SPINE XIX

Cassini Langmuir probe measurements

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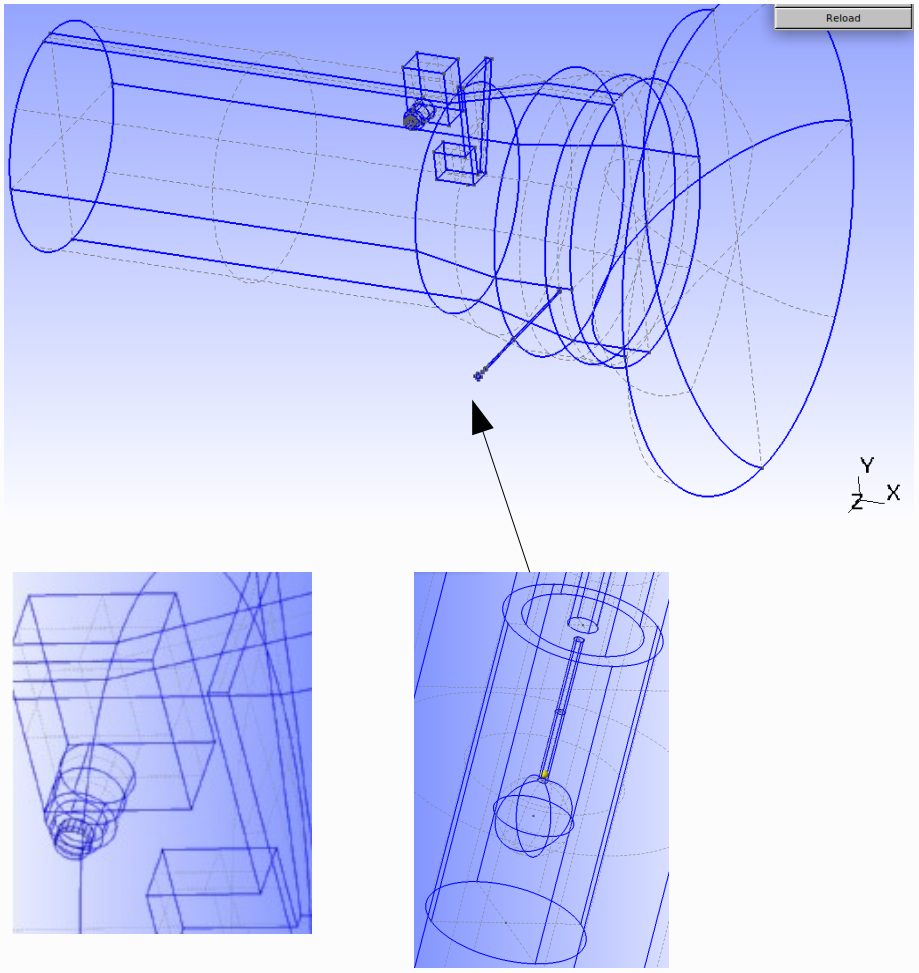
Presentation overview

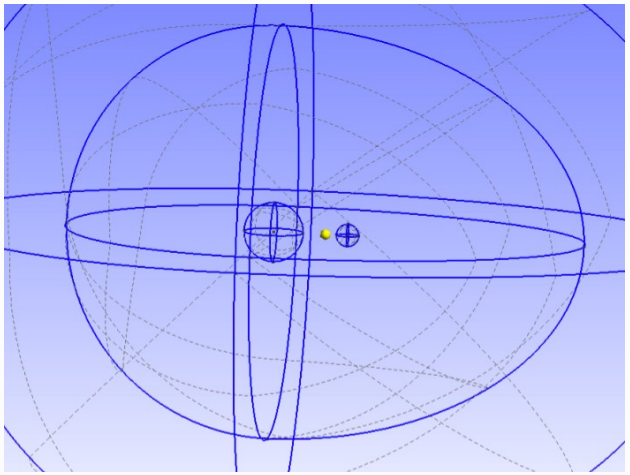
- Cassini overview
- Two sphere simplified case
- Cassini VC12-1, negative s/c potential
- Cassini VC12-2, positive s/c potential
- Conclusions

Cassini overview



- Cassini orbiting Saturn since 2004.
- S/C approximately cylindrical, 6 m long and 4 m in diameter.
- RWPS-LP sphere is 5 cm in diameter and attached to a 1.5 m boom.
- LP is swept ±32V w.r.t. s/c, and OML-based theory used for analysis of data (I-V curves).
  - Not possible to reproduce accurate I-V curves so close to a large s/c in SPIS until now with SPIS-SCI.
  - OML assumes only the LP sphere is present, and possibly a correction factor for the measured s/c potential.
- Cassini CAPS-ELS, electron detector.
  - Rotates ±104° at 1°/s and measures a spectrum of electrons from 0.56 eV to 26 keV.
  - Modeled here with a fixed angle.

