Validation and characterisation of the Sweeping Langmuir Probe (SLP) instrument for the PICASSO mission

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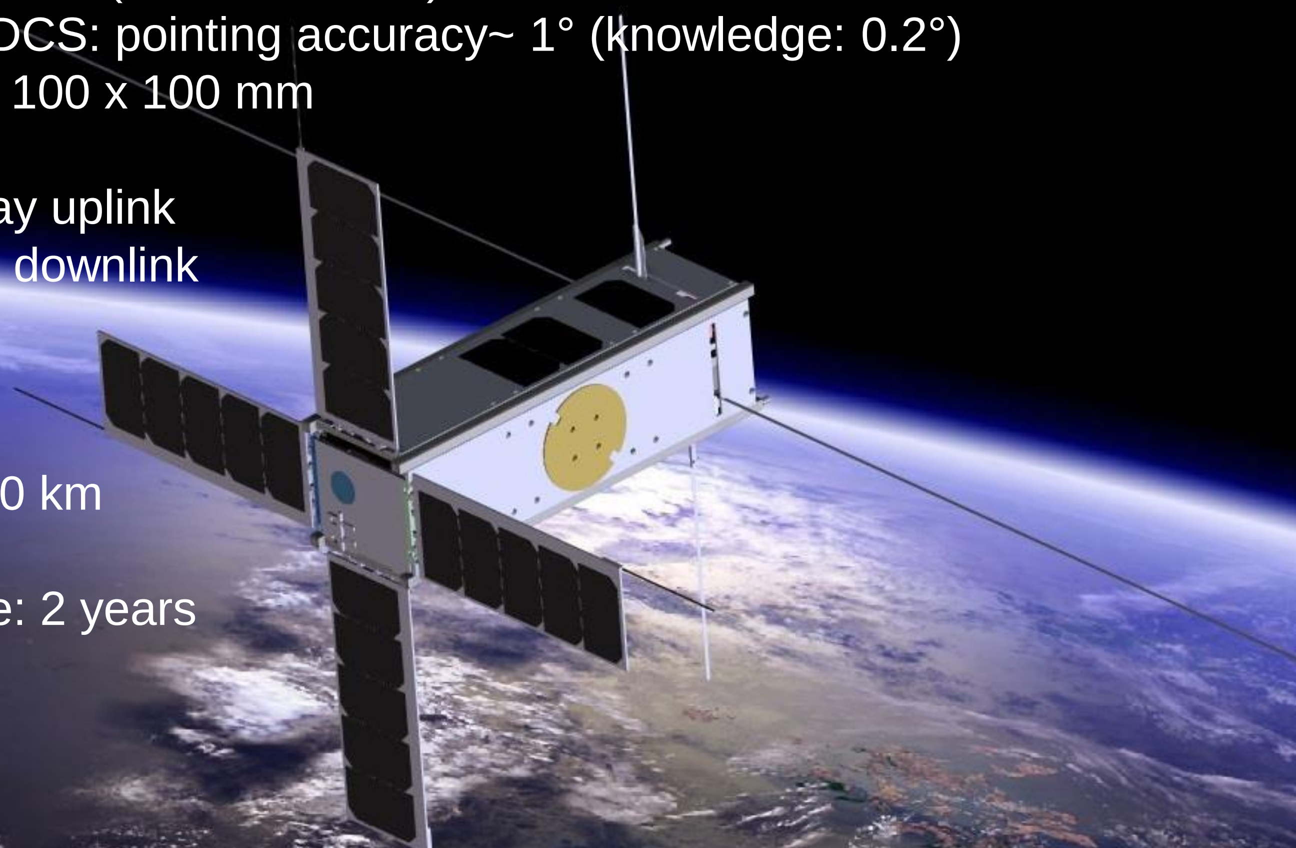
Outline

- PICASSO mission and platform
- SLP
- Measurement principle
- Nominal mode
- S/C charging
- Functional test in plasma chamber
- Conclusions

PICASSO mission and platform

PICASSO (PICo-satellite for Atmospheric and Space Science Observations)

