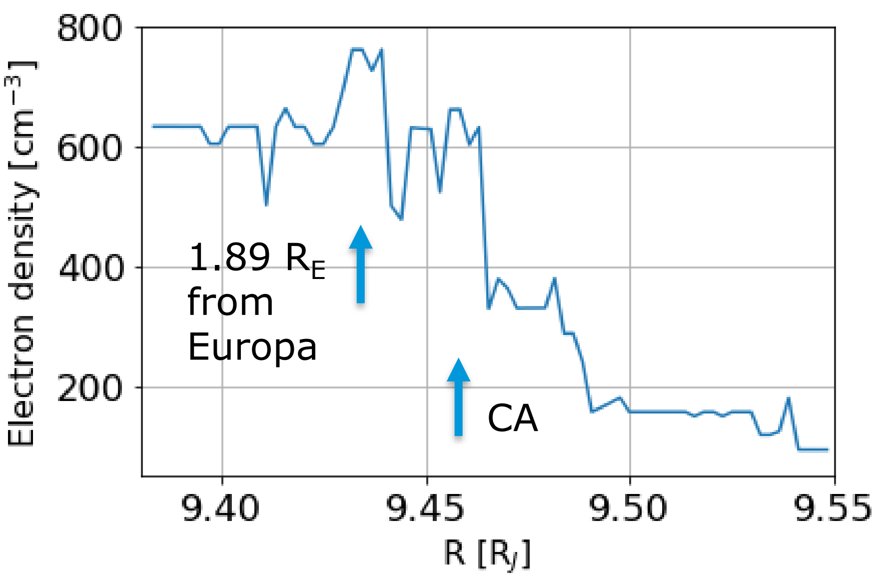
- We simulate the surface charging for typical plasma conditions in the plasma sheet at **9.5 R_J, 15 R_J, 26.3 R_J** from Jupiter(3,4,5,6,7,8,9). The figure shows the simulated spacecraft ground potentials (circles) and the potential ranges (lines) for different spacecraft surfaces, in sunlight (blue) and eclipse (black).

- The simulation results show that surface charging in typical plasma sheet environments will not be a cause of substantial perturbations.



1. The variable Jovian magnetosphere

- Typical plasma sheet densities at **9.5 R_J** are **10-100 cm^{-3}**. However, Galileo/PWS recorded densities around **760 cm^{-3}** at **9.43 R_J**[9] on December 16, 1997 (figure below). This disturbed environment could result in problematic spacecraft surface potentials.
- Variability in the hot electron component will not have a significant impact on the surface charging for the environment at 9.5 R_J due to the large density ratio, **$n_{e,c} > 600*n_{e,h}$**.



- The detected variability in other parameters such as ion temperature, plasma drift speed, magnetic field strength and direction etc., generates only minor changes in the surface potential.
- The surface potential obtained at **26.3 R_J** is mainly due to the emitted and collected **photoelectrons**. Consequently, the variability in the magnetosphere will generate only minor changes in the surface potential for this environment.

