# Heavy Ion Sensor (HIS): The importance of minor ion measurements as a probe of the Sun

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## Abstract:

The Heavy Ion Sensor (HIS) onboard the upcoming Solar Orbiter (SO) mission will measure the composition and kinetic properties of heavy ions in the solar wind, as well as the composition and velocity distribution functions (VDFs) of major ion constituents in the suprathermal energy range (up to ~100 keV/q). These measurements will allow for a comprehensive study of minor ion species in the solar wind between 0.3 and 0.9 AU. Taking these measures will allow for characterization of the origin of the solar wind and parameterization of the corona. This poster will provide a brief introduction to the HIS instrument, as well as a description of how the provided data products will be able to answer open science questions.

## Minor ion species background:

- The solar wind composition is 99.9% $H^+$ and $He^{2+}$.
- Other ions (i.e. O, Fe, C, Mg, and Si) will behave as test particles.
- These minor species do not act as drivers of physical phenomena, however they are still effected by them.
- Once the charge state of heavy ions is set, low in the corona, it is "frozen in".
  - Thus, measuring the charge states of heavy ions can act as a remote sensing of the lower corona.
- As heavy ions propagate away from the sun, they may be energized by a variety of physical phenomena, making it difficult to separate the effects of each at 1 AU.
  - By observing the distributions of these heavy ions at different distances (i.e. 0.3 to 0.9 AU) we will be able to separate out and better understand each of these effects.
- HIS will simultaneously measure the characteristics of plasma in the Corona and the plasma from 0.3 to 0.9 AU. This compliment of measurements is ideal for a mission like Solar Orbiter, whose stated goal is to study the relationship between the sun Sun and the Earth.

## Frozen in condition:

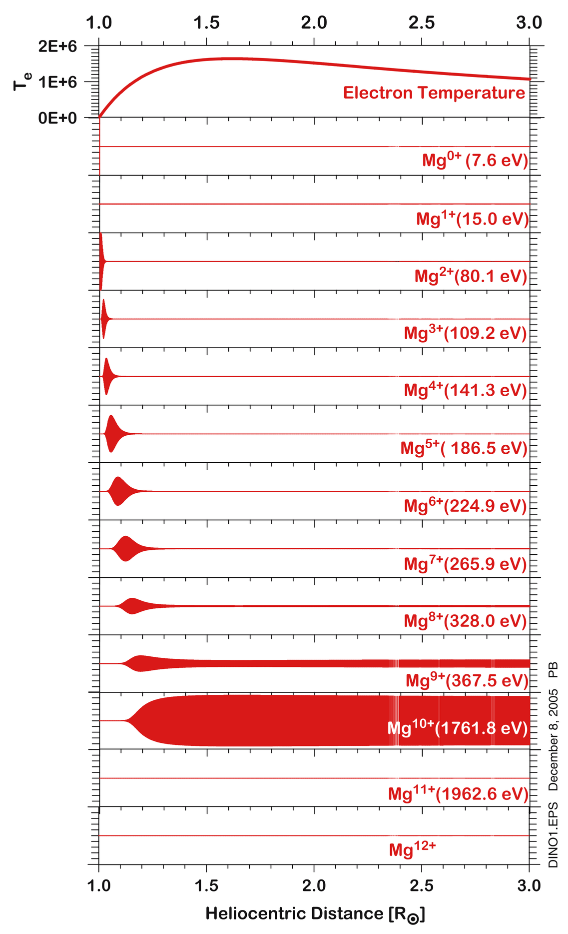
In the inner corona, hot electrons ionize heavy ions.

The rate of electron-ion interactions is a function of the product of the electron and ion densities

Once the rate of collisions becomes negligible, recombination stops and the ion charge state "freezes in".

Thus, the ratio of charge states for an ion can give the electron temperature for where it was frozen in, by:

$$\frac{n_i}{n_{i+1}} = \frac{R_{i+1}(T_e)}{C_i(T_e)}$$




From *Bochsler* [2007].

where R is the recombination rate and C is the collisional ionization rate [*Bochsler*, 2007].

