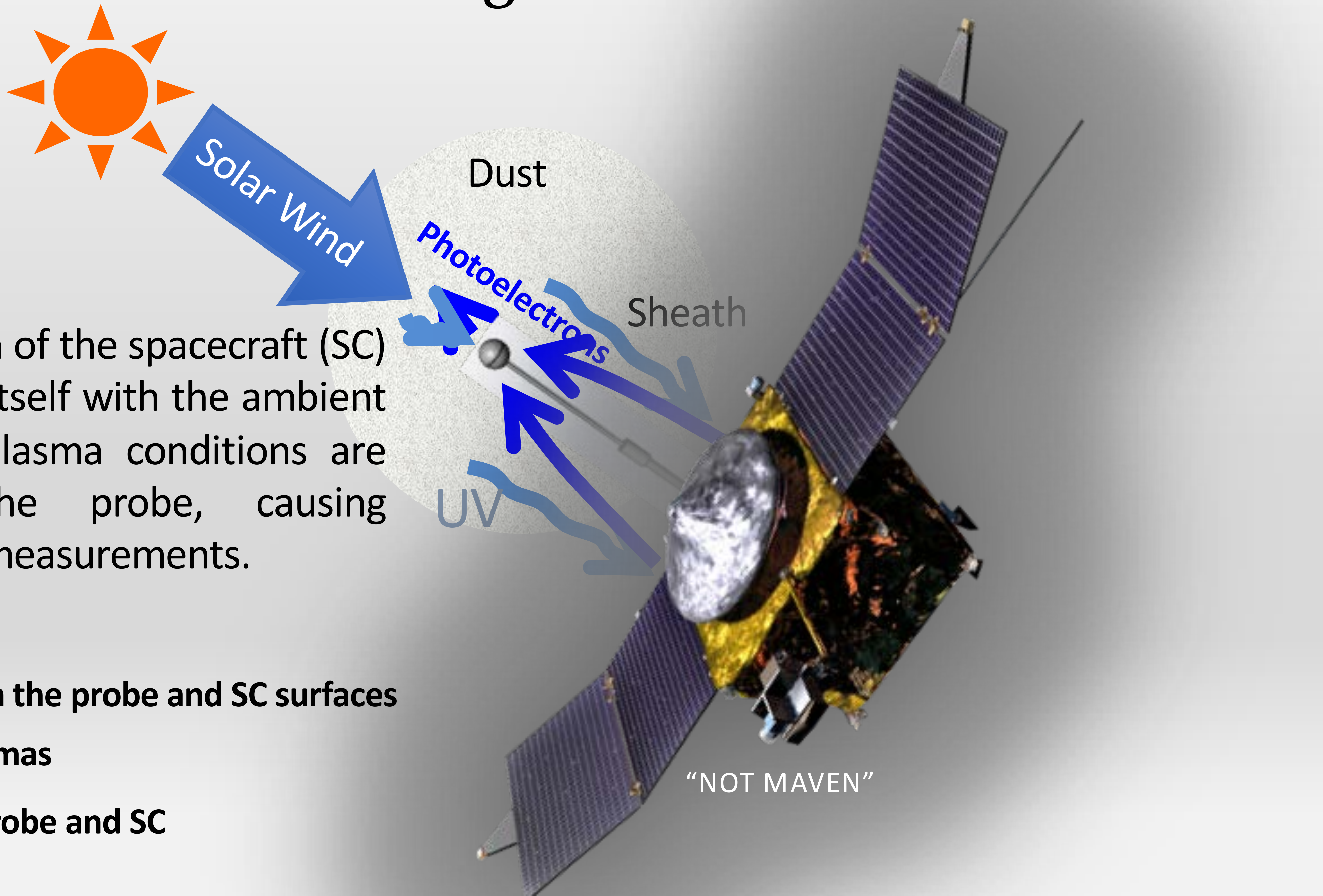
Development of A Double Hemispherical Probe (DHP) for Improved Space Plasma Measurements

X. Wang[1,2], J. I. Samaniego[1,2], H. –W. Hsu[1,2], M. Horányi[1,2], J.-E. Wahlund[3], R. E. Ergun[1], and E. A. Bering[4]

[1]Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, Boulder, Colorado 80303, USA
[2]NASA/SSERVI's Institute for Modeling Plasma, Atmospheres and Cosmic Dust (IMPACT), Boulder, Colorado 80303, USA
[3]Swedish Institute of Space Physics, Box 537, SE 751 21 Uppsala, Sweden
[4]Physics Department, University of Houston, Houston, Texas 77204, USA

The IPPW
June 11-15, 2018

Current In-situ Langmuir Probe Issues



Due to the interaction of the spacecraft (SC) and Langmuir probe itself with the ambient environment, local plasma conditions are created around the probe, causing interference with its measurements.