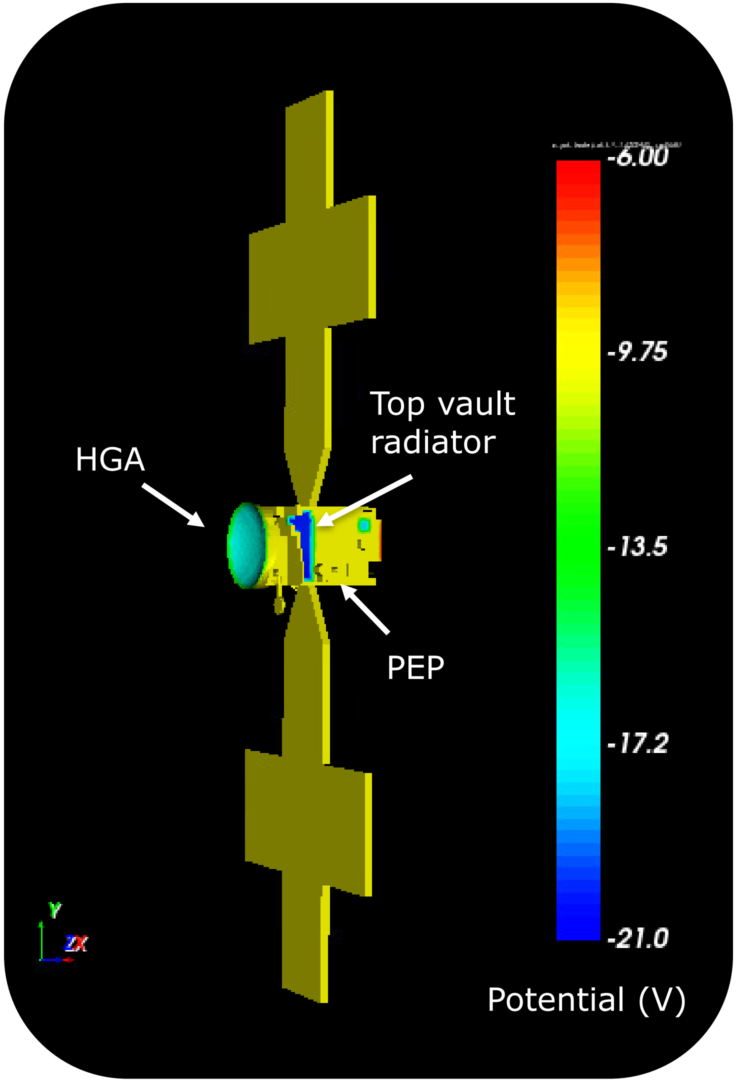
1. SPIS simulation results

- Galileo did not record the electron temperature of the high density plasma detected close to 9.5 R_J. Assuming a negative correlation between the electron density n_e and temperature T_e we look at two cases, **T_e= 5 eV** and **T_e = 20 eV**.

1. T_e = 5 eV, s/c ground ≈ -10 V and potential range -6 to -21 V (right figure)

2. T_e = 20 eV, s/c ground ≈ -17 V and potential range -11 to -60 V

- Low energy electrons will be repelled by the low potential of the spacecraft. In particular from the top vault radiator, which charged to **-21 V** using T_e = 5 eV and **-60 V** using T_e = 20 eV.



