Simulations of spacecraft potential measurements on Cassini

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Overview

- Introduction
- Simulation software (SPIS)
- Cassini spacecraft results
- Langmuir probe results
  - OML and Sheath model.
- Conclusions and outlook
- Questions

What has been investigated?

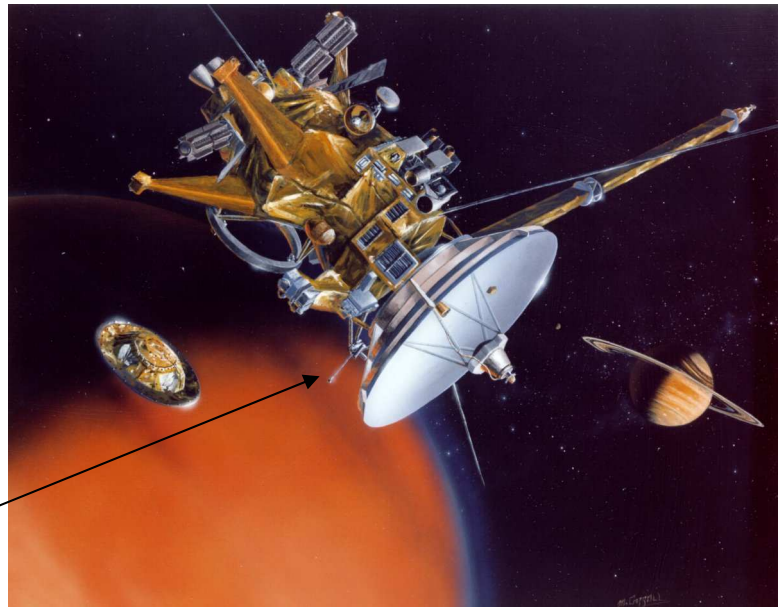
- How does the Cassini s/c affect the spacecraft potential measurements made by the Langmuir probe?
  - Simulations of full s/c without probe
- How does the connecting parts (the “stub”) between s/c and the Langmuir probe affect the probe bias sweeps?
  - Simulations of probe and stub only (no s/c)

The Cassini spacecraft

- **Intro**
- SPIS
- Cassini results
- LP results
- Conclusions

- One of the largest interplanetary spacecrafts ever. (6 m long)
- High gain antenna (4m in diameter)
- The Langmuir probe is on a 1.5 m boom.

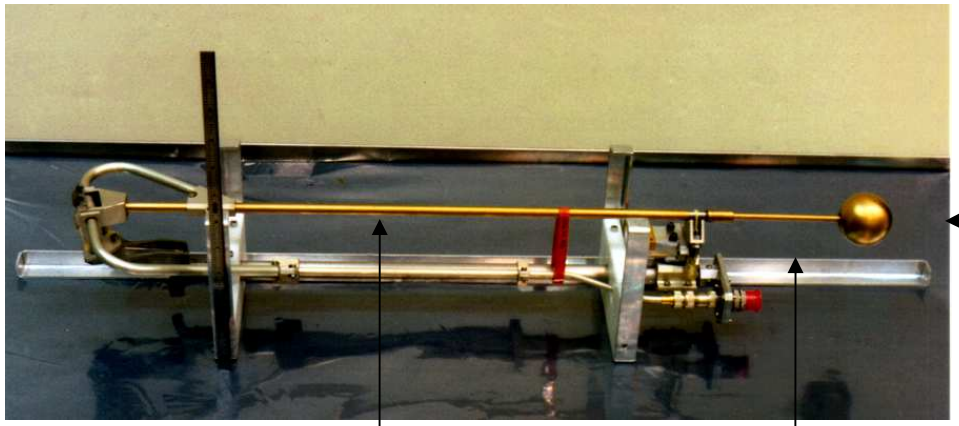
Position of the Langmuir probe on the Cassini spacecraft.



Showing the Huygens probe being released down through the atmosphere of Saturn's moon Titan.