## Acknowledgements:

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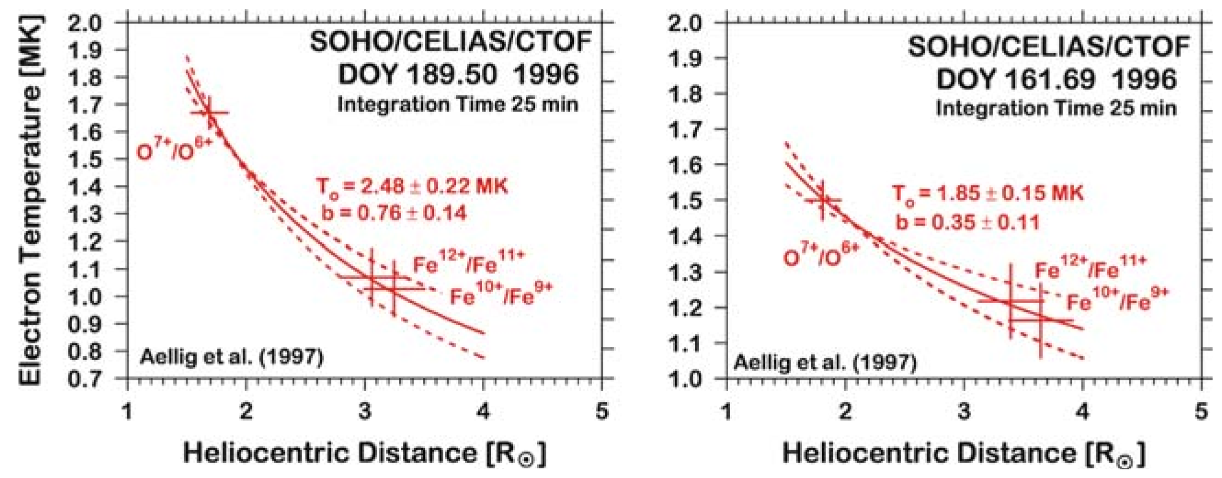
## Temperature gradients in the corona:




Adapted from *Aellig et al.* [1997].

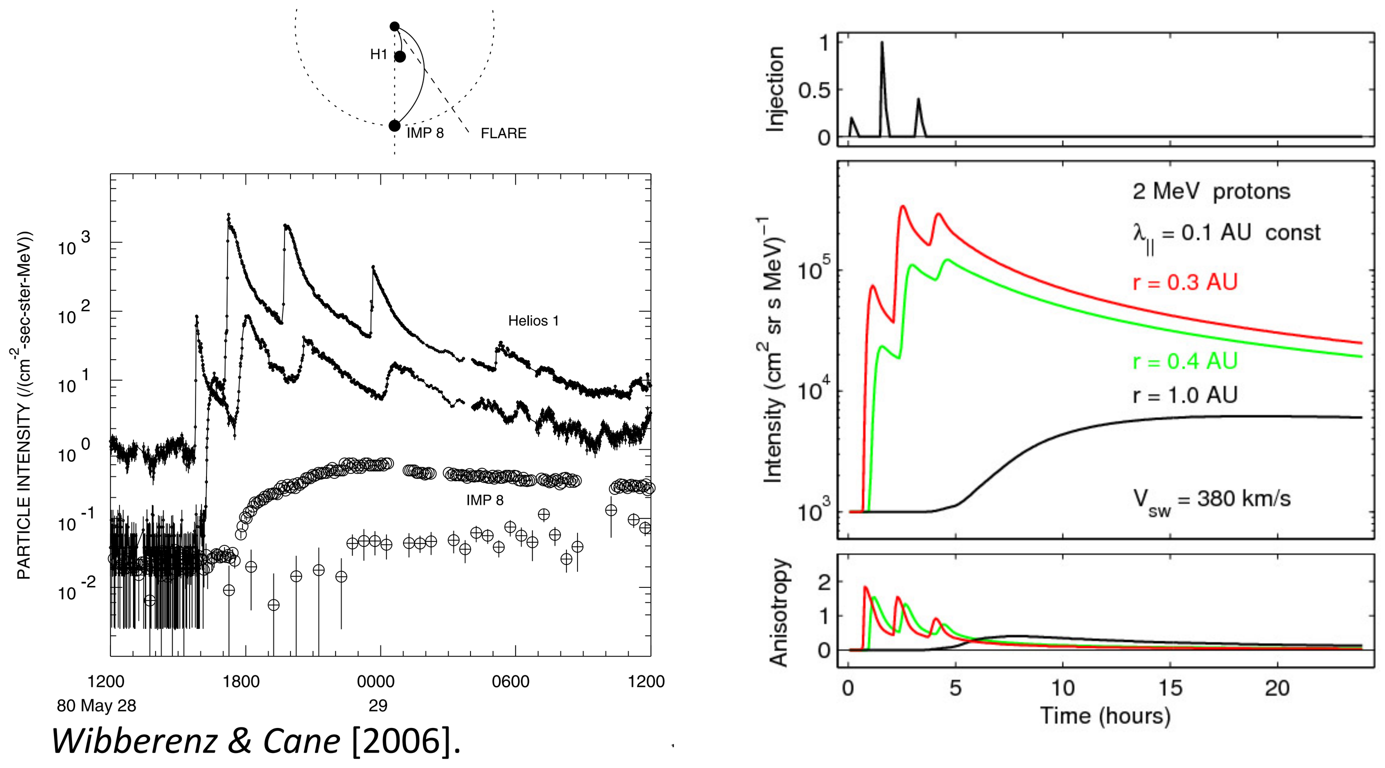
The cross sectional area of an ion increases with mass.