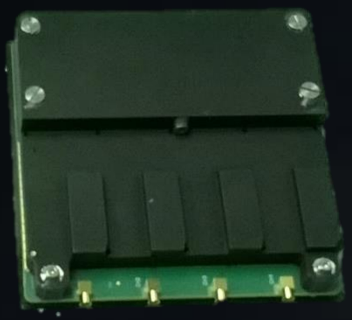
- Four deployable solar panels
- Power generation (ave.): 8,7W
- Two on-board computers (OBC and PLC)
- High performance ADCS: pointing accuracy~ 1° (knowledge: 0.2°)
- Dimensions: 340.5 x 100 x 100 mm
- Mass: 3,9 kg
- UHF/VHF: 400 kB/day uplink
- S-band: 100 MB/day downlink



Orbit: polar, altitude: 550 km
Launch: June 2020
Expected orbital lifetime: 2 years

SLP

SLP (Sweeping Langmuir Probe):
Four channel Langmuir probe instrument

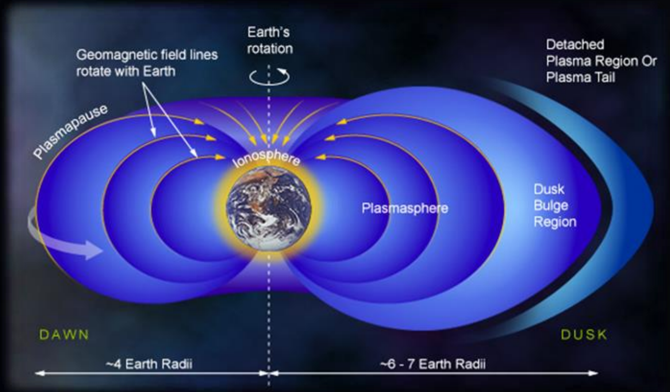


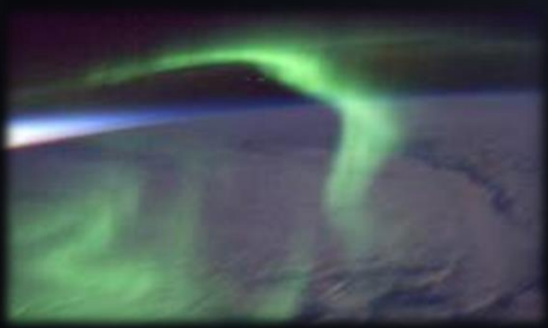
Scientific objectives

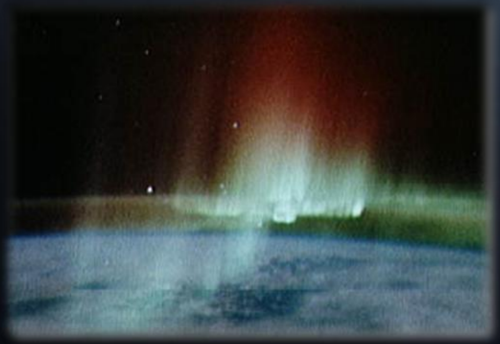
In-situ study of:

1. Ionosphere-plasmasphere coupling
2. Subauroral ionosphere and corresponding magnetospheric features
3. Aurora structures
4. Turbulence (multi-scale behavior, spectral properties)