The Langmuir probe

Made of titanium with a titanium nitride coating



The sphere, radius 25 mm

Boom

The “stub”, radius 3.175 mm length 109 mm, at same potential as the sphere

The simulation software

- Intro
- **SPIS**
- Cassini results
- LP results
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- Spacecraft Plasma Interaction System, (SPIS v.3.7rc09)
- Assumptions/settings:
  - Only hydrogen ions
  - PIC electrons
  - Ti = Te
  - **B** = 0
  - stationary plasma wrt S/C
  - no photoelectrons

Simplified model of the S/C

- Intro
- **SPIS**
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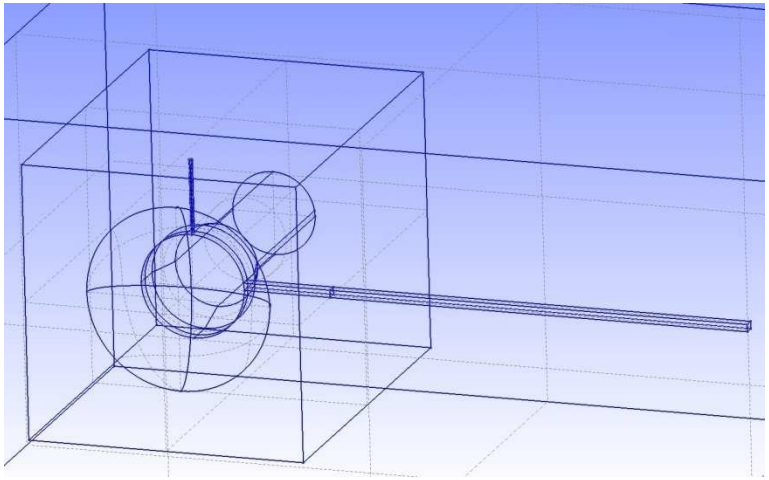
• The Cassini s/c is modelled as a cylinder with varying radius, with the booms for the Langmuir probe and the magnetometer present.

• The LP and stub are omitted.

• Simulated in various plasmas.

- n: 100; 10; 1; 0.1; 0.01 [cm^-3]
- Te: 10; 1; 0.1 [eV]



The nested boxes are there to help optimize the 3D meshing of the simulation volume, finer and more accurate close to the spacecraft. Wider and less accurate at the boundary.