A larger cross sectional area increases the likelihood of collisions with electrons.

Therefore, heavier ions will become "frozen in" at lower densities, or higher up in the corona [*Aellig et al.*, 1997].

Measurements of multiple ions species will then be able to better resolve the temperature gradients in the corona.

## Variations with distance:




*Wibberenz & Cane* [2006].

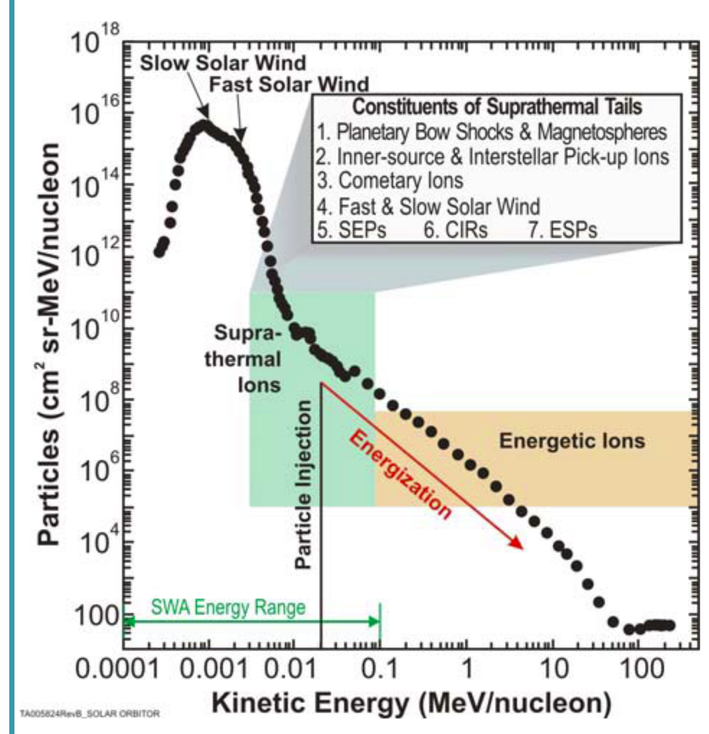
As solar wind propagates outwards magnetic field irregularities will scatter ions.

This causes the energetic particles distributions observed at 1 AU to be different than near the Sun.

Taking measurements all the way between the Sun and the Earth will give important clues on where and how these variations occur.

Knowing more about this variation will help to model energetic particles and solar wind evolution.

## Suprathermal ions:




Adapted from *Mewaldt et al.* [2003].

Suprathermal ions are postulated to be the source of energetic particles (seed population).

HIS will be able to measure both the ion composition, the 3D velocity distributions functions for suprathermal ions, and the solar wind distrubutions with time resolution adequate to study acceleration features.