I. Probe in the SC sheath

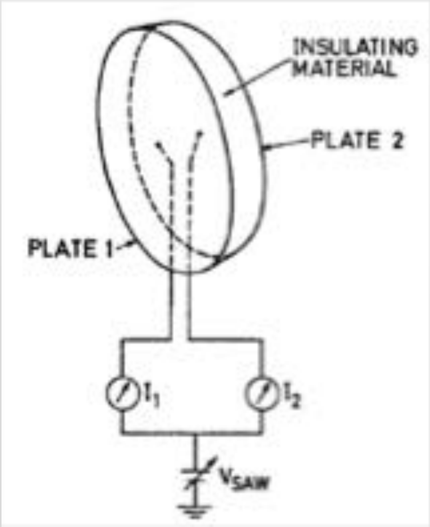
II. Electron emission from the probe and SC surfaces

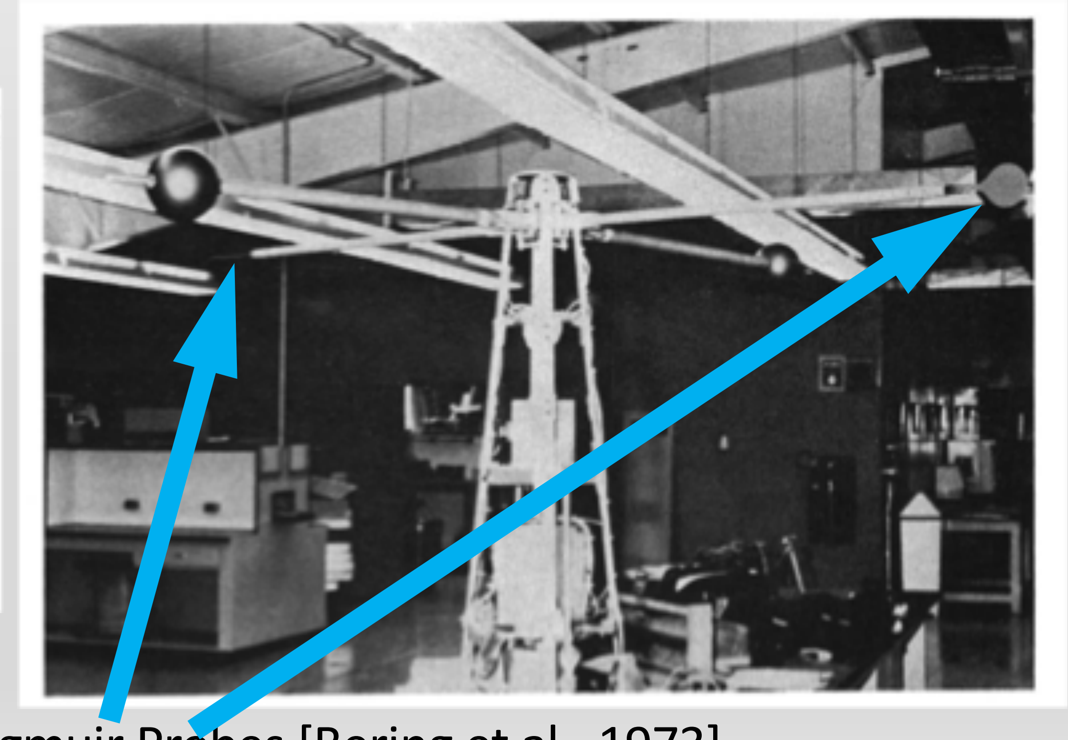
III. Probe in flowing plasmas

IV. Dust impact on the probe and SC

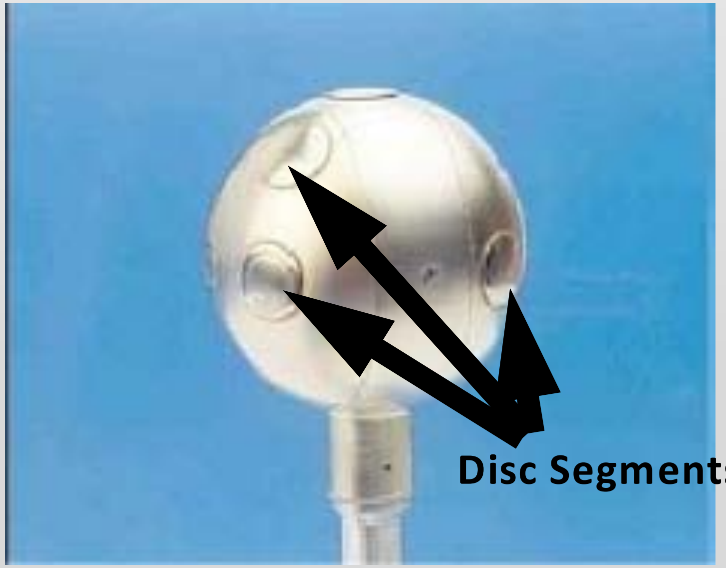
Directional Langmuir Probes

- These local plasmas are anisotropic and/or inhomogeneous.