Two spheres simplification

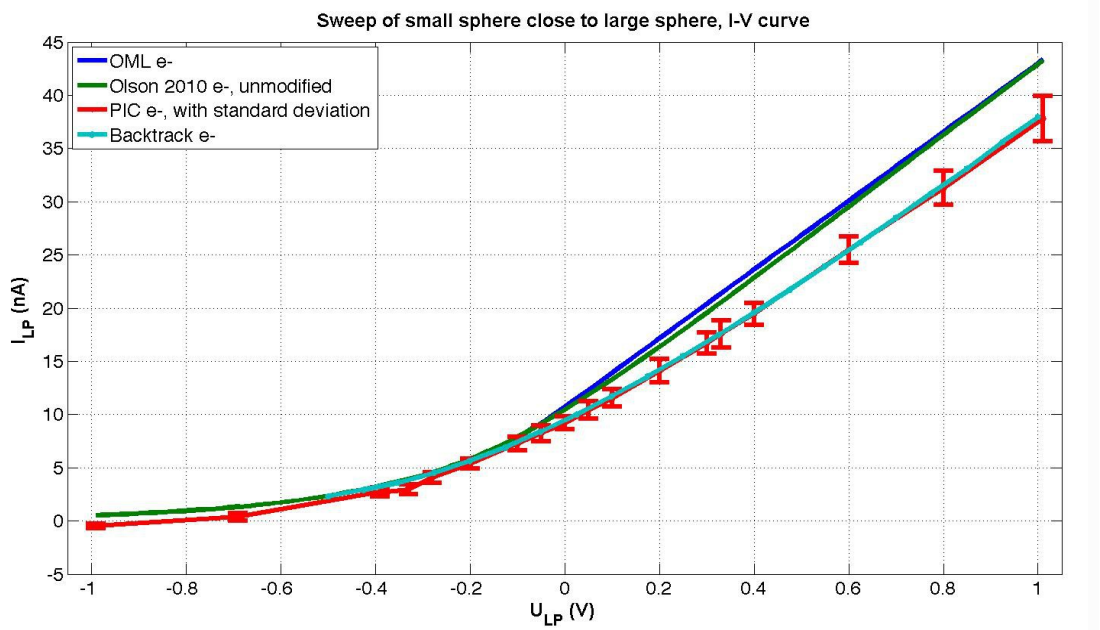


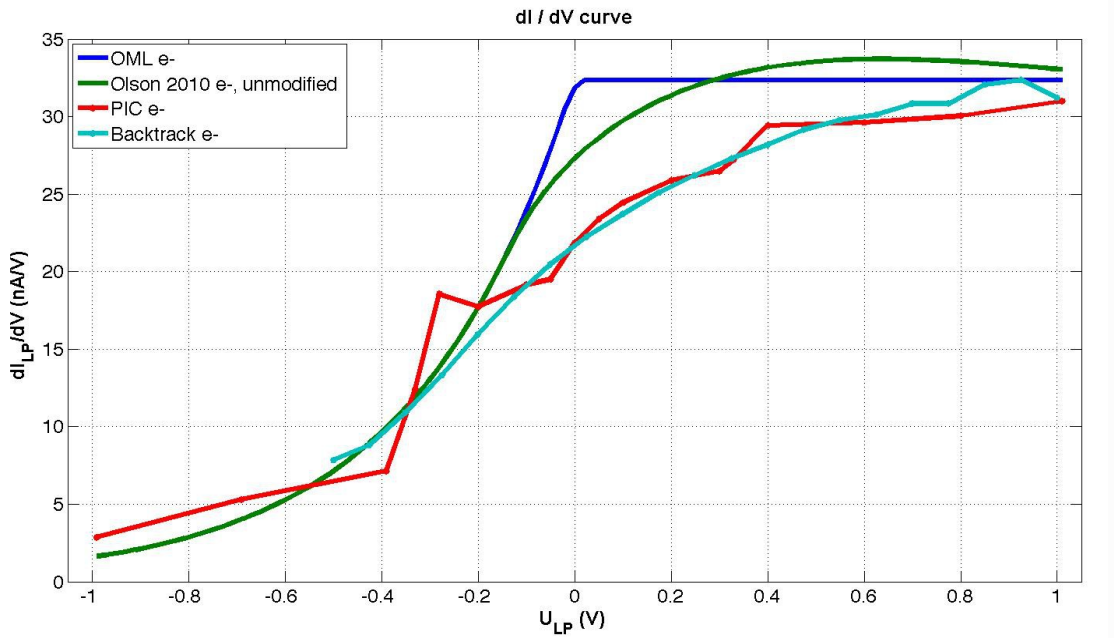
- Olson et al., 2010
  - Current reduced due to energetic exclusion close to repulsive s/c.
  - Approximate theoretical model
  - Can now be compared to simulations