Example result from the Spacecraft simulations

- Intro
- SPIS
- **Cassini results**
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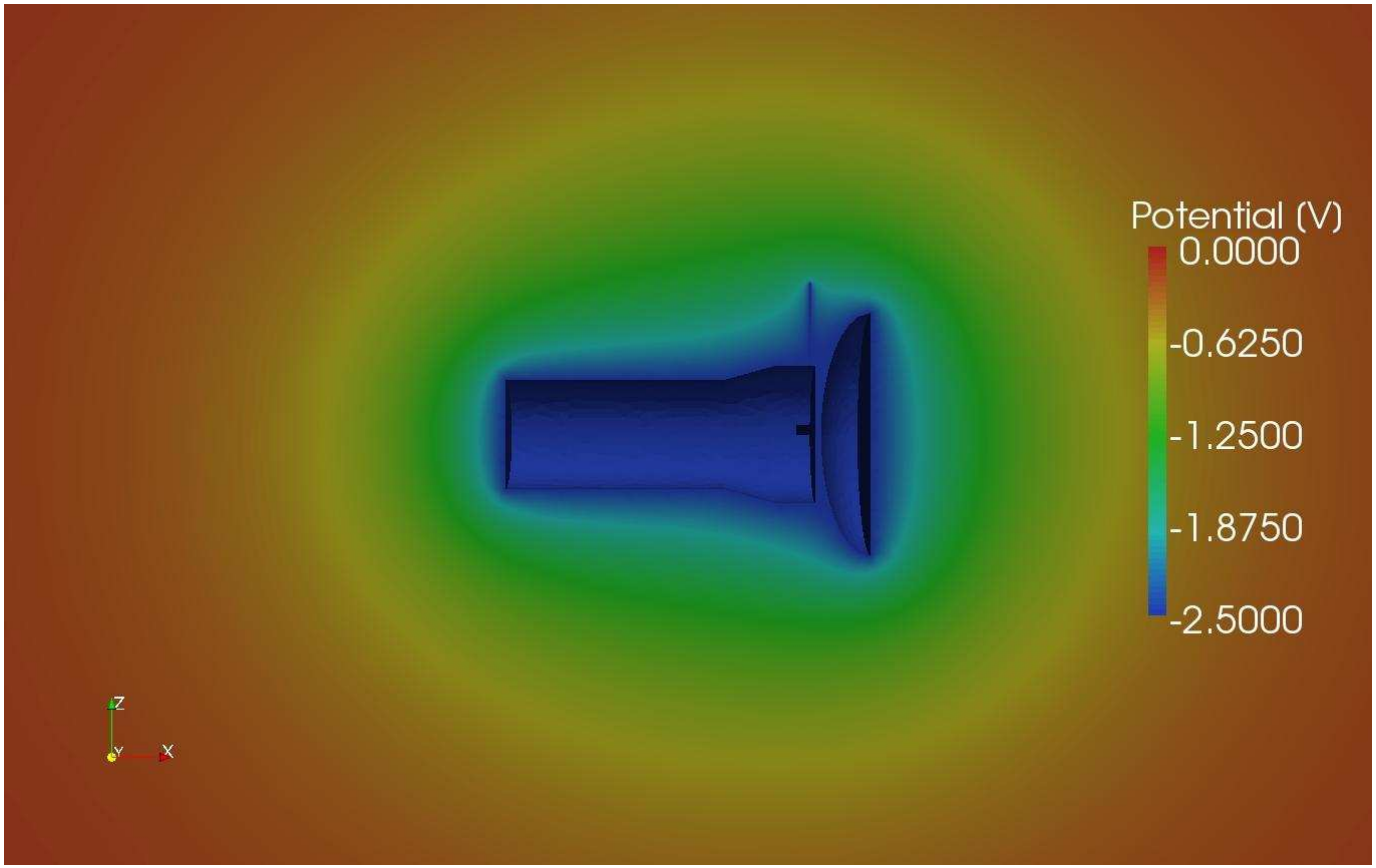

The plasma potential in the vicinity of the spacecraft for a plasma with ne = 1 cm-3 and Te = 1 eV.