Measurements:
Plasma density, electron temperature and spacecraft potential



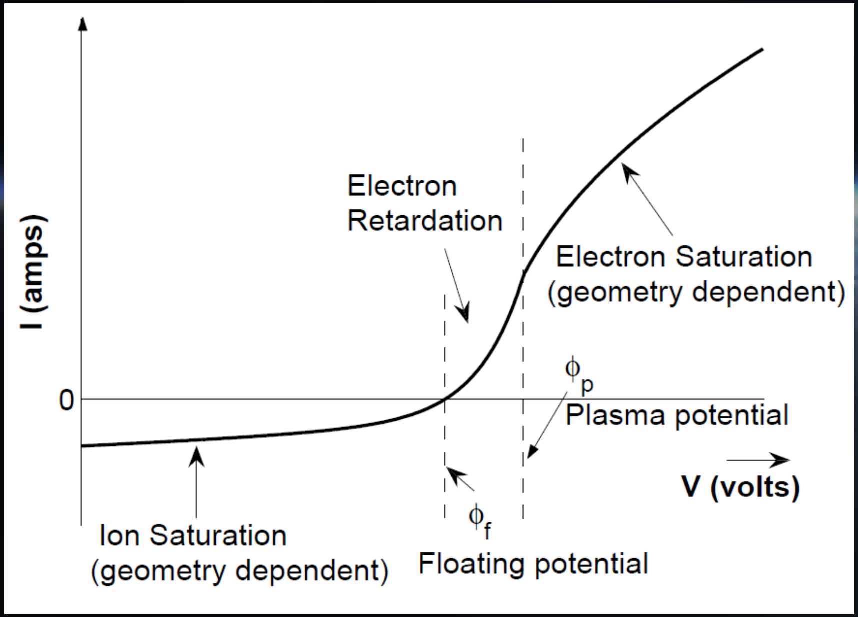




SLP: Measurement principle

Based on conventional Langmuir probe theory

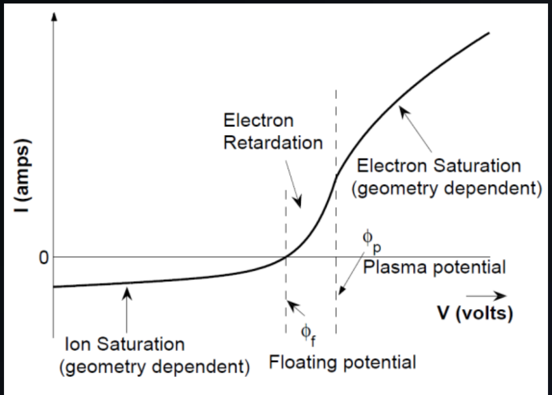
Sweep potential of a probe wrt plasma potential and measure current from probe => current-voltage characteristic
=> electron density and temperature, ion density and S/C potential



3 regions

- Ni derived from ion saturation region
- Electron T° and S/C potential retrieved from electron retardation region
- Electron density derived from electron saturation region

SLP: Nominal mode



- Sweep: -5 V to +13 V wrt S/C potential
- Sampling freq.: 10 KHz
- Limited downlink bandwidth

  => not possible to perform linear sweeps with very fine steps in nominal mode

- 3 regions measured with different step sizes
- Ion and e- saturation regions: large voltage step size (> 1 V)
- Electron retardation region: smaller step size, which depends on e- T°:

region measured with 30 steps, span is adapted as a function of the temperature

On board, inflection point of the I-V curve, which separates e- retardation and e- sat. regions (the plasma potential), determined after each sweep and used to compute the span of the e- retardation region of next sweep.

Step size ranges from ~ 10 mV to 150 mV for e- T° of 600 K and 10.000 K

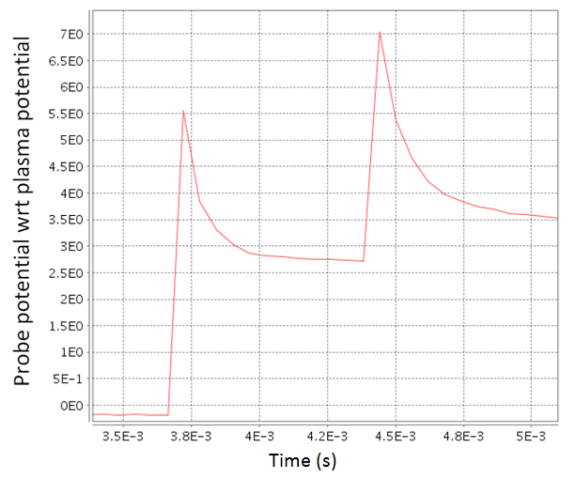
S/C charging

Problem of using LP on board Pico-Satellite:

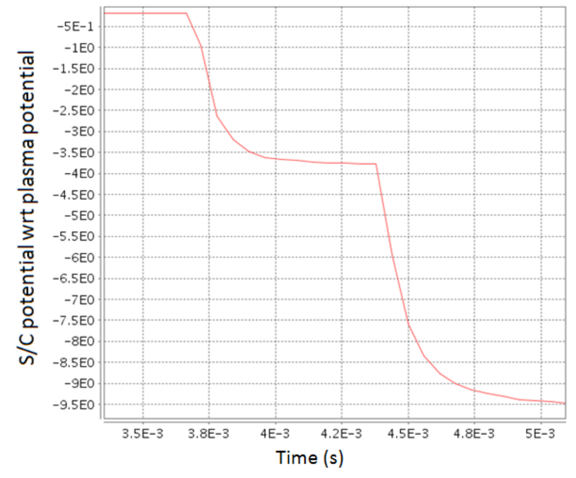
Limited conducting area of the S/C with respect to the area of the probe

=> Spacecraft charging (e- saturation region)
  =>Drift of the instrument's electrical ground during the measurement
  =>Unusable data

Risk:
Too low S/C potential: unable to sweep appropriate potentials (e- saturation region)



Probe potential wrt plasma potential when 6 V and 13 V steps applied to the probe
Ne = $10^{11}/m^3$, e- T°= 600 K



S/C potential wrt plasma potential when 6 V and 13 V steps applied to the probe
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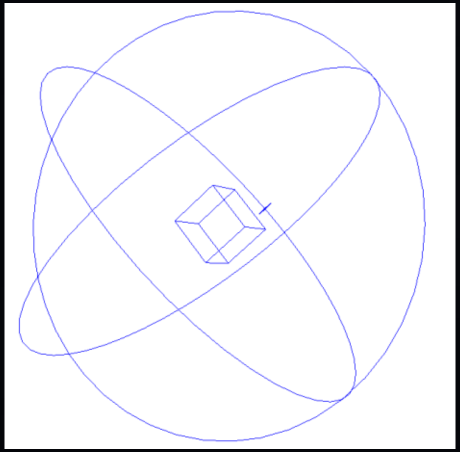
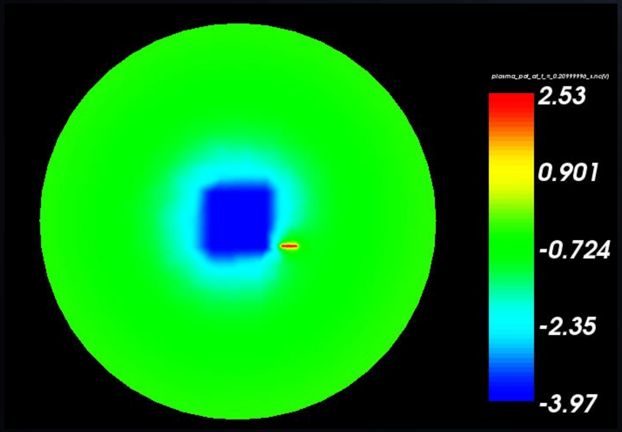




Particle-in-cell (PIC) modelling and simulations (SPIS). Applied Bias: 6.5 V

S/C charging

Proposed solution

- Increase conducting surface of the S/C (at least 200 cm^2 on all sides of the S/C, incl. solar panels)
- Measure the floating potential of one probe while measuring the I-V curve with another probe
  => The 2 probes that are in the same environment (light/shadow, wake)

Advantages:
Robust: no filament
No risk of electron collection from e-gun
Gives insight about S/C charging