- Directional probes are able to characterize their features.





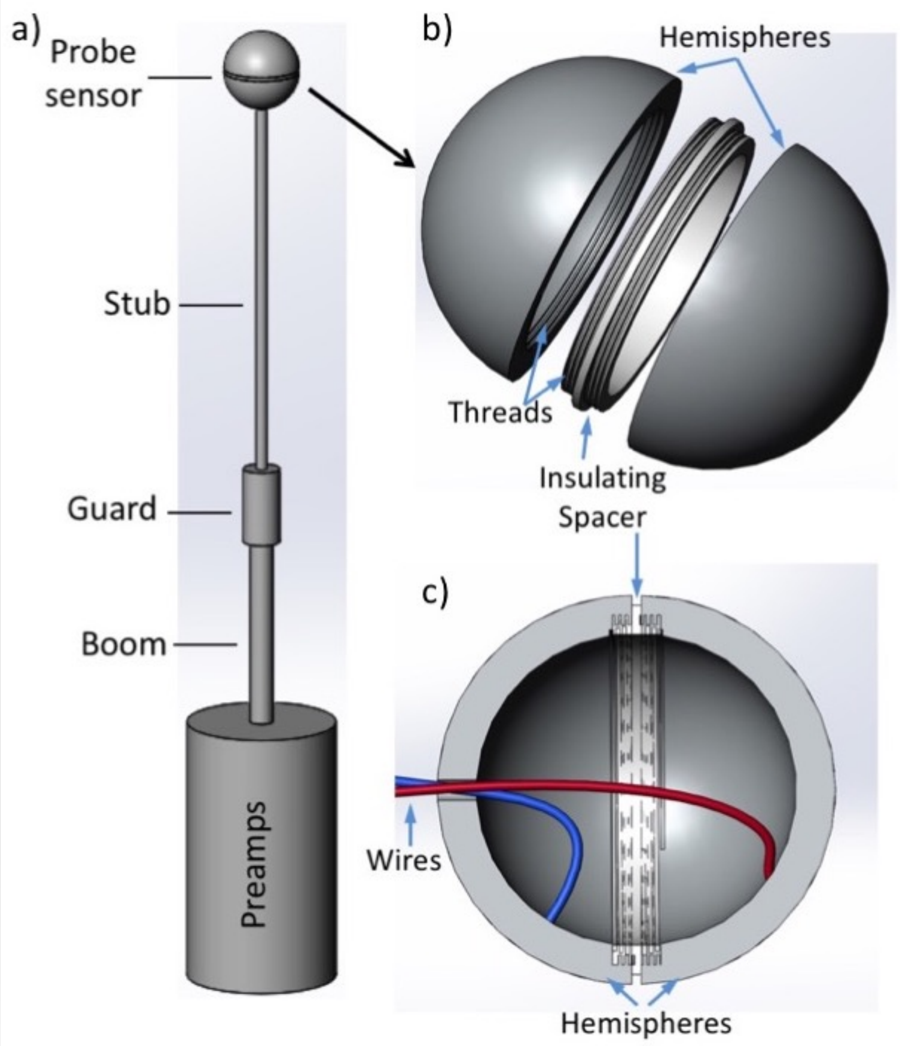
Split Langmuir Probes [Bering et al., 1973]



Segmented Langmuir Probes flown on DEMETER [Lebreton et al., 2006]

These probes have been developed and used mainly for characterizing the ion flow in Earth's ionosphere