Result of the Spacecraft simulations

- Intro
- SPIS
- **Cassini results**
- LP results
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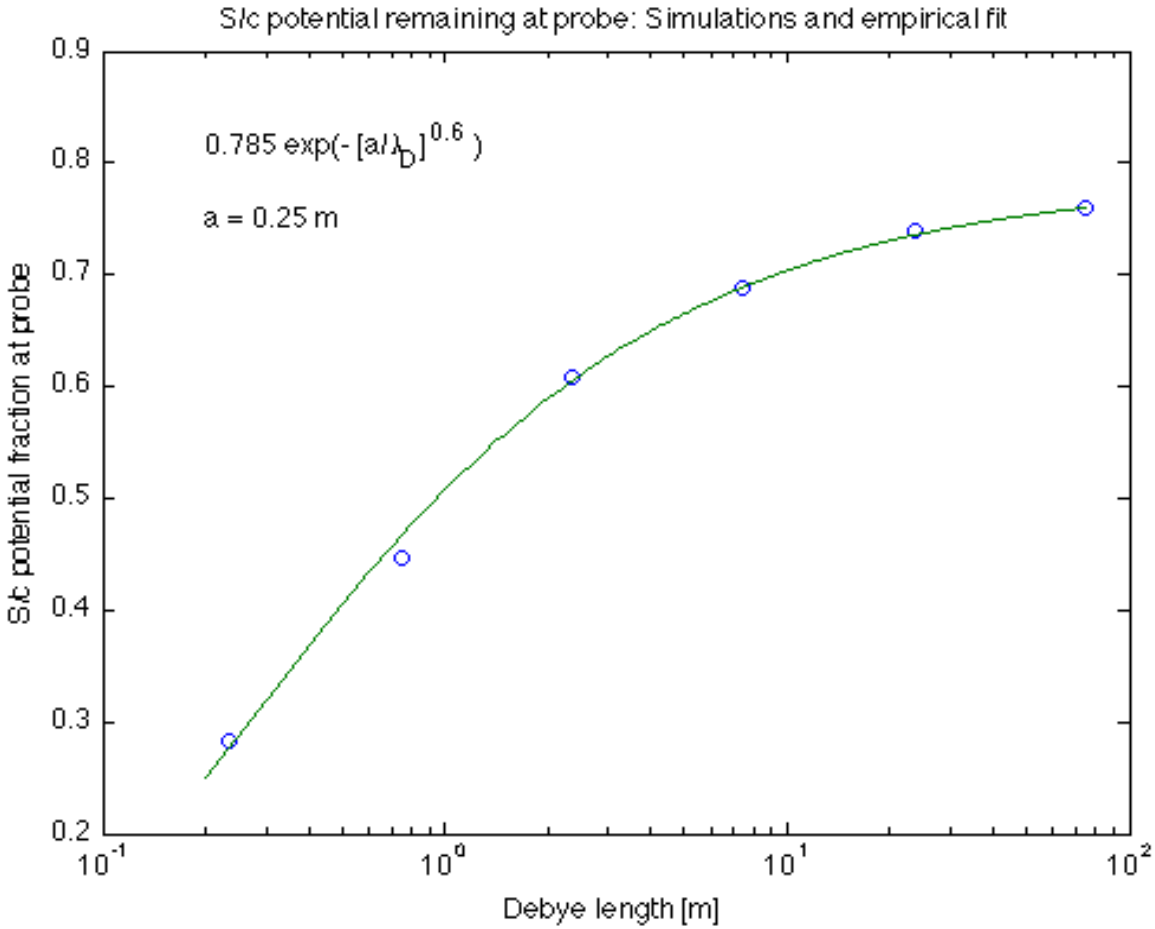
Long Debye length => 78.5% of the S/C potential will remain at the position of the probe.

This means that the true Vsc relates to the measured probe floating potential as Vsc = Vps /0.215 ≈ 4.65 Vps

Agrees well with factor ~5 derived from comparisons of LP to ELS data



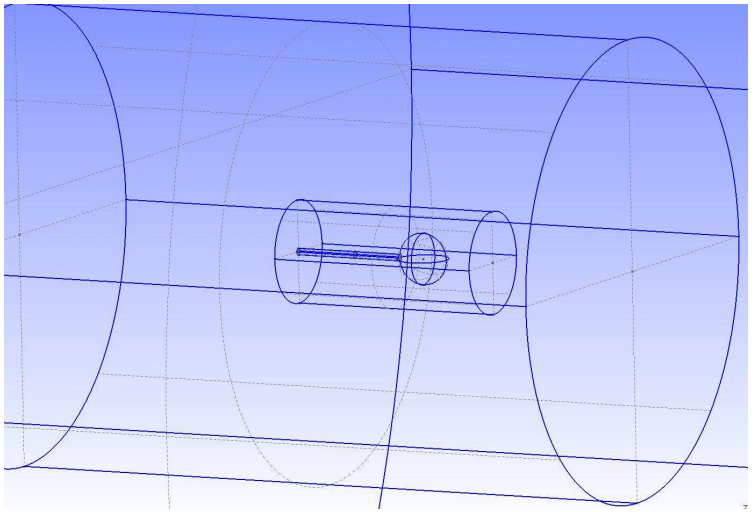
Note: boom but not probe included in the simulation. The potential plotted is the potential at the position where the probe should have been.

Langmuir probe simulations

- Intro
- SPIS
- Cassini results
- **LP results**
- Conclusions

• Two different cases;
- one in OML, where rp<<□D :
ne=1 cm-3, Te= 1 eV. (□D=7.43 m)

- one in between OML and SL:
ne=1,000 cm-3, Te= 0.05 eV.
(□D=5.3 cm)



The Langmuir probe with sphere and stub. Different size cylinders to optimize the 3D meshing of the simulation volume.