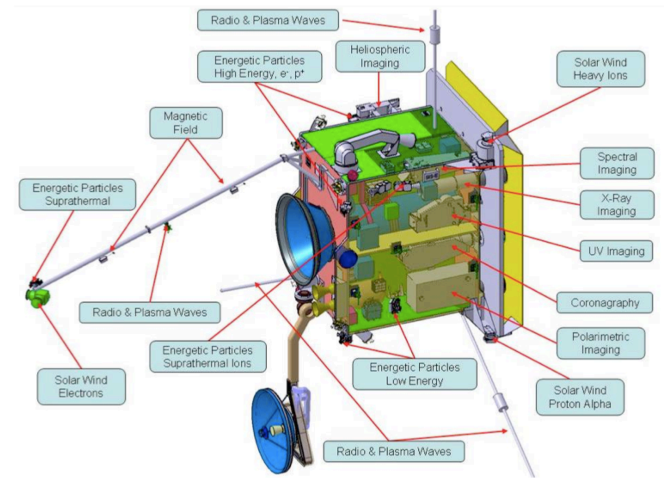
This will allow for study of the spatial and temporal distributions of these particles.

Measurements near shocks will help shed light on how shocks generate SEP's, revealing the origin and dynamics of their source population.

## Solar Orbiter (SO) and Heavy Ion Sensor (HIS):

### Solar Orbiter:

| Orbital parameter | Value |
|---|---|
| Perihelion | ~0.28 AU |
| Aphelion | ~0.9 AU |
| Inclination | ~30° |



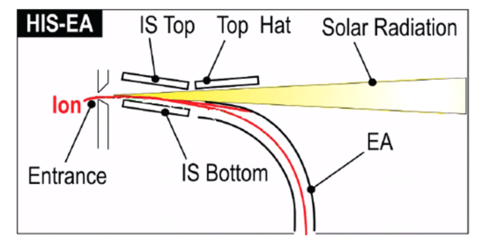
- Planned launch: 2017
- Opportunity to observe the poles of the Sun
- First spacecraft since Helios to sample inside the orbit of Mercury

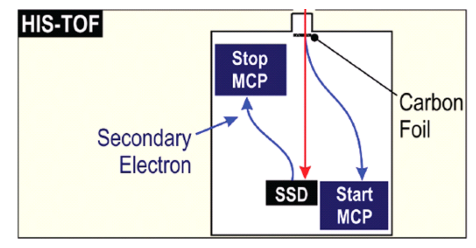
### HIS:

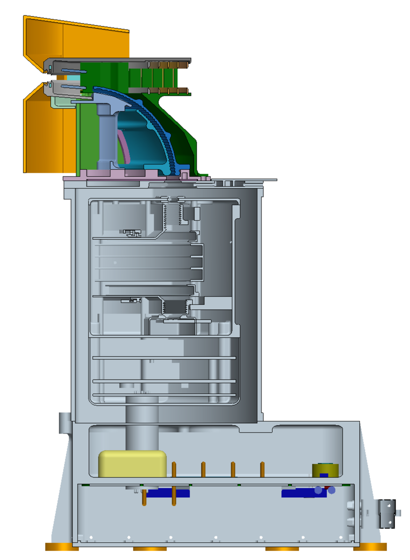
Requirements:

| Parameter | Range/Resolution | HIS |
|---|---|---|
| Mass | Resolution (m/Δm) | 4 |
| Charge state | He | +1, +2 |
| | C | +1, (+4 : +6) |
| | O | +1, (+5 : +8) |
| | Ne | (+6 : +9) |
| | Mg | (+6 : +12) |
| | Si | (+6 : +12) |
| | Fe | (+6 : +20) |
| Energy | Range | 0.5 – 60 keV/q |
| | Resolution Δ(E/q)/ (E/q) | 6% |
| Angle | Azimuth range | -30° : +66° |
| | Elevation range | -17° : +17° |
| Temporal | Resolution | 30 sec |

- Top hat ESA-Time of Flight-SSD
- Makes direct measurements of:
  - Direction of arrival:
    - Elevation
    - Azimuth
  - Energy per charge (ESA)
  - Speed (ToF)
  - Total energy (SSDs)
- Data products:
  - Mass
  - Charge
  - 3D velocity distribution functions



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