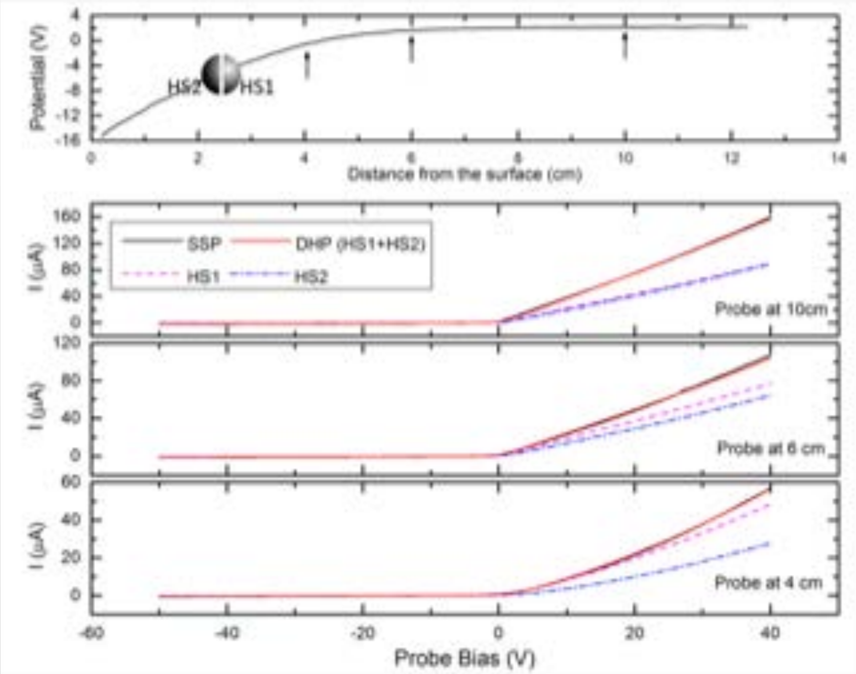
Double Hemispherical Probe (DHP)

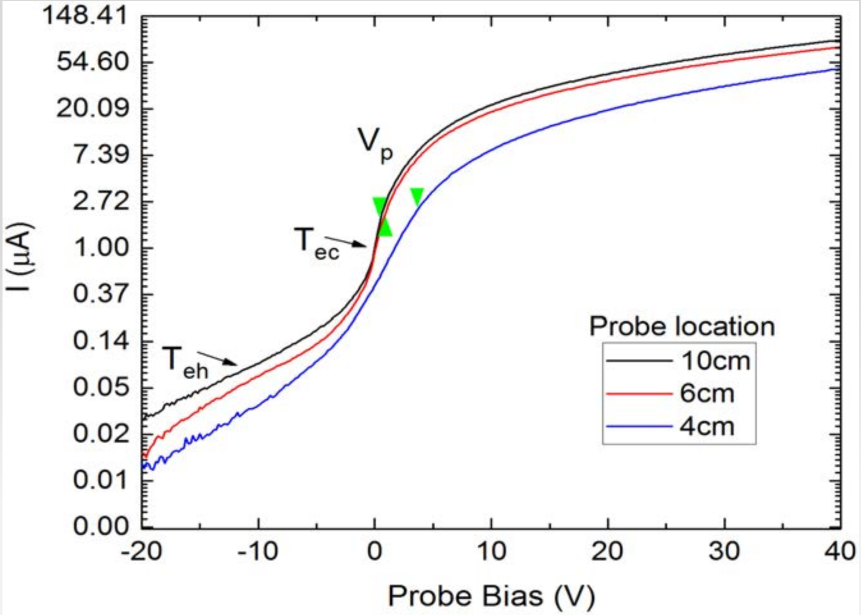


Wang et al., 2018

- DHP consists of two identical hemispheres that are electrically insulated from each other and swept with the same bias voltage simultaneously.
- The difference currents between the two hemispheres are used to characterize the anisotropic and/or inhomogeneous plasma conditions created around the probe, which will be then removed or minimized on the interpretation of their current-voltage (I-V) curves.
- When using the total current from both hemispheres, DHP works identical to a single spherical probe (SSP).

