

Solar wind - planetary magnetospheres interactions: Recent BepiColombo observations

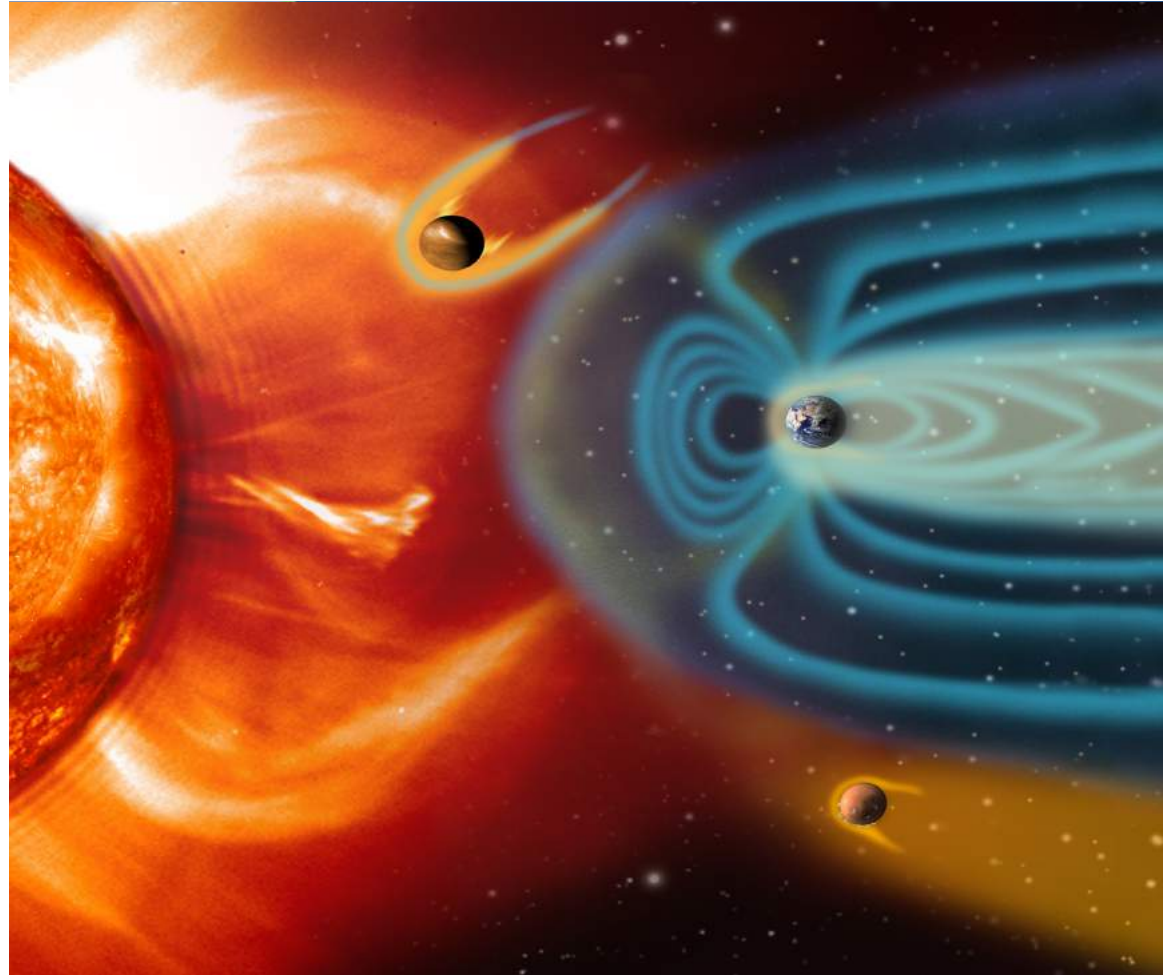
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SF2A, June 20 – 23, 2023