R_sc	0.4 m	U_sc (fixed)	-1 V (w.r.t. ∞)	cl_lp	0.03
r_lp	0.15 m	U_lp	-1 to +1 V (w.r.t. ∞)	cl_sc	0.08
Separation (centre to centre)	1.0 m	Ion flow	0 m/s	cl_boundary	0.56
Density (ne=ni)	2.452 cm^-3	Boundary	6.3 m	# tetrahedra	185 376
Temperature (Te=Ti)	0.33 eV	Secondary emission	All off	LP max energy	3.3 eV
Debye length	2.73 m	Simulation duration	0.055 s	LP dt	1 ms

Two sphere, results from SPIS

- As expected, a lower current than unperturbed OML is measured.
- PIC results from SPISv4.3 with standard deviation as error bars, backtrack from new SPIS-SCI.
  - If OML is applied on such a smaller sphere the derived density would be too low.
  - Olson et al., 2010, similar in shape but not sufficiently low.
- Using a single sphere simulation for a similar plasma the SPIS-SCI LP instrument measured a factor 0.974 times the expected OML current for similar settings (cl_lp, LP maximum energy etc). The decrease caused by the second sphere is much larger than 2.6%.





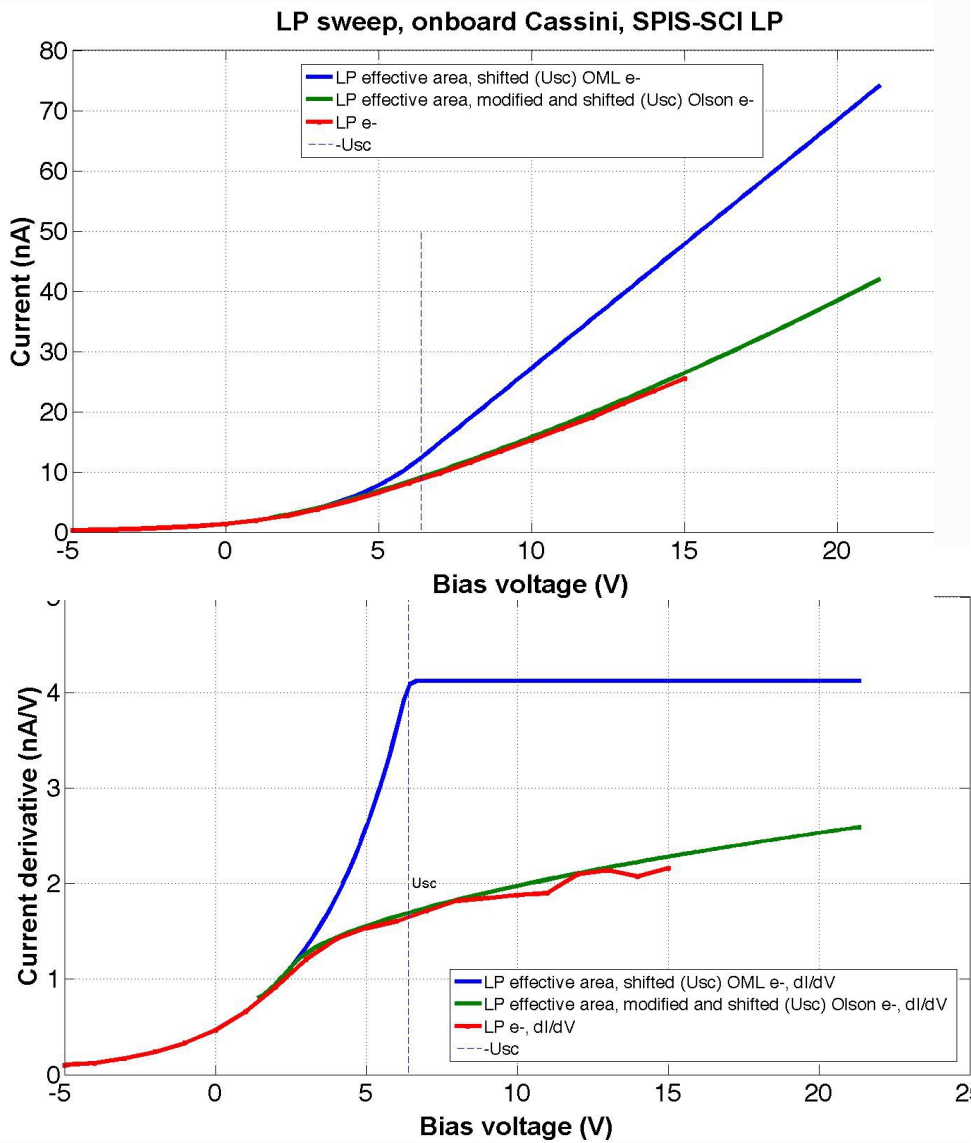
Cassini VC12-1, settings

Density (ni=ne)	35 cm^-3	C_sat	1 μF	LP max Energy	40 eV
Temperature (Ti=Te)	3 eV	Simulation duration	5 s	LP dt	1 ms
Debye length	2.18 m	cl_lp	0.005 m	LP bias	-10 to +10 V, w.r.t. S/c
Ion flow (-z)	17 000 m/s	cl_sc	0.2 m	Usc	≈ -6.4V
Photo Emission	3 (PIC)	cl_boundary	0.9 m	Boundary	7.5 m
Sun {x,y,z}	{0.3425, -0.914353, 0.215959}	#tetrahedra	178 500	Mach number	0.71

- Olson, 2010, modified:
  - R_sc = 3 m (instead of 8 m).
  - U_min was extracted from SPIS in one sweep and a fit was made by modifying boom length.
  - Boom length = 0.62 m (instead of 1.5 m).
    - Justification: Olson does not account for boom effects. Nilsson, 2009, showed the potential is carried outwards by boom and in the end shortening the effective boom length. (No geometrical exclusions due to spacecraft in Olsons approach).

