Surface charging of the Jupiter Icy Moons Explorer (JUICE) spacecraft in the solar wind

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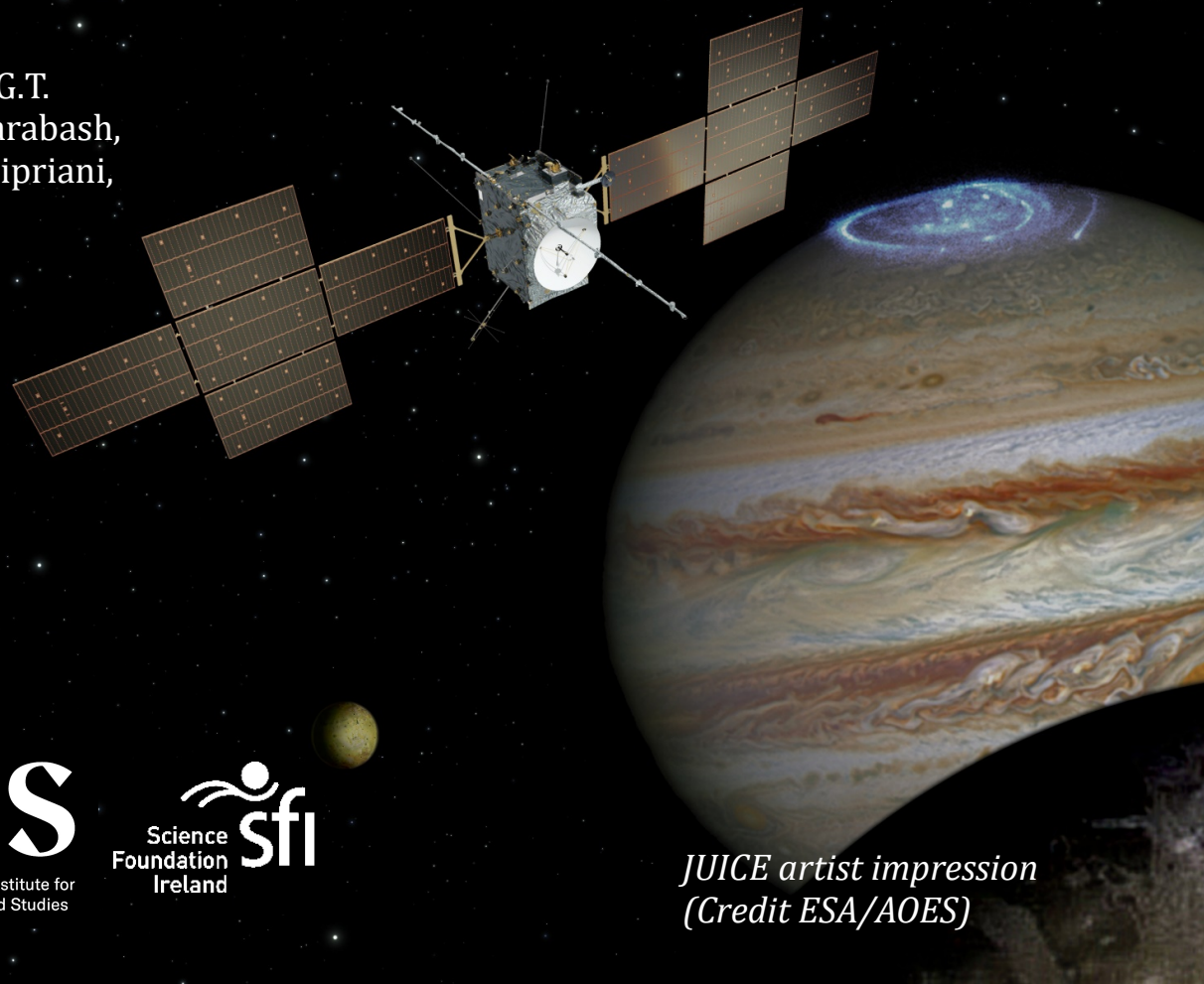
EPSC