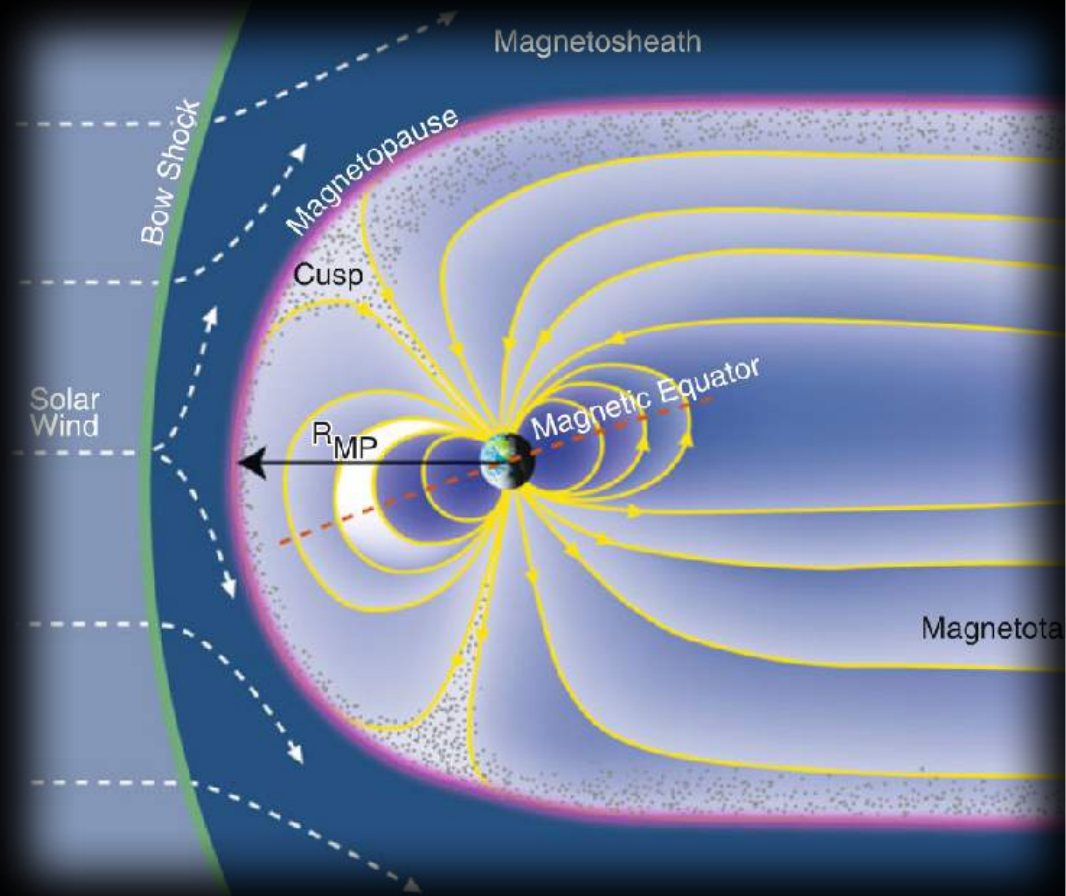
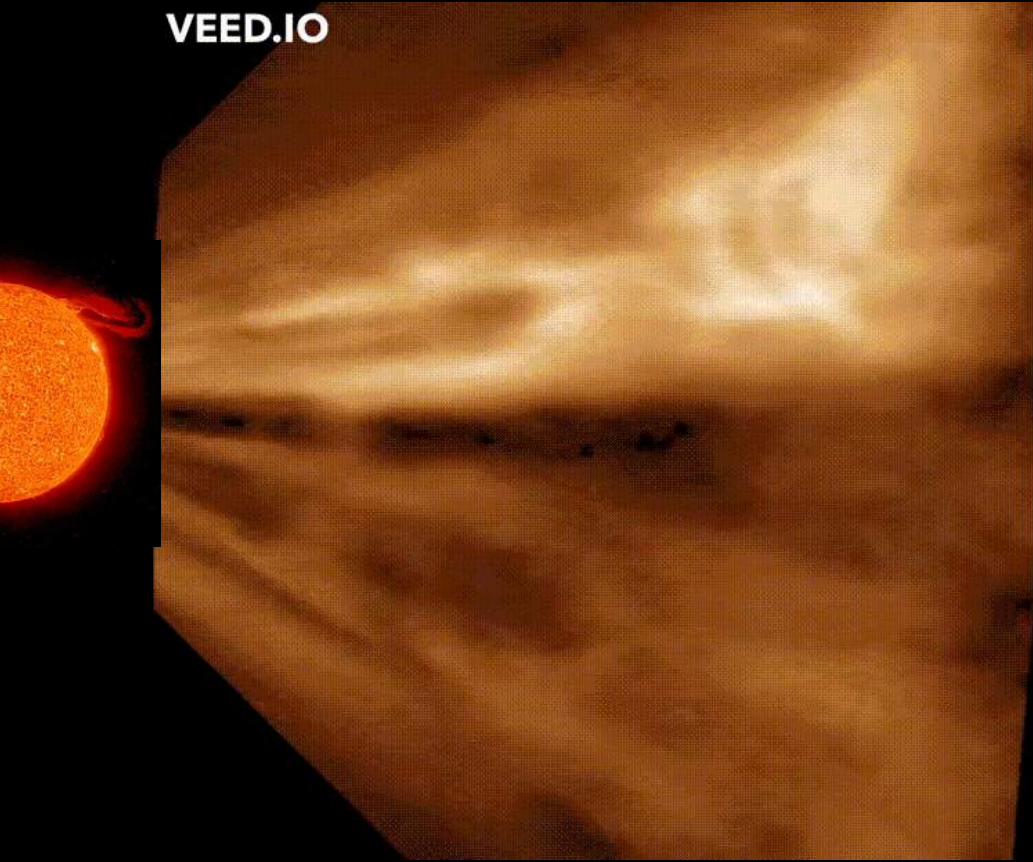
Magnetosphere:

The region of space influenced by the planet's magnetic field.

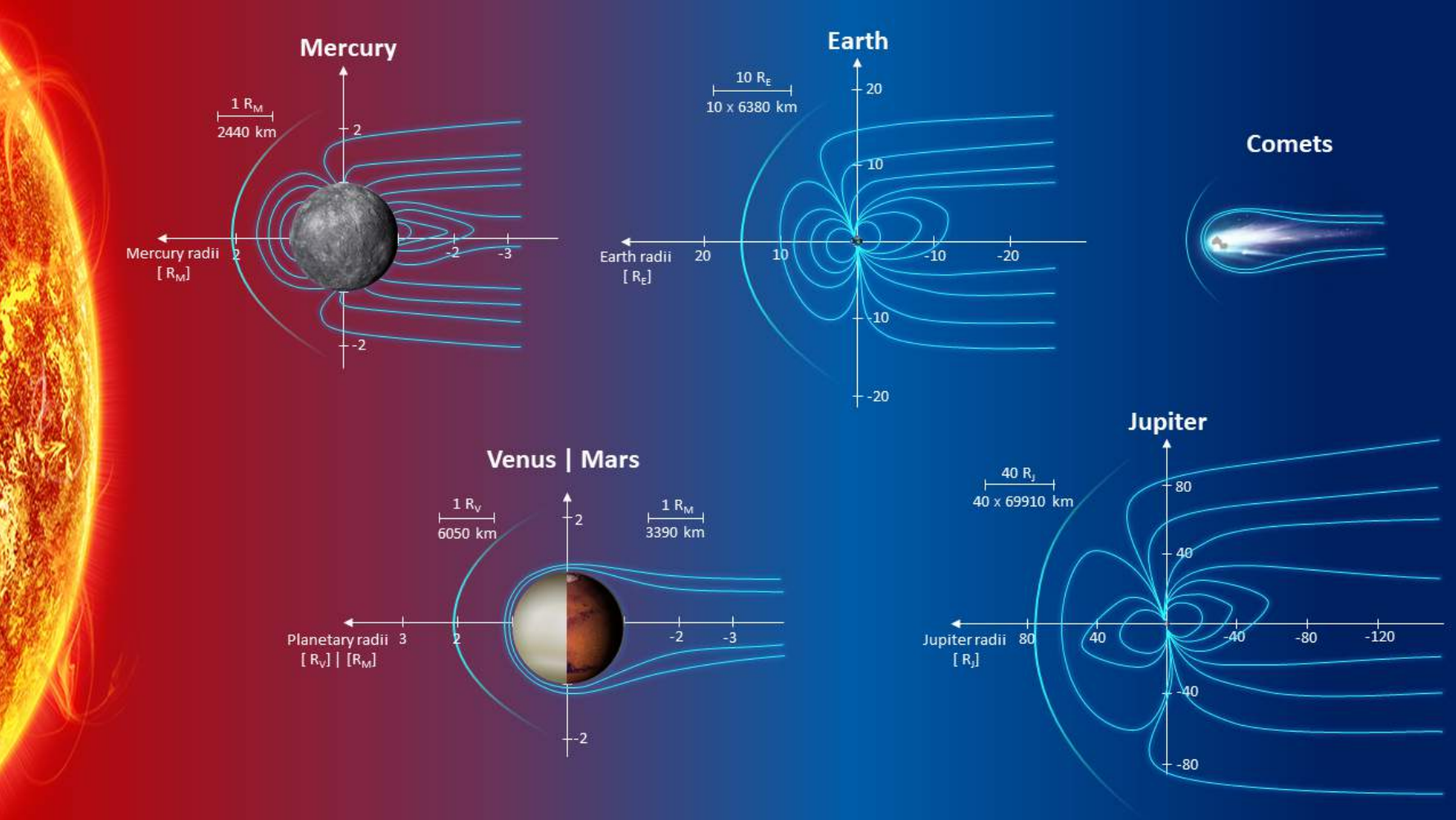


Anatomy of a magnetosphere

VEED.IO

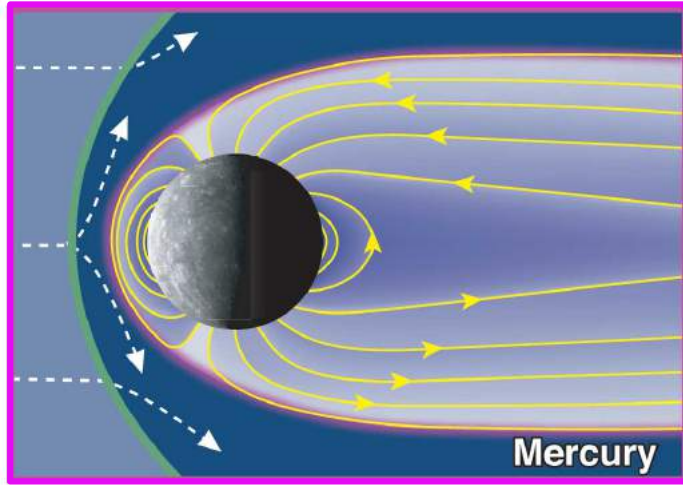