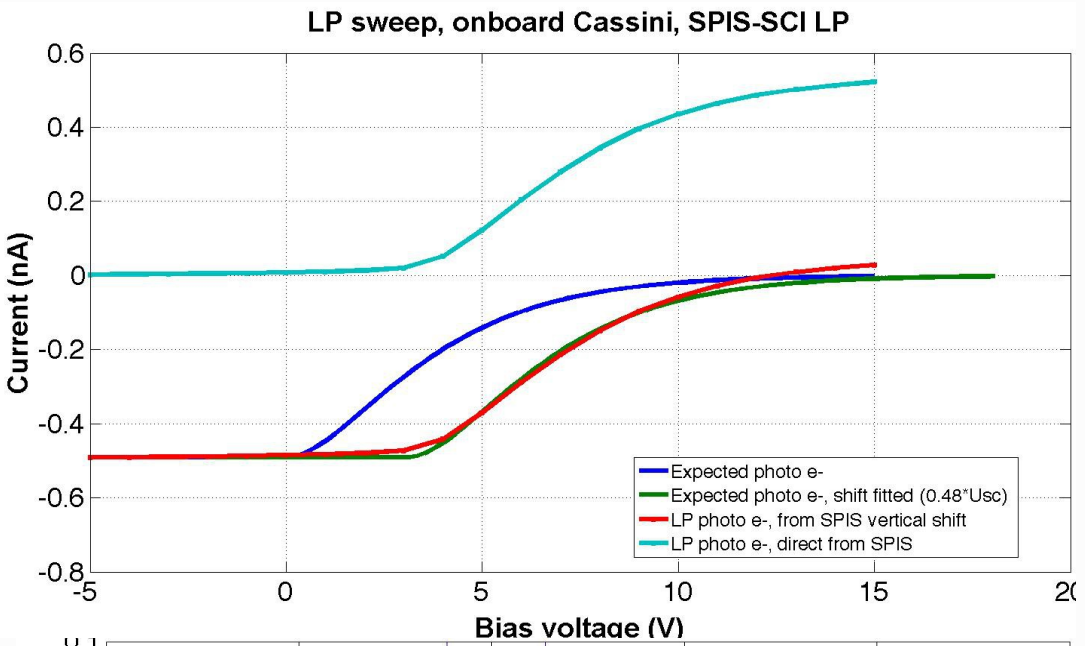
Cassini VC12-1, LP results

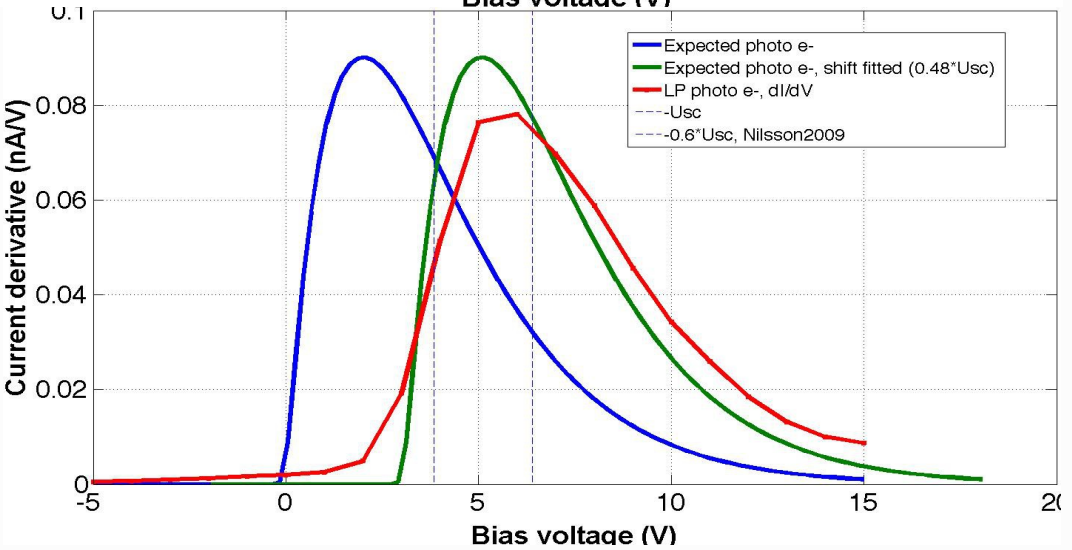
- Measured current of plasma e- is decreased.
- Agreement to Olson 2010 only after heavy parameter tuning.
- As voltage increases, the Olson model approaches OML quicker than SPIS-SCI results.



Cassini VC12-1, LP results cont.

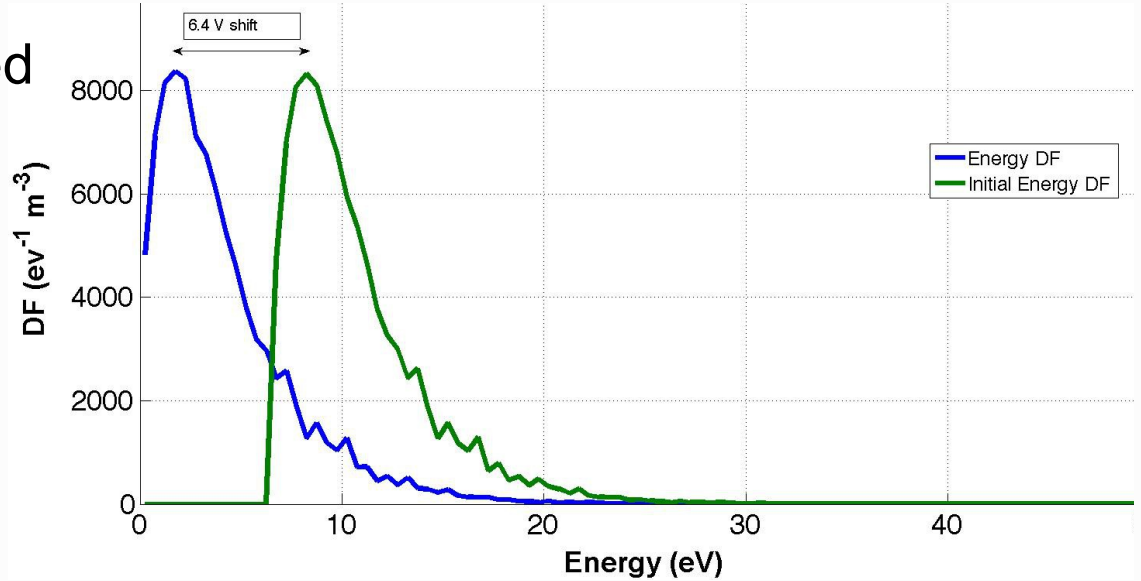
- Measured current of photoelectrons show an increase (at bias>10V) beyond what the sphere itself can generate.
  - SPIS-SCI shows collected photoelectron current depends on s/c pointing. Analysis of data show a strong correlation between measured current and orientation towards the sun.
  - Direct output from SPIS have to be shifted vertically first as only net current is of interest.