JUICE artist impression (Credit ESA/AOES)

European Space Agency
Agence spatiale européenne

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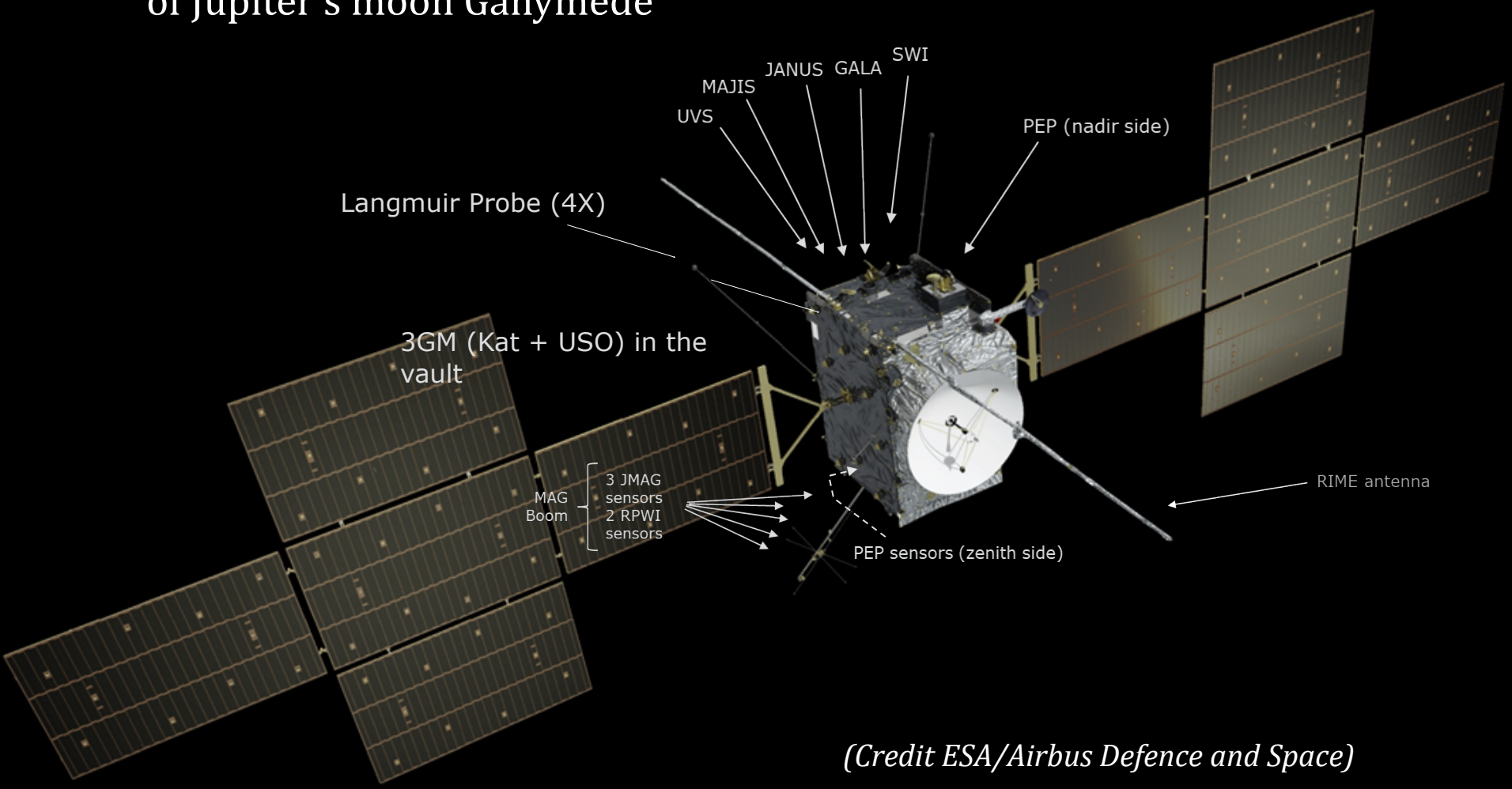
The JUICE spacecraft