For each of these two cases a simulation without the stub present was also performed.

The Langmuir probe theory

- Intro
- SPIS
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- Orbit motion limited, OML, where rp << □D
- Sheath limited regime, SL, where rp >> □D

- For the case in between a model of the sheath is required. The model used is the one published by Walker, 1964.

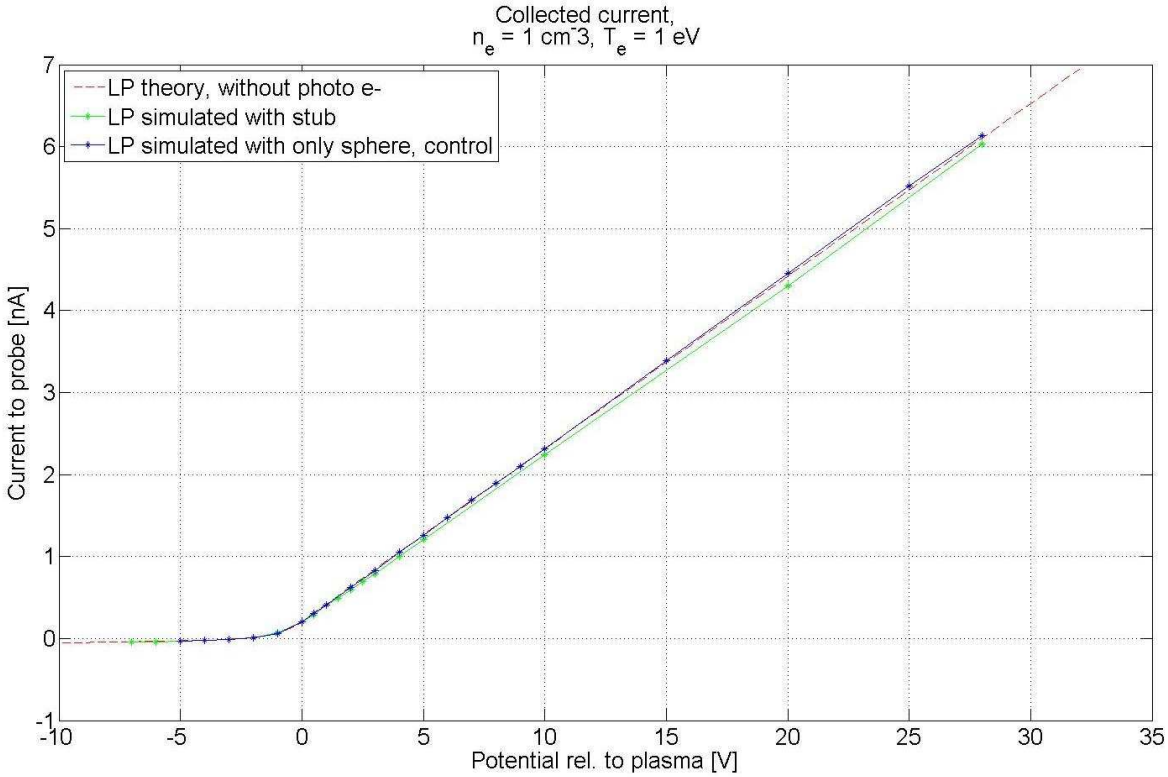
Results of OML case

- Intro
- SPIS
- Cassini results
- **LP results**
- Conclusions

• The collected current to the probe in the simulations with the stub is slightly lower (4%) than when the stub is absent.

• Ip Ap, => we could expect 1% decrease with the stub due to the interface.

•Hence, the stub “steals” some electrons that should otherwise have hit the probe.



The simulated sweep for the Langmuir probe with (green) and without the stub (blue). The OML predicted curve dashed in red.
Each ’*’ represents one simulation.