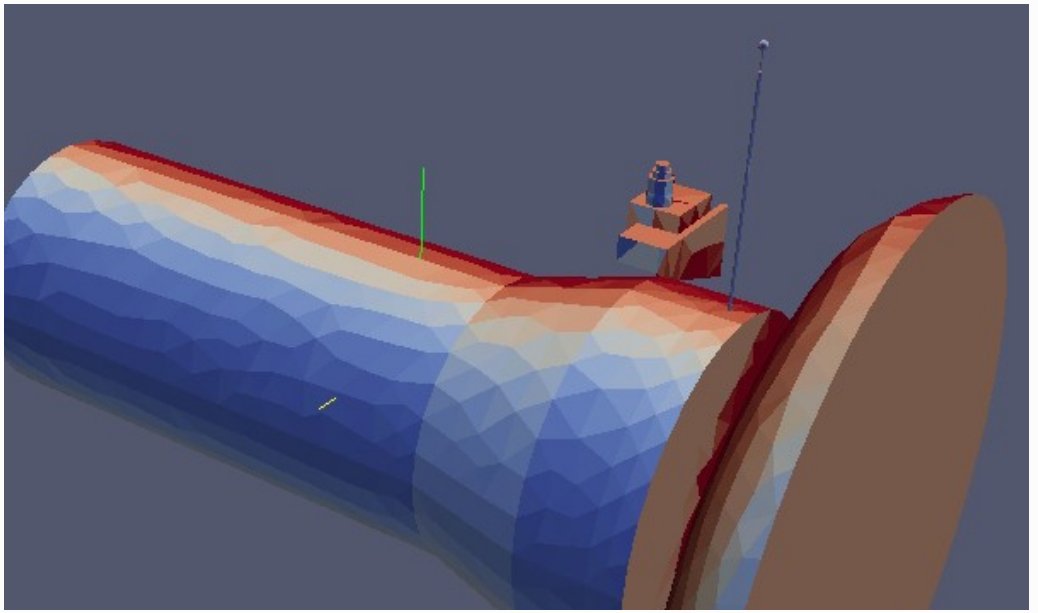
Cassini VC12-1, CAPS-ELS results

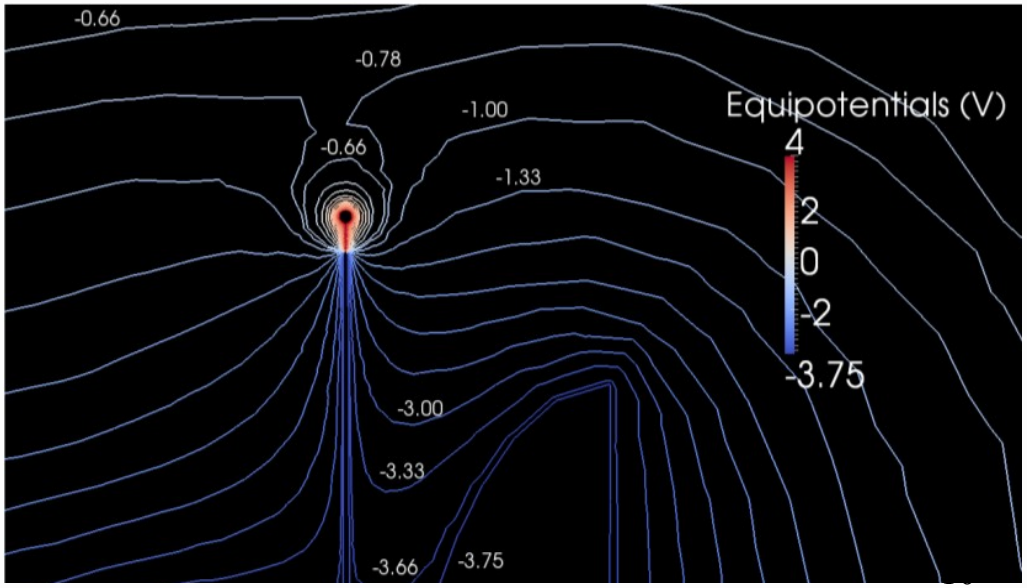
- In reality the CAPS-ELS rotates (±104 degrees) and measures up to 26 keV particles. Here only fixed orientation and for a single Maxwellian electron population with T_e = 2eV.
- A shift of 6.4V is clearly visible, corresponding to the s/c charged voltage.



Cassini, surroundings

- Photoemission on s/c surface clearly show shading effects and possible sources of photoelectrons measured by Langmuir Probe and ELS.
  - Shading is a new feature in SPIS-SCI
- A very similar plasma potential structure as used by Olson, 2010, is visible.
  - The potential structure shown here was created from a different simulation, not listed here. (vtk files are not generated for each bias by the LangmuirProbe instrument in SPIS-SCI).