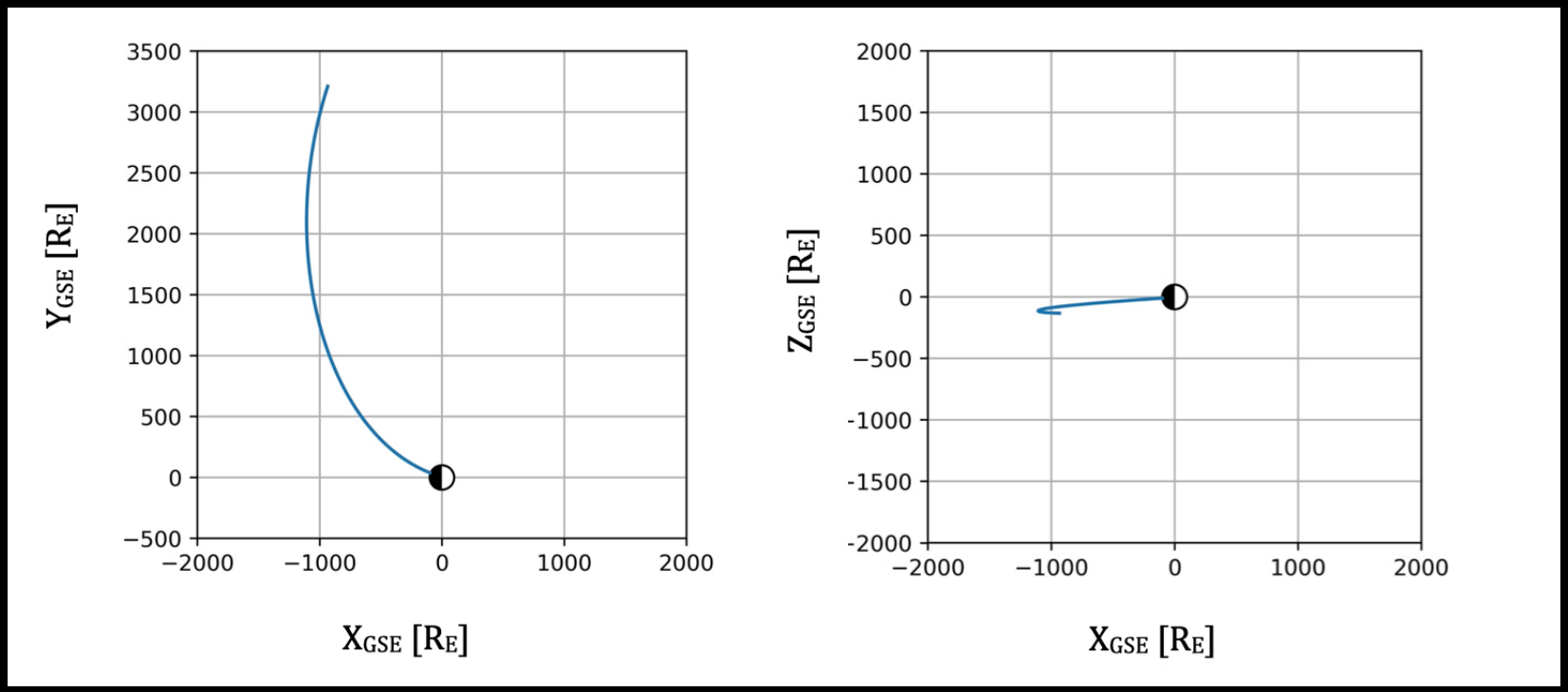
- Scheduled for launch on April 5, 2023
- Study the Jovian system with a special focus on the habitability of Jupiter's moon Ganymede



(Credit ESA/Airbus Defence and Space)

The JUICE NECP orbit

- JUICE orbit from April 5 to June 28, Near Earth Commissioning Phase
- First JUICE measurements in the solar wind at around 1500 to 3200 R_E
- Solar panels and HGA towards the Sun
- Maximum distance from Sun is 1.06 AU