Results of case in between OML and SL

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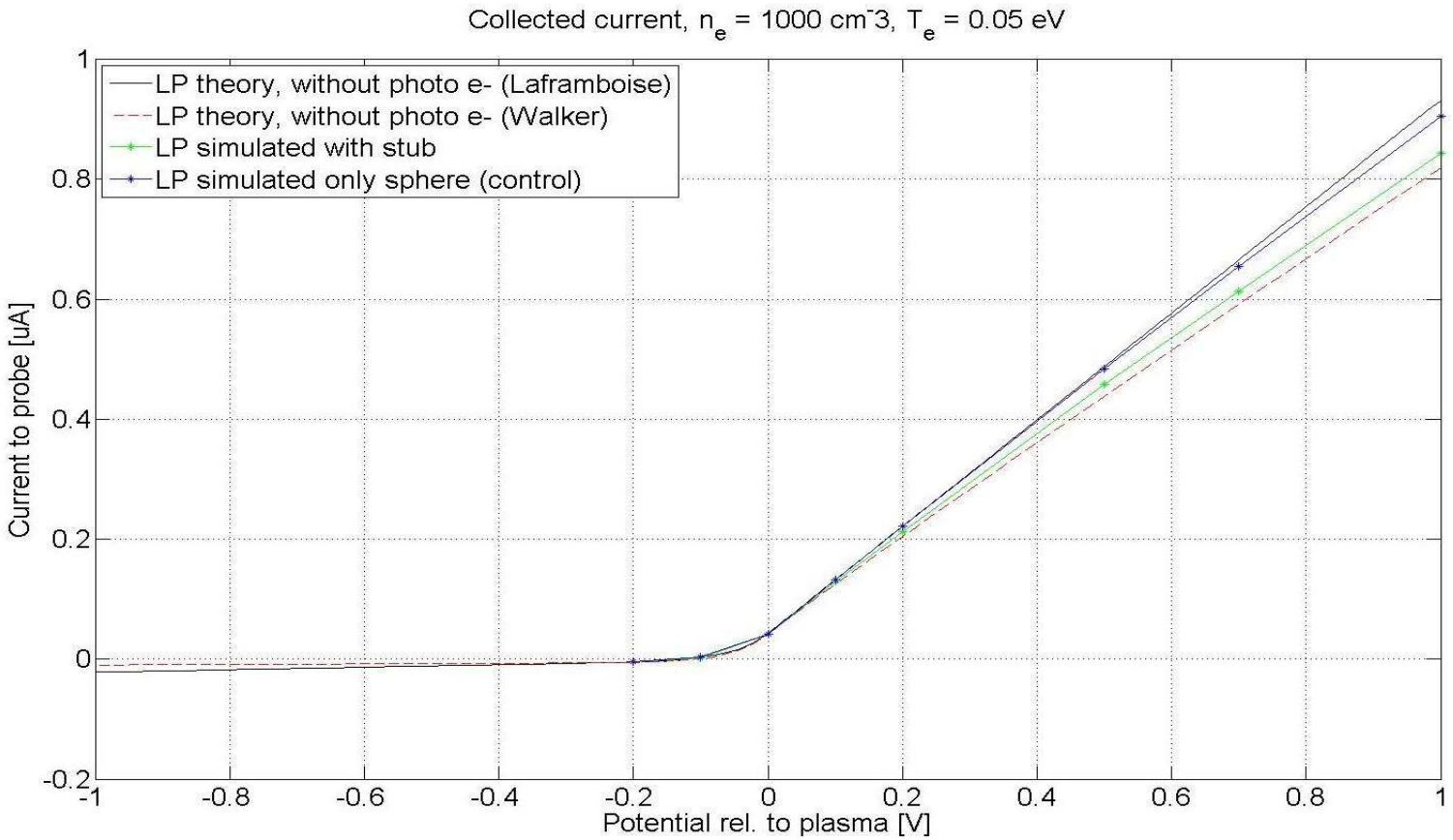

The one without the stub collects far more than the Walker model states and agrees well with the work by Laframboise. About 10% current reduction when stub is attached.