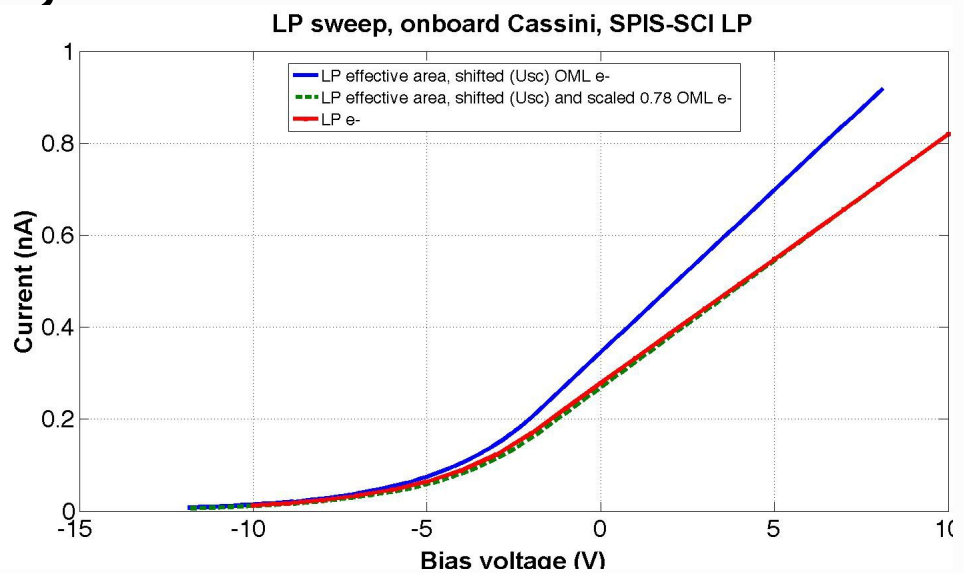


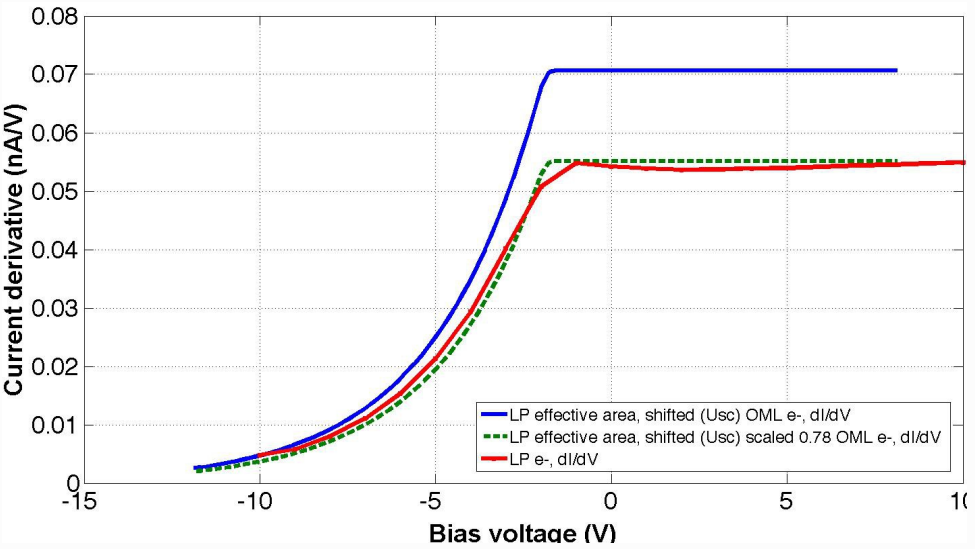
Cassini VC12-2, settings

Density (ni=ne)	0.6 cm^-3	C_sat	1 μF	LP max Energy	40 eV
Temperature (Ti=Te)	3 eV	Simulation duration	5 s	LP dt	1 ms
Debye length	16.6 m	cl_lp	0.005 m	LP bias	-10 to +10 V, w.r.t. S/c
Ion flow (-z)	0 m/s	cl_sc	0.2 m	Usc	≈ +1.8V
PhotoEmission	3 (PIC)	cl_boundary	8.0 m	Boundary	28 m
Sun {x,y,z }	{-0.883341, -0.067416, 0.463858}	#tetrahedra	110 000		

