The Big Picture: Main Neutral and Ionized Constituents Measurements on an Uranus/Neptune Atmospheric Probe

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Abstract

Mass spectrometers on atmospheric probes provide measurements of heavy element, noble gas, and isotope abundances. These observations are the key to revealing and understanding the physico-chemical conditions and processes that led to formation of the planetesimals that eventually fed the forming planets.However, due to inherent instrumental limitations to achieve the required accuracy of abundances measurements of the main atmospheric constituents, such as hydrogen and helium in the ice giants case, and trace elements, such as noble gases and their isotopes, may not be possible with one mass spectrometer with sufficient accuracy. Therefore, an additional sensor is required to measure abundances of hydrogen and helium, as was the case on the Galileo atmospheric probe (GP). GP carried a dedicated Helium Abundance Detector (HAD) to measure the helium abundances with an accuracy of 0.1%. The accomplished measurement of the He mole fraction in the Jovian atmosphere gave 0.1350 ± 0.0027 (von Zahn et al., 1998), with a somewhat lower accuracy than expected, but still better than is possible by a mass spectrometric measurement. Therefore, a HAD-like instrument is included in the model payload of an Uranus/Neptune atmospheric probe (Mousis et al., 2018).
The focus of mass spectrometric measurements is on the neutral atmosphere composition with a dedicated neutral gas mass spectrometer. The composition measurements of ionized components both positive and negative cannot be achieved by one mass spectrometer due to constrains on the duty cycle and dynamical range. However, ionospheric measurements are the key to understanding how the atmosphere works. An ionosphere, the outermost layer of any planetary atmosphere is an inherent interface between the space environment and a planet. Ionospheres control such processes as non-thermal atmospheric escape, energy and matter inputs from space or magnetosphere down to the atmosphere and related phenomena, aurorae and airglows. Knowledge of the ionosphere composition is required for understanding the photochemistry of atmospheres. A number of previous atmospheric probes carried ionospheric instruments as summed up below.

NASA Viking 1 and 2 landers (1976):

Retarding Potential Analyzer: The composition, structure, and temperature of the ionosphere;

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PVO Probe bus (1978):

Ion mass spectrometer: The solar wind interaction with Venus, upper atmosphere photochemistry, and the mass and heat transport in the atmosphere;

NASA Galileo Atmospheric Probe (1995):

Energetic Particle Detector: The energetic particle population (electrons, protons, alfa-particles, Z> 2) from 5 RJ to the top of the atmosphere.

We thus argue that an atmospheric probe to Uranus/Neptune shall carry an ion mass spectrometer for positive and negative ions.
The presentation reviews a possible architecture of a package to profile the main ionized constitutes of the Uranus/Neptune ionospheres and main neutral (hydrogen and helium) components and its science objectives.

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