Results of case in between OML and SL

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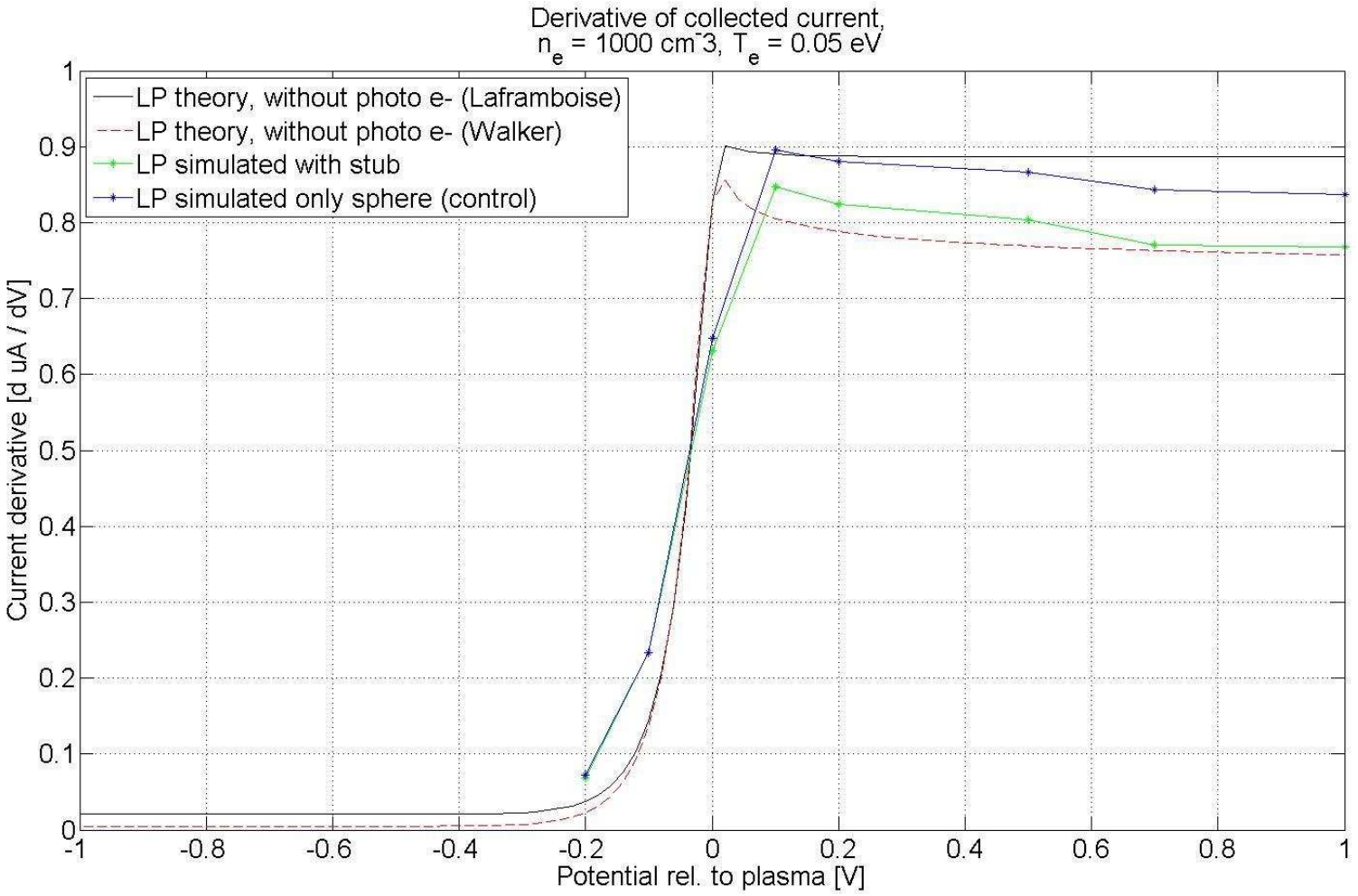