Case I – Probe in the SC sheath





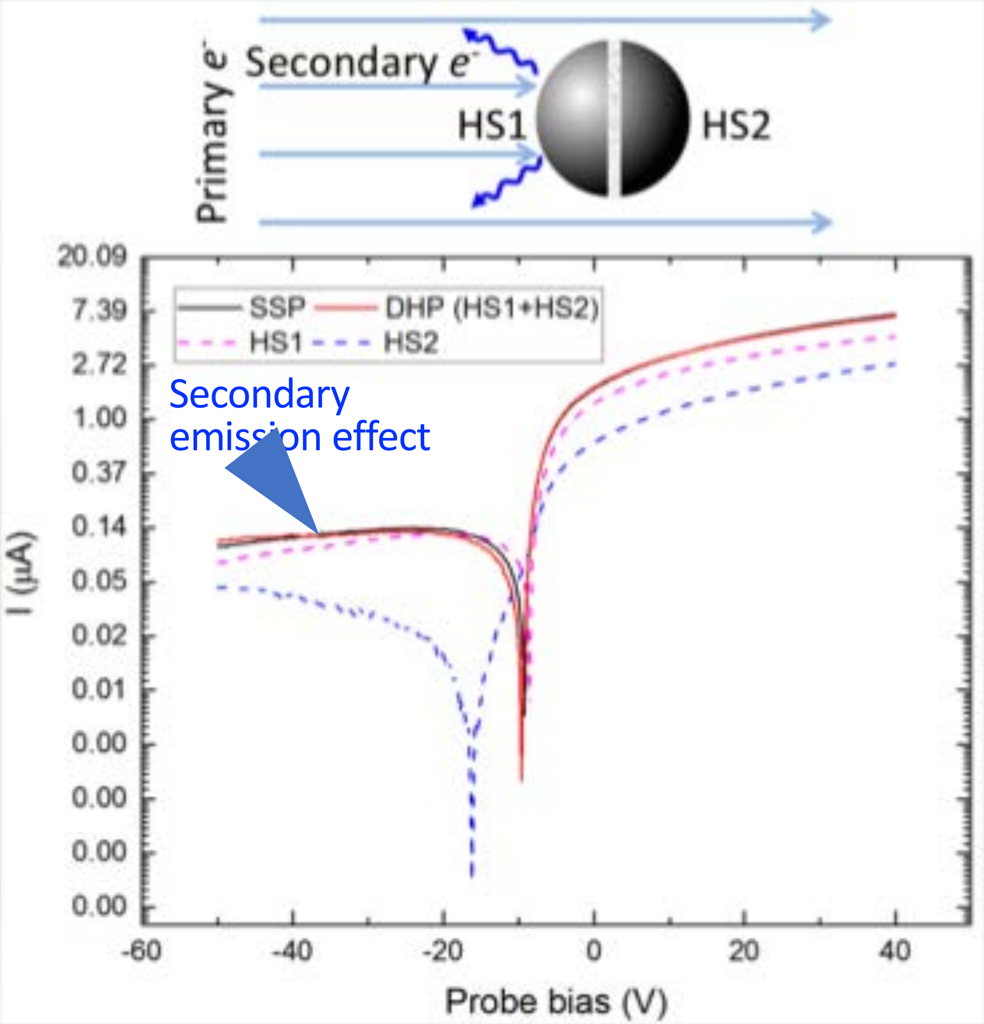
Low density plasmas (e.g., magnetospheres and interplanetary plasma)

- The currents are same in the bulk plasma and deviate as the probe moves into the sheath. The difference currents become bigger as the probe is in the 'deeper' sheath.
- The plasma facing side hemisphere HS1 collects more currents than the SC facing side hemisphere HS2.
- The empirical relationships of measured vs. true plasma parameters will be established to retrieve true ambient plasma characteristics.

Lab DHP model: 4 mm in diameter
SSP : Single Spherical Probe
HS1: Hemisphere 1
HS2: Hemisphere 2

Poster Session: A Double Hemisphrecial Probe (DHP) for Interpreting Probe Measurements in the Spacecraft Sheath, Samaniego et al.

Case II – Electron emission from the probe and SC surfaces



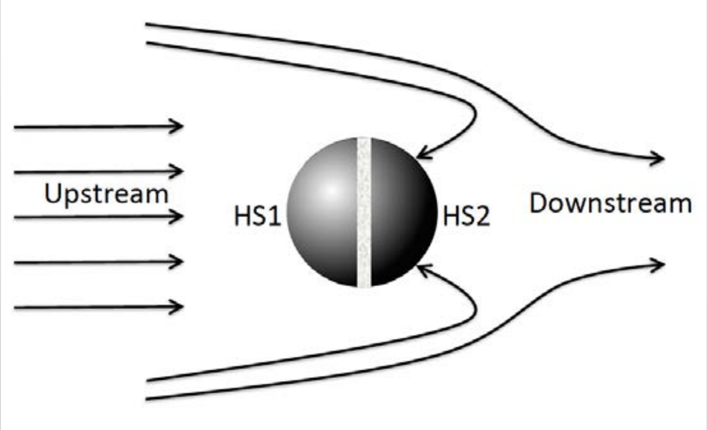
High surface emission environment (e.g., close to the sun): Photoemission and/or secondary emission from the probe and SC.