Cassini VC12-2, LP results

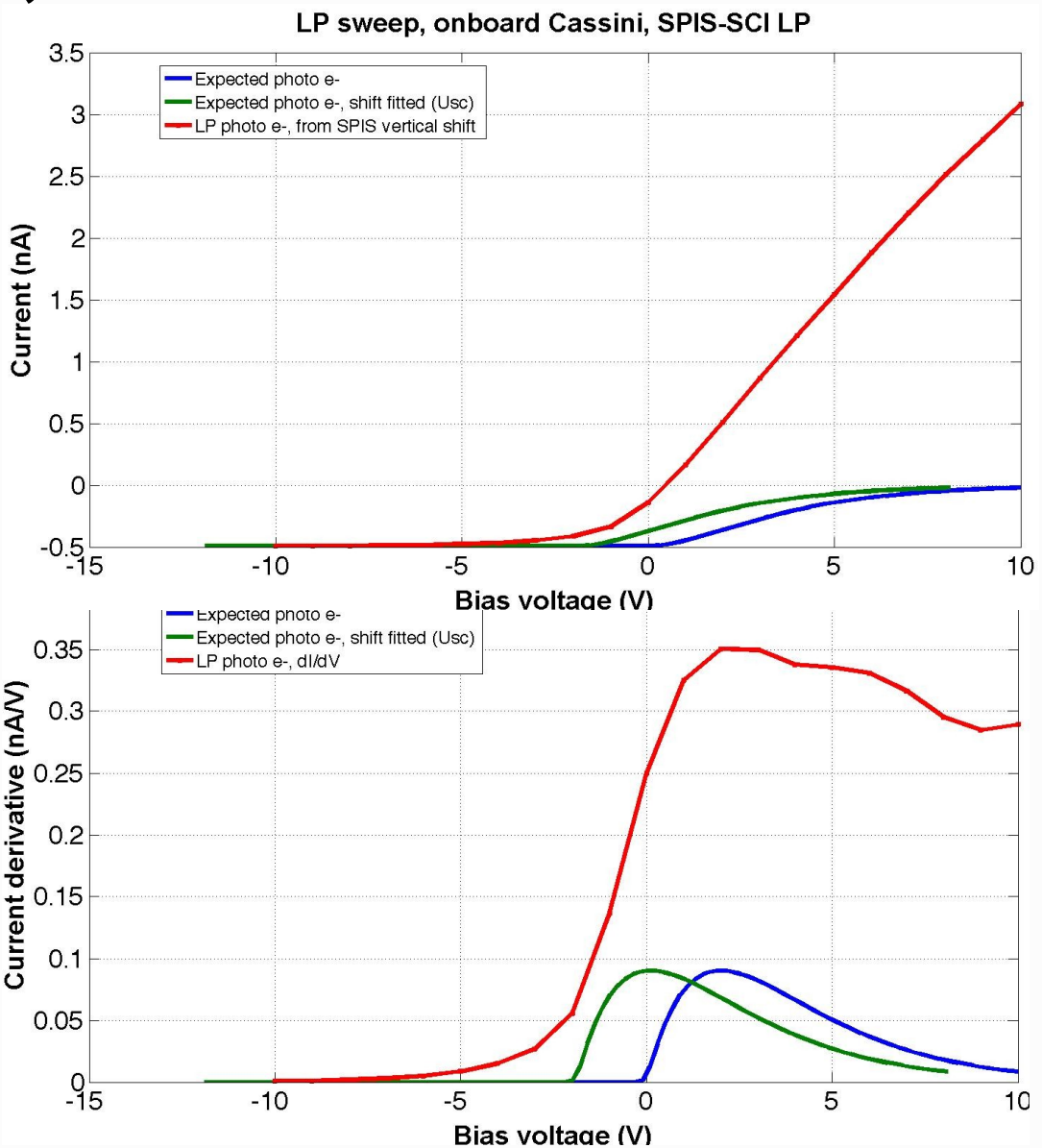
- A decreased current of plasma electrons is also measured in this case.
- SPIS-SCI results suggests:
  - If sweeps like this are measured and analyzed with OML a too low density would be inferred. (Green dashed line)
  - Compared with an unperturbed density at infinity, in this particular case 0.78*n_e.
  - This effect is not only present on repulsive s/c potentials but as seen here also when it is attractive on the particle population measured.





Cassini VC12-2, LP results cont.

- Photoelectron current is in this case significantly increased beyond particles from only the LP sphere.
- SPIS-SCI shows collected photoelectron current depends on s/c pointing. Analysis of data show a strong correlation between measured current and orientation towards the sun.



Conclusion

- With SPIS-SCI it is now possible to analyze the direct influence of the s/c itself on measurements made by instruments, such as small Langmuir probes.
- The charged s/c has an influence on the total measured current beyond simply shifting the potential. This effect is not only present for repulsive s/c potential but also for attractive s/c potentials.
  - No reliable theory exists which takes into account both geometric and energetic exclusions for instruments mounted a distance away from the s/c body.
- Instruments such as CAPS-ELS will still require a lot of manual work in the geometry configuration if a full study of its field of view is to be undertaken with the help of SPIS-SCI.

Questions?