A Double Hemispherical Probe for the Advancement of In Situ Plasma Measurements

Joseph Samaniego\textsuperscript{1,2} and Xu Wang\textsuperscript{1,2}

\textsuperscript{1}University of Colorado - Boulder, IMPACT and LASP, Physics, United States of America (joseph.samaniego@colorado.edu)
\textsuperscript{2}NASA/SSERVI's Institute for Modeling Plasma, Atmosphere, and Cosmic Dust (IMPACT) at the University of Colorado, Boulder, Colorado, USA

Langmuir probes are conductors of simple geometries (spheres, disks, cylinders, etc.) inserted into a plasma. By sweeping a voltage on the probe and measuring the current collected or emitted, a current-voltage (I-V) relationship can be found and interpreted to derive the density, temperature, and potential of the ambient plasma. Over the past 50 years, Langmuir probes have been flown on spacecraft missions for in-situ measurements of the local plasma environment. However, even after decades of use, there are still challenges in the analysis and interpretation of Langmuir probe measurements due to local plasmas created around the probe as a result of plasma interactions with the probe itself and spacecraft.

The Double Hemispherical Probe (DHP) is a directional Langmuir probe made of two hemispheres that are electrically isolated from each other and swept with a voltage together to get two separate I-V curves. The DHP uses the I-V curve differences between the two hemispheres to gain information of the asymmetry of the local plasma around the probe to retrieve the true ambient plasma parameters. Specifically, the DHP is intended to improve the plasma measurements in the following scenarios: i) Low-density plasmas; ii) flowing plasmas; iii) high-surface-emission environments; and iv) dust-rich plasmas. The following discusses the current progress of the DHP development.

Low-density plasmas create large Debye sheaths around the spacecraft that may engulf the Langmuir probe attached to a boom with a finite length. The potential drop in the sheath can change the characteristics of charged particles collected by the probe, causing mischaracterization of the ambient plasma. As expected, the I-V curves of both hemispheres match in the bulk plasma. It was found that as the DHP is moved ‘deeper’ into the sheath of the spacecraft, the currents of the two hemispheres diverge. The saturation current ratio of the hemispheres of the DHP was found to have monotonic relationships with the plasma characteristics measured in the sheath. A technique was created to retrieve the ambient plasma parameters.

In space ions generally have relative velocities with respect to the spacecraft due to flowing plasmas or fast-moving spacecraft, creating an ion wake behind the probe itself. This self-wake can cause issues in interpreting the I-V curves for both ion and electron species. The ion saturation current of either hemisphere of the DHP is dependent on the ion Mach number (the ratio of the
ion flow speed to the thermal speed). Electrons are generally in the thermal state. However, depending on the ratio of the probe size to the Debye length, ambipolar electric fields can be created at the wake boundaries, causing the reduction of the electron density in the downstream side of the probe and its subsequent underestimation measured by traditional single Langmuir probes. It was shown that the DHP can identify this self-wake effect and properly measure the true ambient plasma parameters.

Future work will explore the effects of high-surface-emission environments and dust-rich plasmas on DHP measurements and to develop techniques to resolve the true ambient plasma parameters in these environments.

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