2. Plumes of Europa

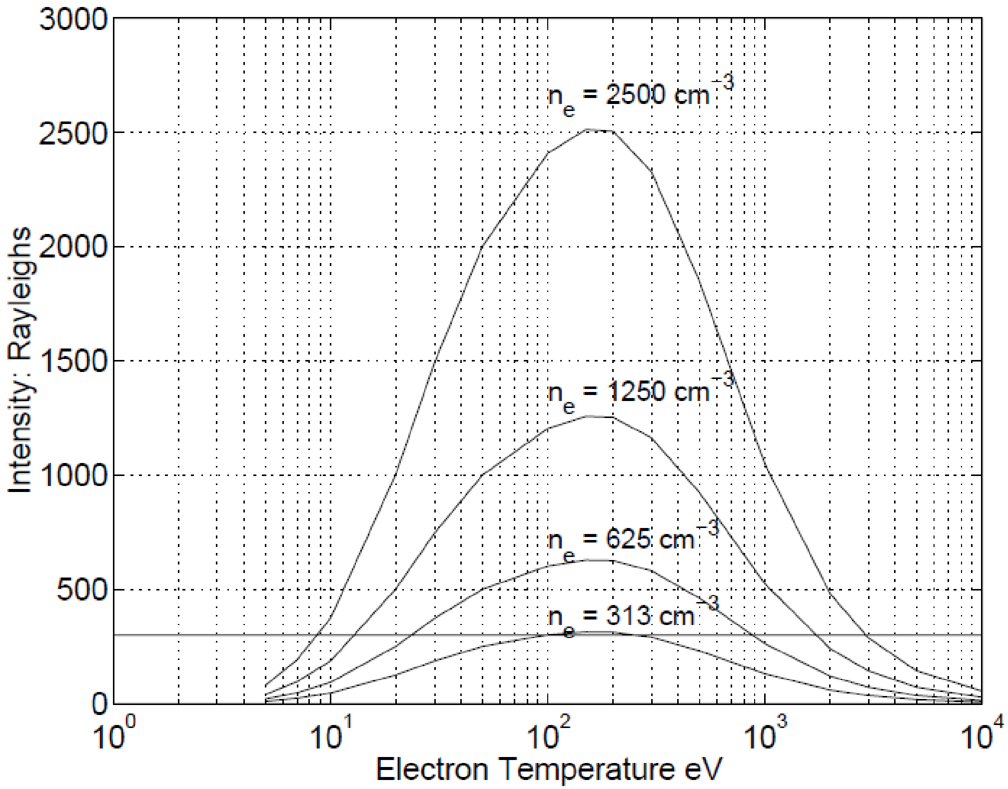
Global parameters	Plume 1	Plume 2	Plume 3
Ionosphere plasma density [5,9]	200 cm^{-3}	200 cm^{-3}	200 cm^{-3}
Ionosphere e^- temperature	5 eV	5 eV	5 eV
Ionosphere ion temperature [10]	90 eV	90 eV	90 eV
Ionosphere flow velocity, v_x	-56.5 km/s	-56.5 km/s	-56.5 km/s
Ionosphere flow velocity, v_y	56.5 km/s	56.5 km/s	56.5 km/s
Dominant ion species	O^+	O^+	O^+
Plume plasma density [11,12]	1000 cm^{-3}	10,000 cm^{-3}	10,000 cm^{-3}
Plume e^- temperature	5 eV	0.5 eV	0.5 eV
Plume ion temperature [13]	45 eV	45 eV	5 eV
Plume flow velocity, v_z	-1.5 km/s	-1.5 km/s	-1.5 km/s
Dominant ion species	H2O+	H2O+	H2O+
Spacecraft velocity	17.2 km/s	17.2 km/s	17.2 km/s
Magnetic field strength	480 nT	480 nT	480 nT

Simulation results, surface potentials

Ionosphere, no plume	-9.5 (-13.7 to -5.6) V
Plume 1	-15.5 (-18.7 to -13.3) V
Plume 2	-1.7 (-2.0 to -1.0) V
Plume 3	-2.0 (-6.9 to -1.9) V

3. Aurora of Ganymede

- Background emission with occasional bright spots above 300 Rayleigh.
- What electron temperatures are needed to produce intensities above 300 Rayleigh?
- $\mathbf{T_e = 100 - 230\ eV}$ and $\mathbf{n_e = 313\ cm^{-3}}$ will generate the same intensity as $\mathbf{T_e = 9\ eV}$ and $\mathbf{n_e = 2500\ cm^{-3}}$
- Preliminary results from the first simulations show surface potentials of



Calculated intensity of aurora emission from Eviatar et al 2001b. The vertical line marks 300 Rayleigh.

Discussion and conclusions, perturbations of JUICE particle and field measurements

- Typical magnetospheric conditions will not cause large measurement perturbations.
- However, occasional plasma environments with high electron densities and/or temperatures might cause substantial surface charging.
- Extra large plumes of Europa will not cause perturbations due to surface charging
- Bright aurora at Ganymede seems to produce substantial charging, further investigation needed
- Large negative surface potential values will prevent cold electrons from reaching the particle instrumentation on the spacecraft. This is a concern in particular for the Particle Environment Package (PEP) that is located close to the dielectric surface of the top vault radiator.
- Large differential charging will create large contaminating electric fields and currents which can interfere with electric field measurements by the Langmuir probes.
- Our simulations also show that the spacecraft potential can be altered slightly by controlling the direction of the solar panels, which could be used to reduce the perturbations in particularly problematic environments such as the ionospheres of Europa and Ganymede.

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