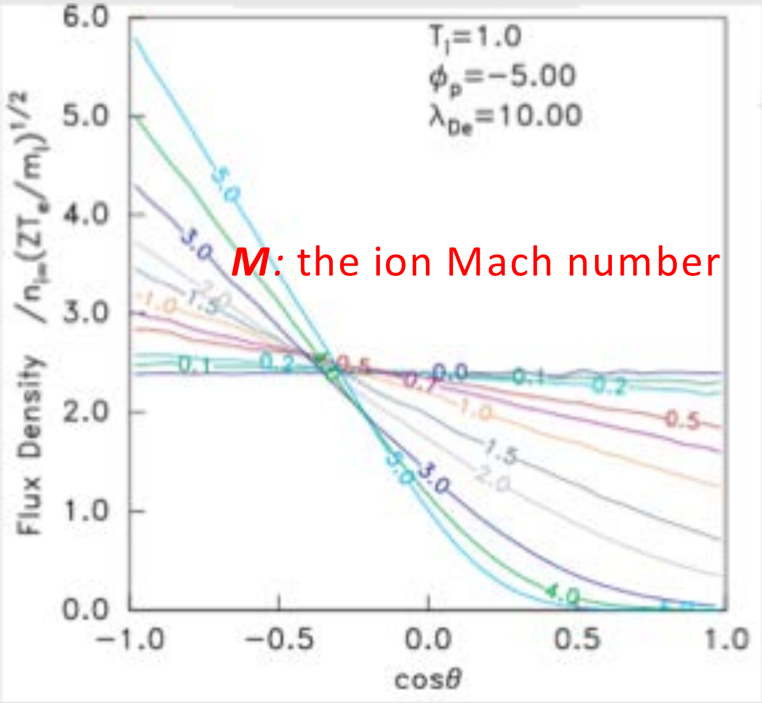
- In the ion saturation region (i.e., negative bias region), HS2 shows a 'negative' slope due to the collection of ions.
- Both HS1 and SSP show a 'positive' slope due to the effect of secondary electron emission from HS1.

Probe in the beam of energetic electrons

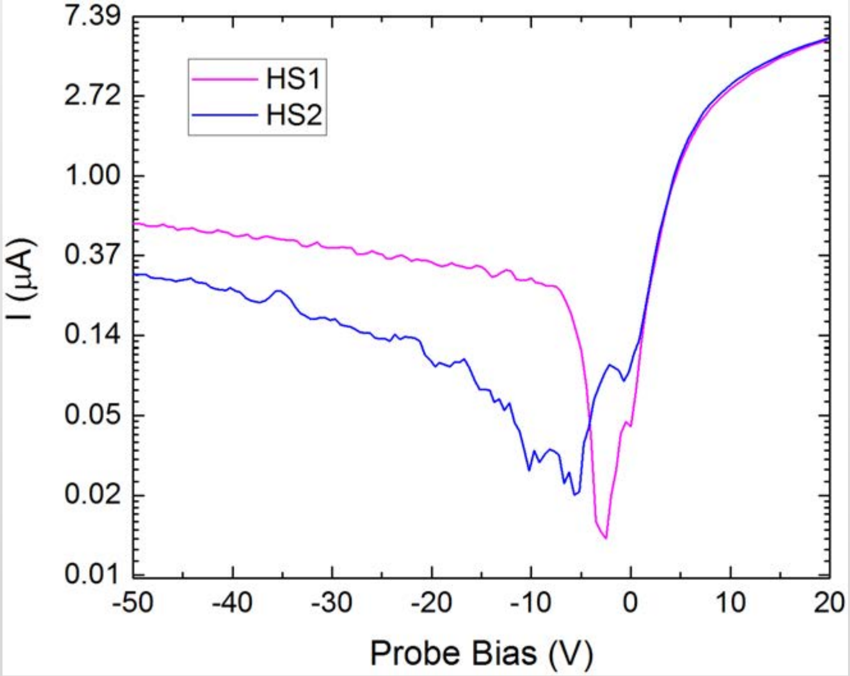
Case III – Probe in flowing plasmas

Probe in solar wind, co-rotational plasma or plasma w.r.t. high-speed SC: Ion and electron wake effects





[Hutchinson, 2003]