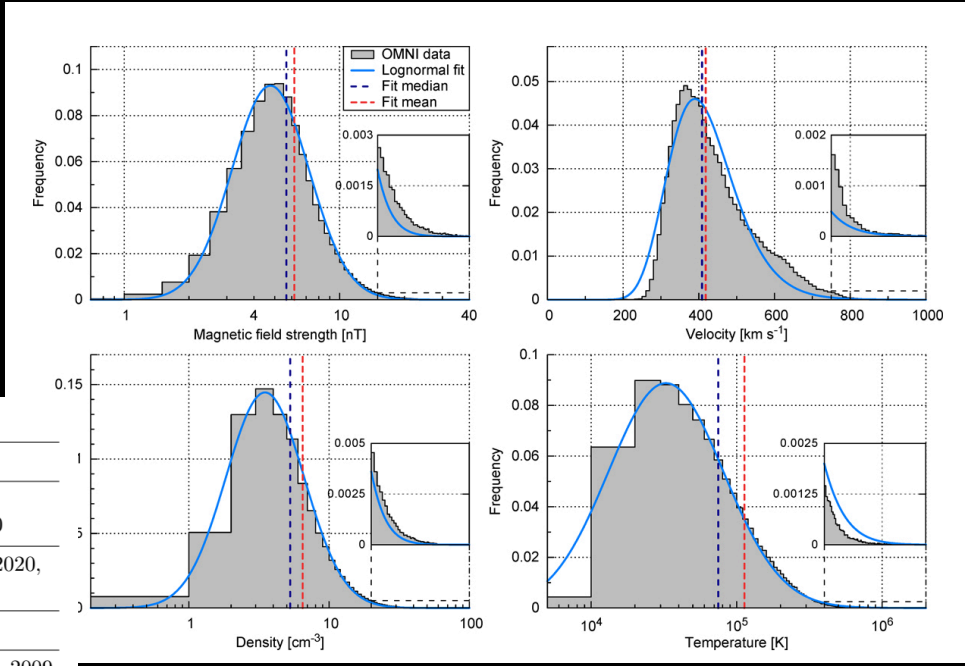


Earth not to scale!

The solar wind at 1 AU

- Mean solar wind properties are used as input for spacecraft -plasma interaction simulations
- 20 years (2001-2021) of solar wind observations by Cluster, Double Star, Themis and MMS