Nature of the interaction between planetary magnetospheres and the SW

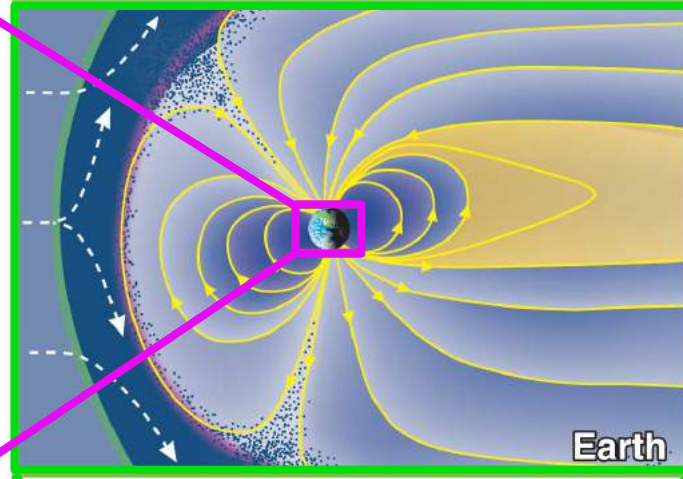


HUGE range of scales !

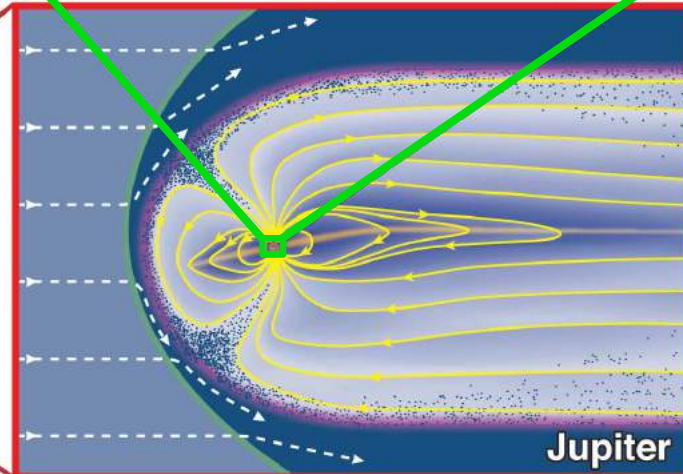
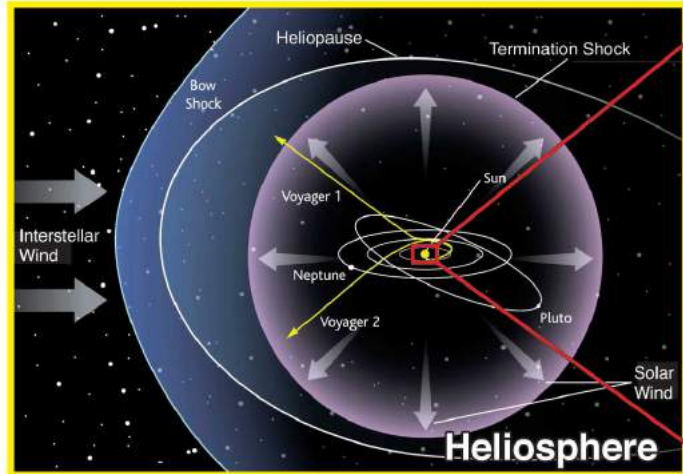
“Small/Mini”