Disadvantage:
Limited range in e- saturation region in very high density plasma

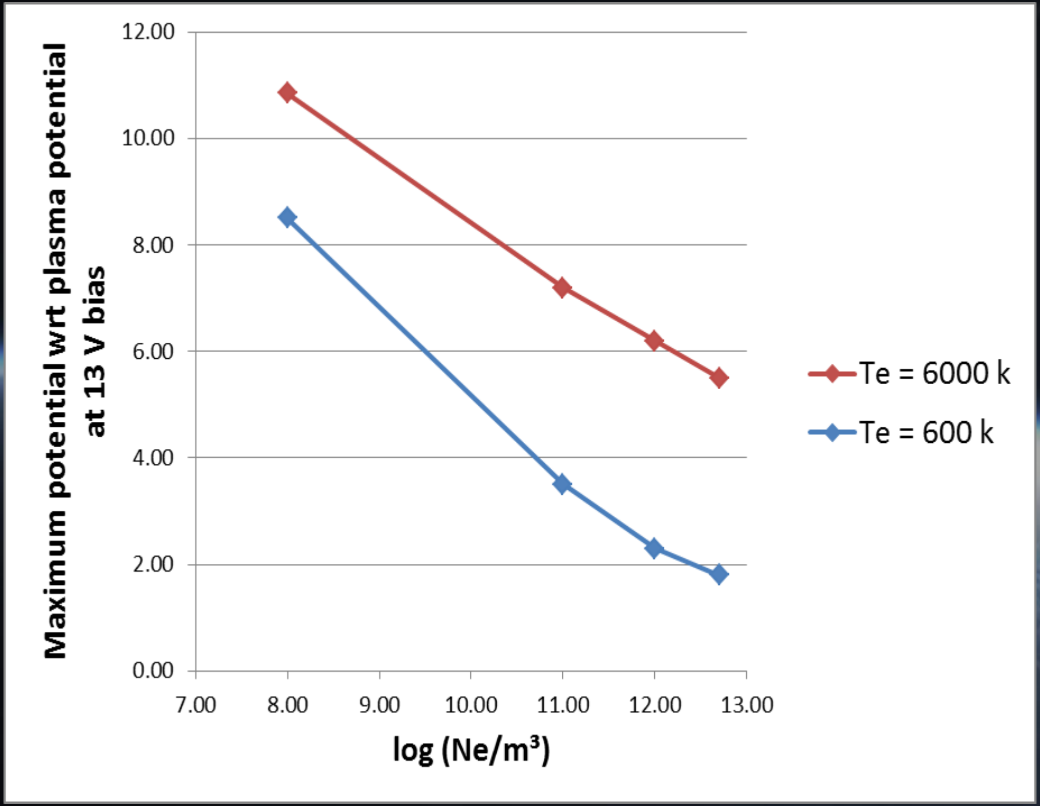
S/C charging

Maximum probe potential with respect to plasma potential

SPIS simulations for extreme cases

Most unfavourable case:
- High Ne
- Low Te
- Eclipse (no photoelectron)