Probe in a flowing plasma with *M* ~ 5

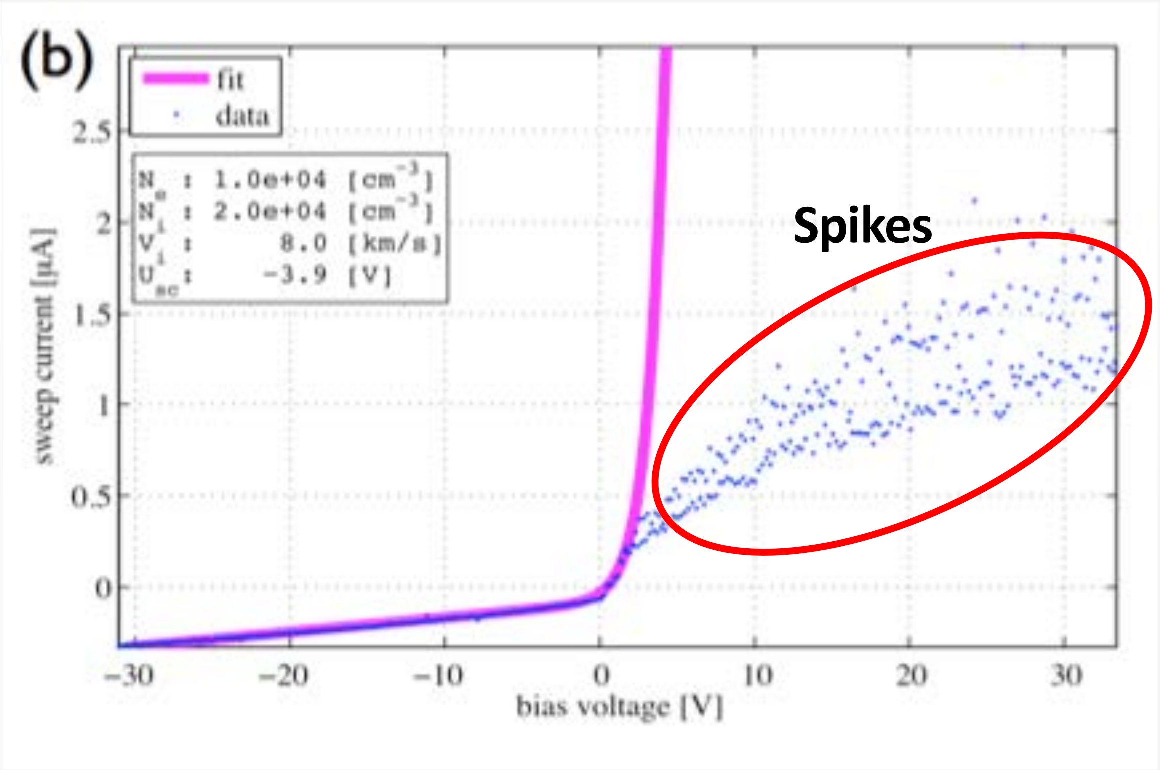
$M \le 5$ The ion flow velocity can be determined with I_{i1}/I_{i2} using Hutchinson's simulation results [Hutchinson, 2003].

$M > 5$ $I_{i2} \approx 0$. Electrons are characterized from the I-V curve of HS1 after subtracting I_{i1}.

- HS2 collects smaller ion current than HS1 ($I_{i1} > I_{i2}$).
- Electron currents to both hemispheres are similar. However, it was found that $I_{e1} > I_{e2}$ even when the Debye length is larger than the probe radius (Bering et al.,1973; Bering 1975).

Case IV – Dust impact on the probe and SC

Dust-rich environment (e.g., Enceladus's plume)



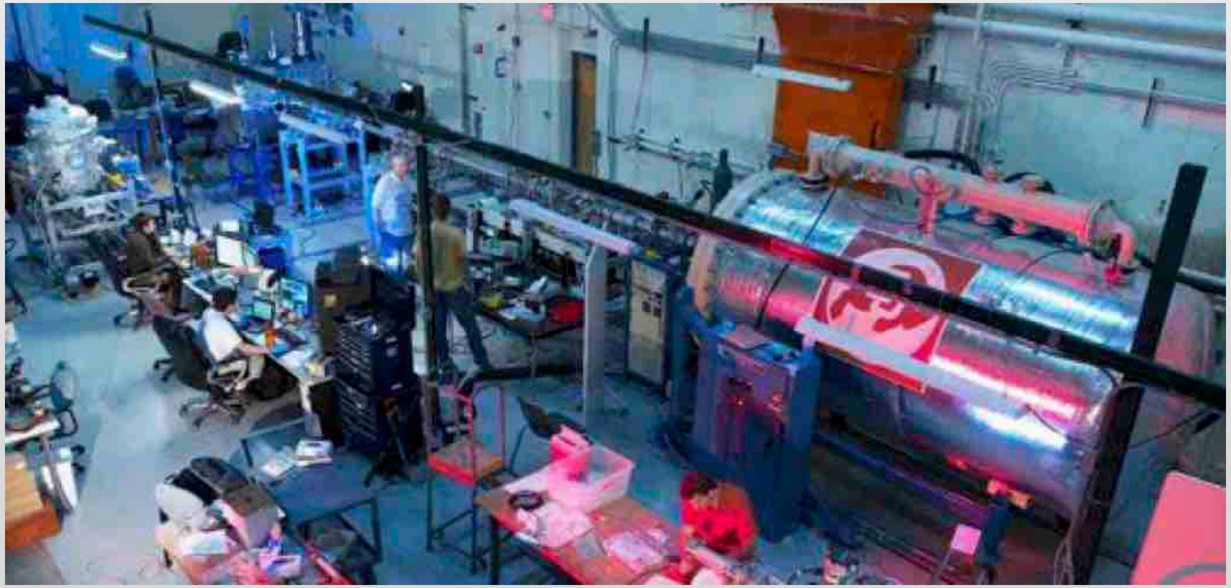
(Morooka et al., 2011)

