DEVELOPMENT OF ION MASS SPECTROMETERS WITH HIGH-MASS RESOLUTION

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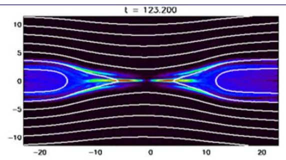
Abstract

In-situ measurements of ion composition with high mass resolution become of primary importance in various environments : terrestrial and planetary environments, solar wind, … They represent a key element to identify the particle sources or sinks and to investigate the escape, transport and acceleration processes. The major plasma components mainly contribute to the plasma dynamics and it is important to measure them with an accurate energy resolution and with the best space and time resolution. The minor components contain information on impulsive and/or intense processes such as sputtering, reconnection, ejection, outflows, … that contribute to extract particles from atmospheric layers or even from planetary surfaces. These minor components may modify the plasma structure and dynamics, and therefore, it is important to resolve them measurements with a high mass resolution.

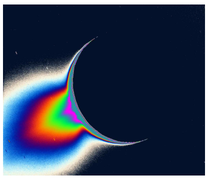
Objectives for composition measurements of thermal ions (1 eV – 30 keV) with for high-mass resolution :



- **Earth's magnetosphere:**

Ion sources: ionosphere & solar wind: H^+ and O^+; little knowledge of minor species He^+, N^+, O^{++}, NO^+, N_2^+.
Important contribution of ionospheric O^+ ions in plasmasheet & energetic ring current during storms/substorms, near duskside magnetopause.. *(Yau and André, 1997; Seki et al., 2001; Bouhram et al., 2005; Kronberg et al., 2012)* ;

→ Role in lowering threshold for triggering different processes as: reconnection, Kelvin Helmoltz instability, …



Enceladus' plume (false colors)- Cassini/NASA

- **Planetary magnetospheres:** Ion sources: ionosphere, active moons, planetary or moons' surfaces, *solar wind*

Ex: Mercury: Na^+, Mg^+, Si^+, O^+, water group due to the sputtering of the surface by solar wind ions *(Zurbuchen et al. , 2011)*

Ex: Jupiter: H+, H_3^+ from ionosphere; O^+, O^{++},S^+, S^{++}, S^{+++}, Na^+ due to volcanic Io; water group around moons;
(Mc Nutt et al., 1981 ; Frank et al., 2002; Radioti et al., 2005)

→ Role in identifying particle sources and sinks; transport and acceleration processes;

- **Solar Wind:** main elements H, He, and minor species O, C, N, Mg, Si, Fe… at different charge states *(von Steiger, 2000)*

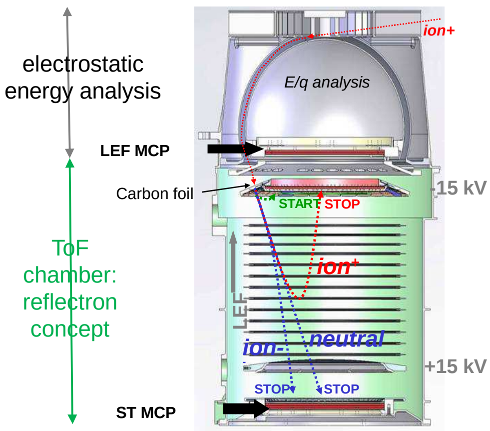
Composition differences in slow/fast solar wind

→ Role in probing source regions in solar atmosphere (altitude, magnetic topology, …) and emission processes

Ion mass spectrometers with high-mass resolution:

Concept:

- Electrostatic energy analysis: 1 eV – 40 keV
- Time of Flight chamber, polarized with Linear Electric Field (LEF)
  - → reflectron : collection of $Ions^+$ on LEF MCP ($m/\Delta m$ = 40)
  - → Straight-Through: collection of $Ions^-$ and Neutrals on ST MCP (high count amount)



Achievement:

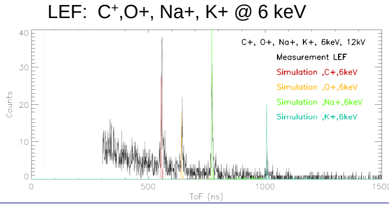
MSA onboard BepiColombo/MMO

Optics: 1.9 kg
HVPS: 1.45 kg
LVPS + CPU: 0.9 kg

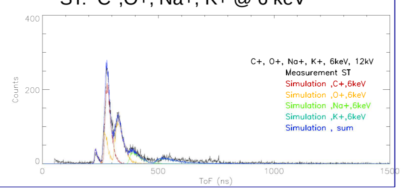
Power: 9 W

Examples of results:

LEF: C^+,O+, Na+, K+ @ 6 keV



ST: C^+,O+, Na+, K+ @ 6 keV

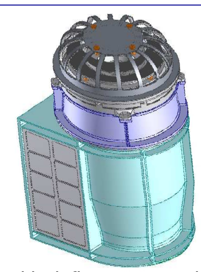


Adaptation to different mission types :

Composition measurements of thermal ions (0 – 40 keV):
- Ajustable geometry factor to magnetospheric and solar wind conditions (spoiler)
- Adaptation of the mass resolution up to m~ 60 with $m/\Delta m$ ~40
- Spinning / stabilized spacecraft: entrance with « top hat » / deflectors for 2π st coverage (cf. IMS design for JUICE)
- Radiatif environments (cf: Jupiter, Earth's radiation belts): coincidence techniques

Heritage at Laboratoire de Physique des Plasmas (LPP), France:

- Thermal ion spectrometer Hyperboloïd onboard French-Soviet auroral probe INTERBALL
- Electrostatic optics for CPS / IMS onboard NASA-ESA mission CASSINI
- Thermal ion mass spectrometer MSA onboard ESA-JAXA mission Bepi Colombo



Design with deflectors covering 2π st

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