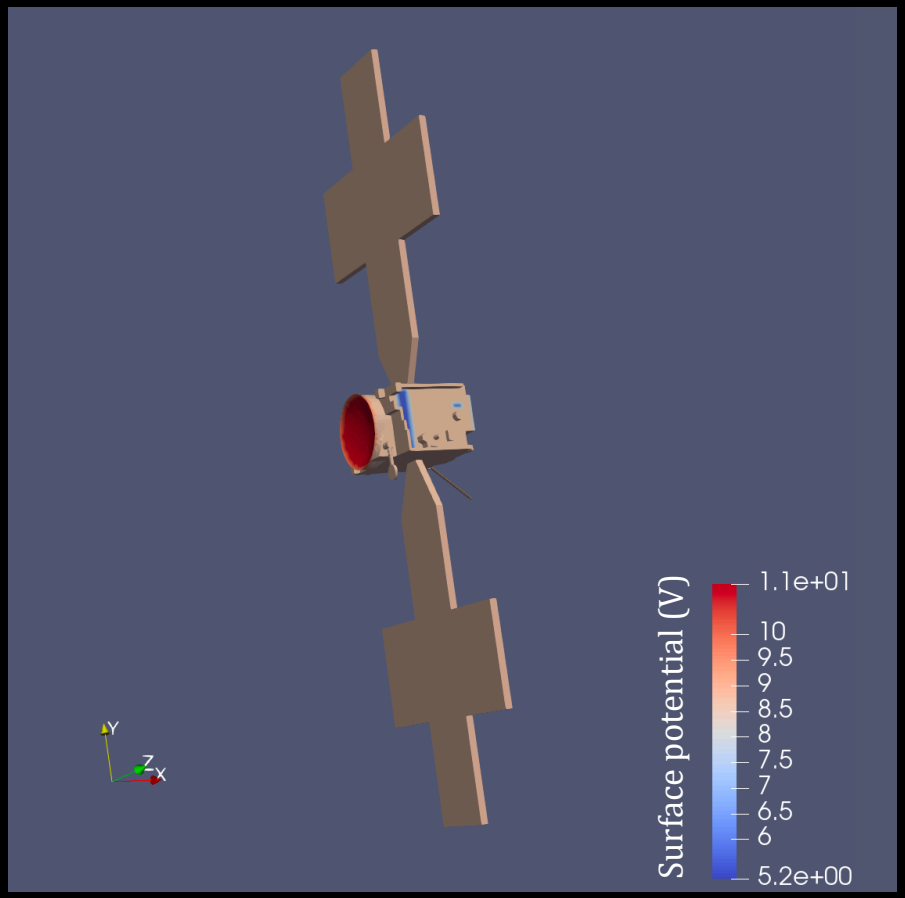
Parameter	Input value	Values	References
$n_{e,c}$	5.4 cm^{-3}		Assuming $n_{e,c} + n_{e,h} = n_i$
$T_{e,c}$	10 eV	10, 12.2, 10, 8.5-10	Gosling 2014, Wilson et al. 2018, Lazar et al. 2020, Pierrard et al. 2020
$n_{e,h}$	0.2 cm^{-3}	0.2, 0.2-0.3, 0.2	Maksimovic et al. 2005, Lazar et al. 2020, Pierrard et al. 2020
$T_{e,h}$	60 eV	60, 60-66	Lazar et al. 2020, Pierrad et al. 2020
Kappa	5	4.9, 4.5-5, 5-5.7, 5-5.5	Maksimovic et al. 2005, Strevak et al. 2009, Lazar et al. 2020, Pierrard et al. 2020
n_i	5.6 cm^{-3}	5.6, 6.4 (0.03-72), 6 (0.5-117)	M1, M2, Wenzmer and Bothmer 2018
T_i	8 eV	4.3-10.3, 12.7, 8, 9	Gosling 2014, Wilson et al. 2018, M2, Wenzmer and Bothmer 2018
v_{sw}	413 km/s	468, 413, 427, 410 (156-1189)	Gosling 2014, M1, M2, Wenzmer and Bothmer 2018
Ion species	H^+		
$v_{s/c,x}$ $v_{s/c,y}$ $v_{s/c,z}$	-1.0 km/s -3.3 km/s -0.04 km/s		From the spacecraft trajectory file Crema 5.0b23.1
B	5.5 nT	6.2, 6 (0.4-62), 5.7, 5.5	Gosling 2014, Wenzmer and Bothmer 2018, M1, M2



From Venzmer and Bothmer 2018
OMNI (Helios, ACE, Geotail, WIND and DSCOVR) data from 1963-2016

JUICE surface potential

- Spacecraft Plasma Interaction Software (SPIS)
- Commonly used to assess the risk of electrostatic discharges (ESDs)
- Charging may also interfere with measurements