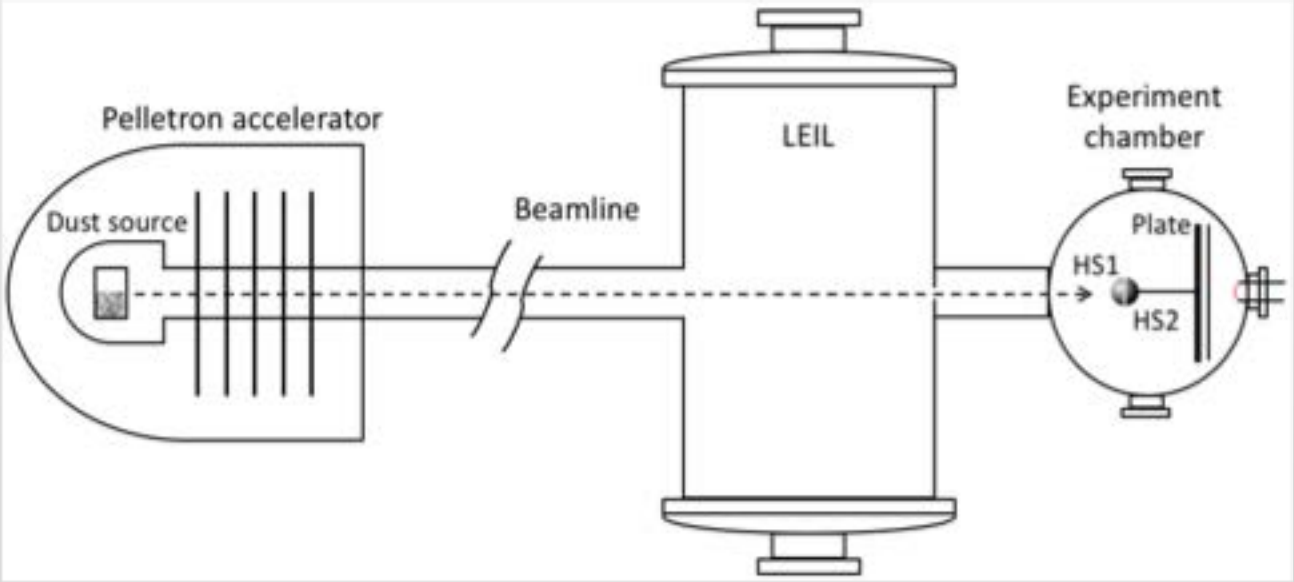
A Cassini Langmuir probe I-V curve taken inside the Enceladus's plume

- The spikes are likely as a result of dust impacts on the probe rather than the SC, which generate local plasma clouds.

Case IV – Dust impact on the probe and SC

Dust accelerator at SSERVI/IMPACT at the University of Colorado





1) Test the effects of impact plasma from the probe and SC on probe measurements;
2) The impact generated plasma collected by the probe can be analyzed from the difference currents between two hemispheres. These impact features will be characterized as a function of the dust size and speed as well as the probe potential.

Summary

A new Double Hemispherical Probe (DHP) is under development to improve space plasma measurement in the following scenarios:

I. Low density plasmas (e.g., magnetospheres, interplanetary plasma): Probe in the SC sheath

II. High surface emission environment (e.g., close to the sun): Photoemission and/or secondary emission from the probe and SC.

III. Flowing plasmas (e.g., solar wind, co-rotational plasma or plasma w.r.t. high-speed SC): Ion and electron wake effects

IV. Dust-rich environment (e.g., Enceladus's plume): Dust impact on the probe and SC