Floating potential:
-0.16 V for Te = 600 K
-1.9 V for Te = 6000 K

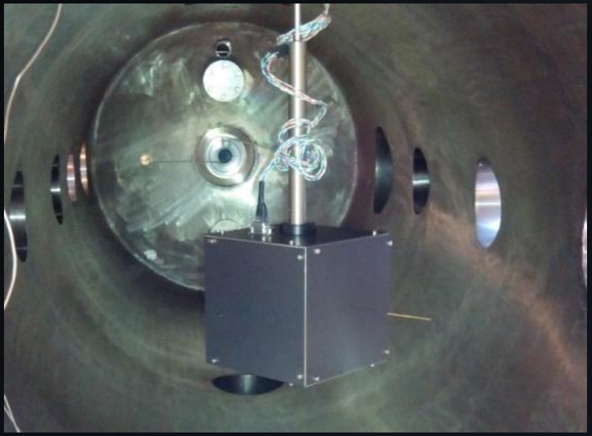


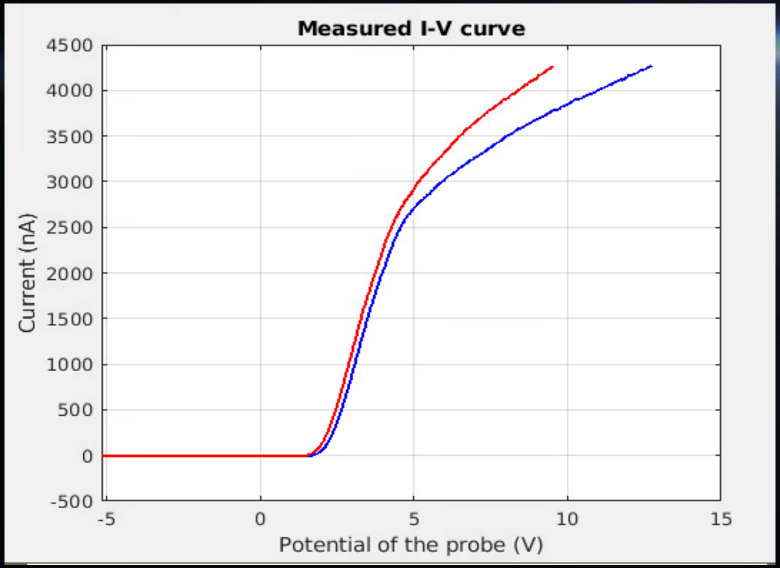
=> Always possible to reach electron saturation region

Validation of the measurement principle

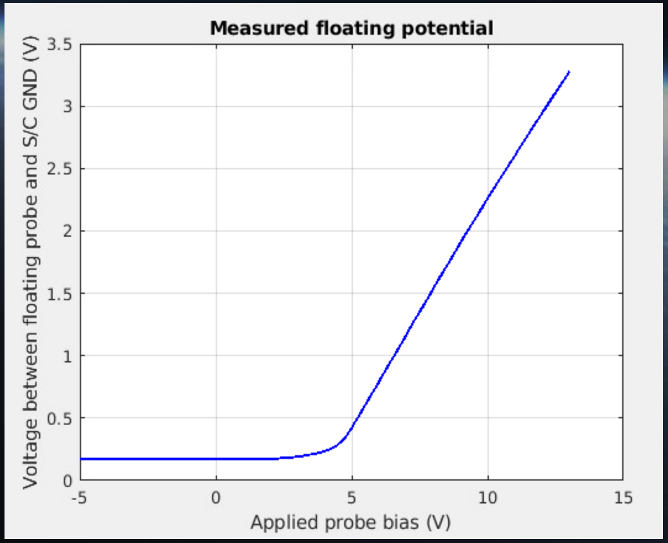
Test of electrically representative model of PICASSO in plasma chamber at ESA/ESTEC

When probe in electron saturation region: S/C potential drops and voltage between floating probe and S/C GND increases
=> In line with simulation results





Measured current as a function of probe potential
1) with respect to the S/C potential (blue),
2) with respect to the floating potential (red).



Measured potential of the floating probe (with respect to the spacecraft GND) as a function of the applied bias.

Test results

Limitations of the test:

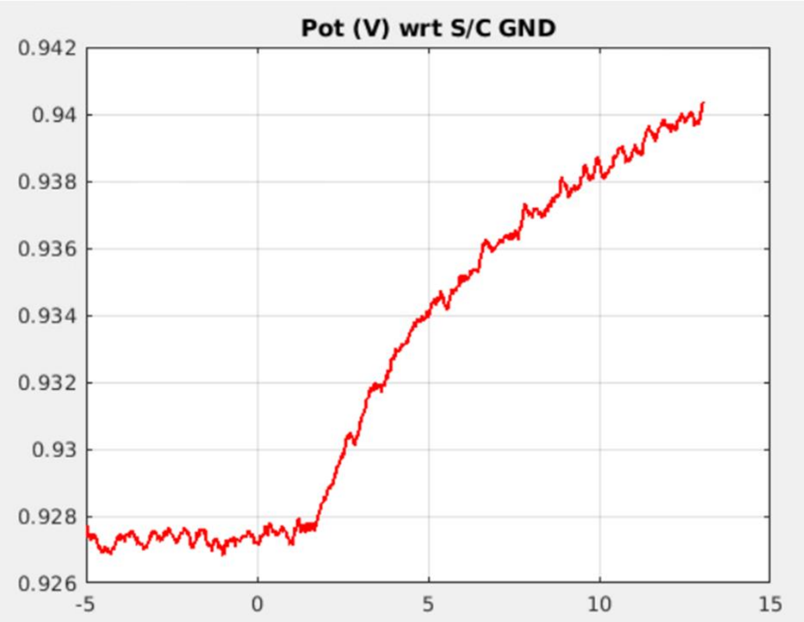
- When instrument grounded => difference of potential between the floating probe and the S/C GND.