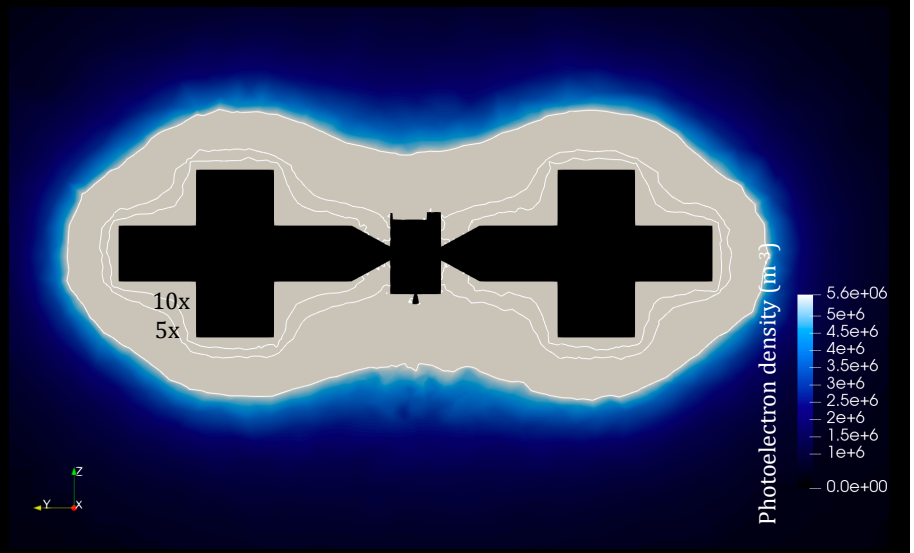


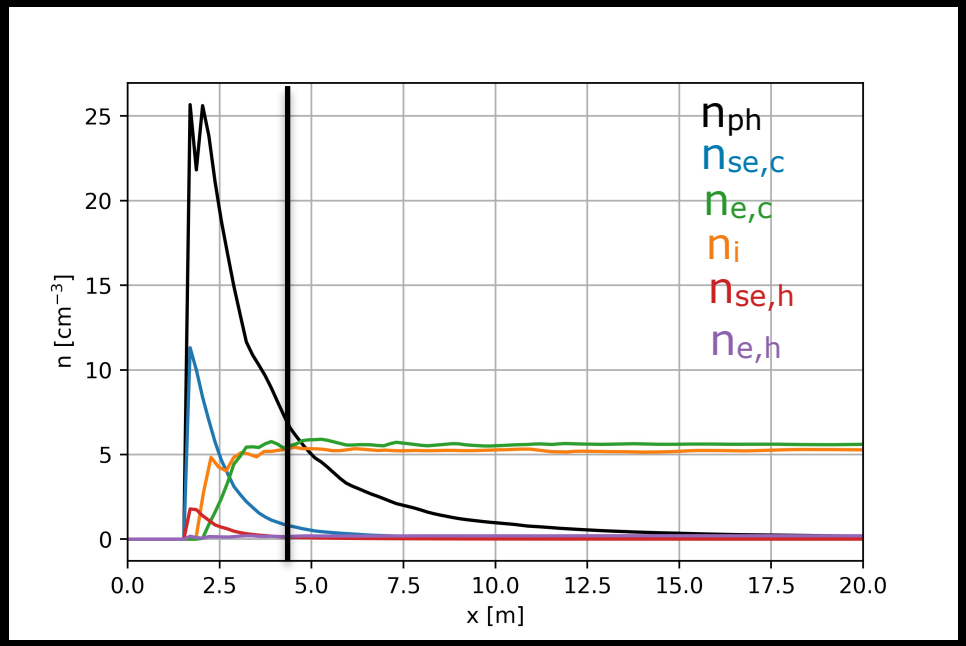
- Surface potential 8.5 (5.2-11) V for typical solar wind

Current	Magnitude
Photoelectron current, emitted	2.8 mA
Photoelectron current, collected	2.7 mA
Core electron current	0.23 mA
Secondary electron current, emitted	0.17 mA
Secondary electron current, collected	0.15 mA
Ion current	0.04 mA