Sheath around the Langmuir probe

- Intro
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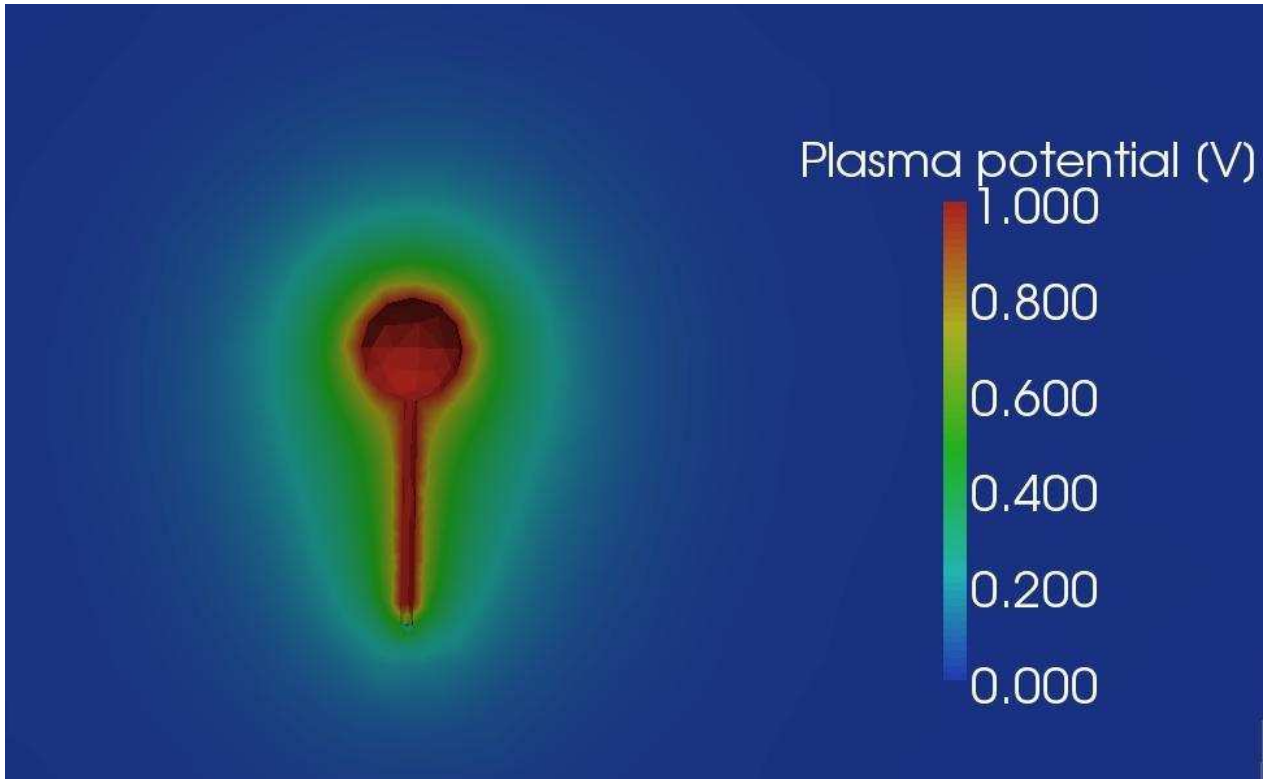

Showing the plasma potential around the Langmuir probe with its stub present for a plasma with ne = 1’000 cm-3 and Te = 0.05 eV.

Conclusions

- Intro
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- LP results
- **Conclusions**

- Walker analytical model needs some improvements.
- The probe current when the stub is present is lower than without the stub. (worse with shorter Debye length)
- 75-80% of Vs/c remains at the probe position for long Debye lengths.
  - Factor ~5 should be used for calculating s/c potential from probe-to-s/c potential.

Outlook / Problems

- Intro
- SPIS
- Cassini results
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- **Conclusions**

- Future work may include:
  - Moving plasma with respect to the spacecraft (and/or probe).
  - Photoelectrons, SPIS v3.7rc09 have some difficulties with shadows.
    - Model of the probe and stub ready for this, only a small modification in SPIS is needed. (material properties)
    - Cassini model would need bigger modifications. (shadows on a curved surface)
  - To fully simulate s/c influence on LP, SPIS must include e.g backtracking possibility to probe to improve statistics

Questions?