⇒ The plasma is slightly changing due to the collection of charges during the sweep (possibly due to limited volume and plasma supply).

- No pure axial symmetry of the plasma inside the chamber, possibly due to the geomagnetic field.

- The floating probe can be in the sheath of the S/C mock-up.

⇒ Altered floating potential measurement



Measured potential (with respect to S/C GND) of the floating probe as a function of the applied bias, when the instrument is grounded.

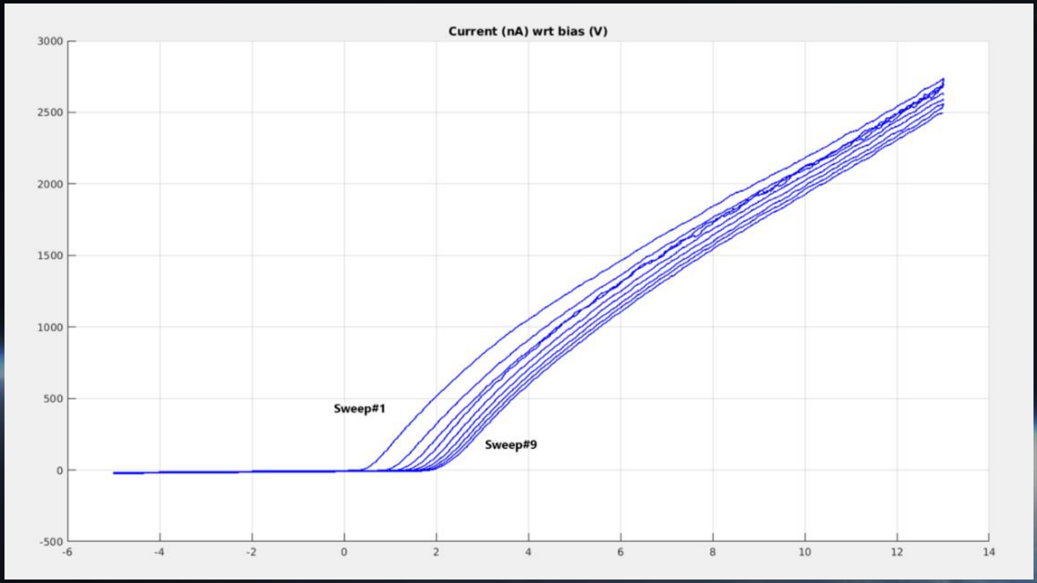
Test results

- At the beginning of a series of sweeps, apparent temperature seems to increase (shift of the I-V curve), even when instrument grounded.

⇒ Most probable reason: contamination of the probes under test.

- The Orbital Motion Limited (OML) theory cannot be applied directly since the length of the probe is not sufficiently long as compared to the Debye length.

⇒ The gamma coefficient, which defines the slope of the I-V curve in the electron saturation region is not equal to 0.5 (as assumed in OML theory) but must be computed for each sweep.



Measured current as a function of the applied bias for 9 consecutive sweeps.

Conclusions

- SLP developed at BIRA-IASB to monitor the upper ionosphere
- Scientific objectives:
    - ionosphere-plasmasphere coupling
    - subauroral ionosphere and corresponding magnetospheric features
    - auroral structures and polar caps
- I-V curves from SLP => Ne, Te, Ni and S/C potential
- Main issue of LP on nano-satellite: S/C charging
- Proposed solution: measure floating potential while performing sweeps
- PIC simulations performed to analyse and quantify S/C charging: SLP can operate even in most unfavourable conditions of the PICASSO mission
- SLP tested and measurement principle validated in plasma chamber
- OML theory cannot be applied directly