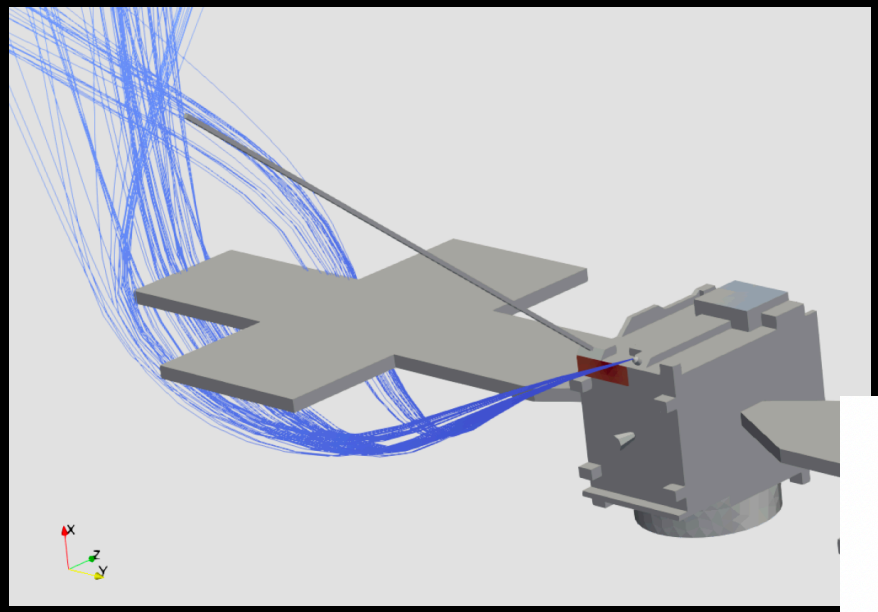
The particle environment

- Particle densities along a line 20 m from the center of the spacecraft, crossing the position of one Langmuir probe (black vertical line)
- Dominated by photoelectrons (black line)
- Not including photoelectrons and secondary electrons produced by the Langmuir probe itself!



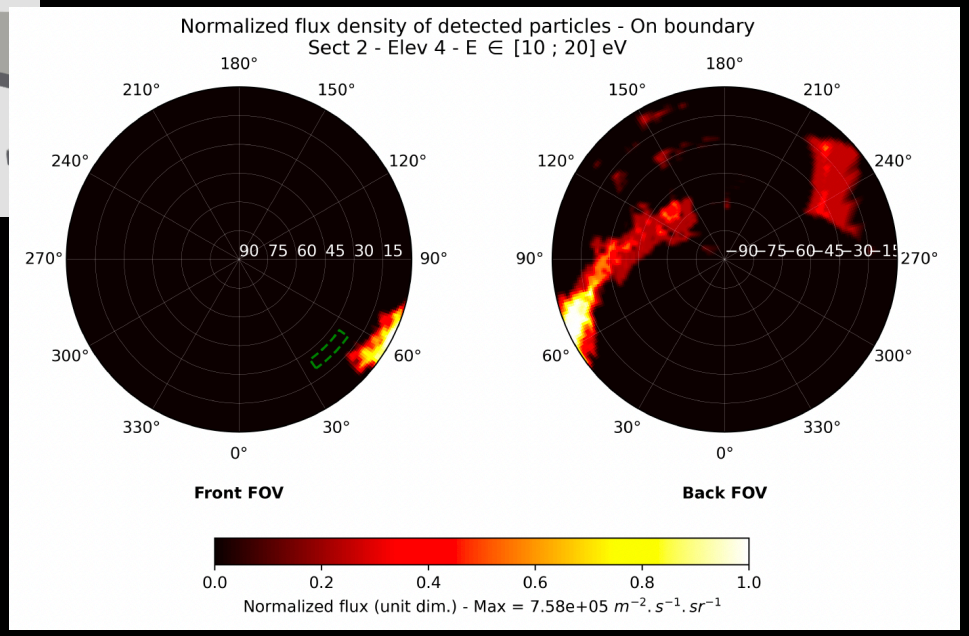


Interference with measurements



- Distortion of ion trajectories due to the charging of the JUICE solar panels

- SPIS simulations of the perturbed Jovian Dynamics and Composition Analyser (JDC) measurements



From Bochet et al., in prep.

Summary

- For typical solar wind conditions JUICE will charge to 8.5 (5.2-11) V
  - The spacecraft will be in a dense photoelectron cloud with densities >10x the ambient plasma density
  - Secondary electron densities >2x the ambient plasma density
- Understanding the spacecraft - plasma interaction is crucial
    - It interferes with measurements
    - Simulations are needed for reliable data analysis
- Future work
  - “Extreme” solar wind
  - Sensitivity study of the different parameters
  - Outgassing from the spacecraft
  - Simulate the JUICE/RPWI and PEP measurements