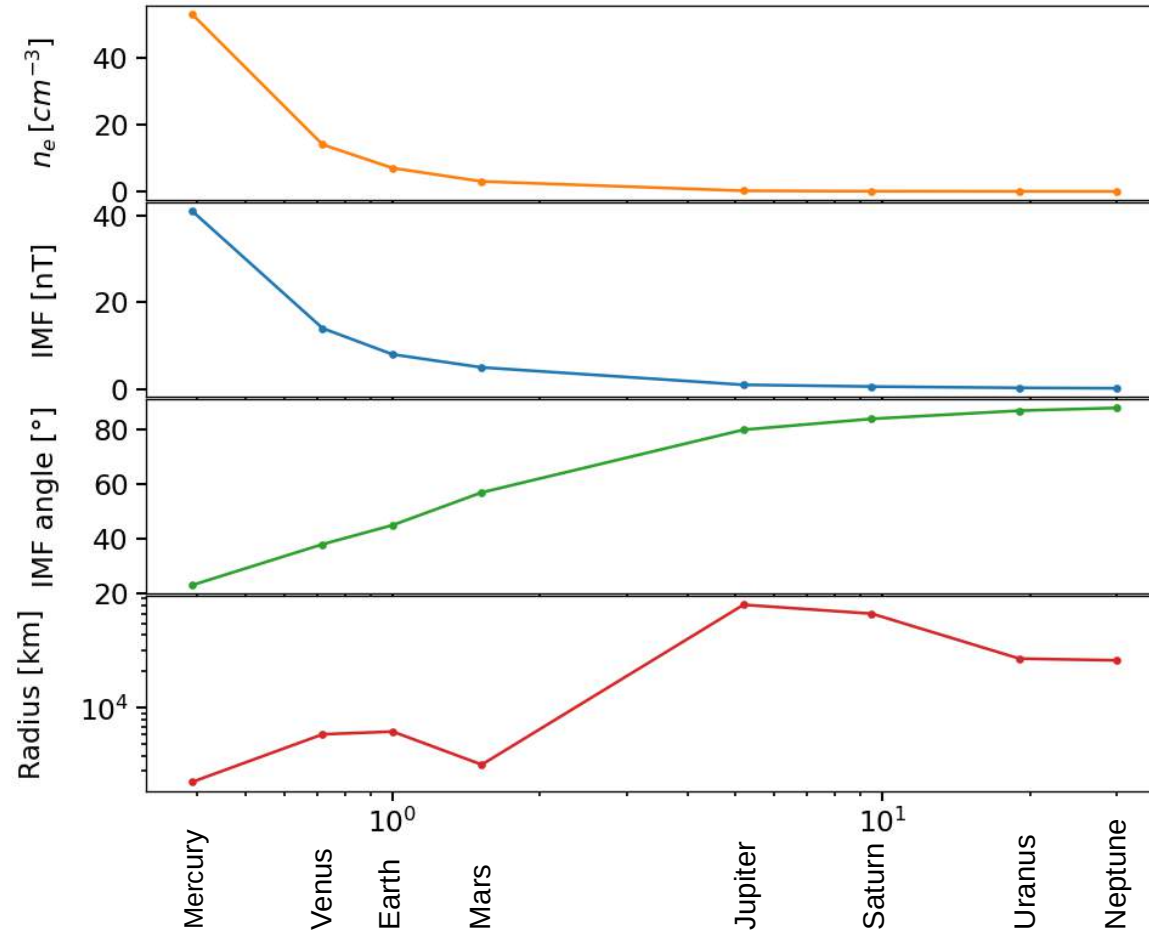
“Medium”



“Large”



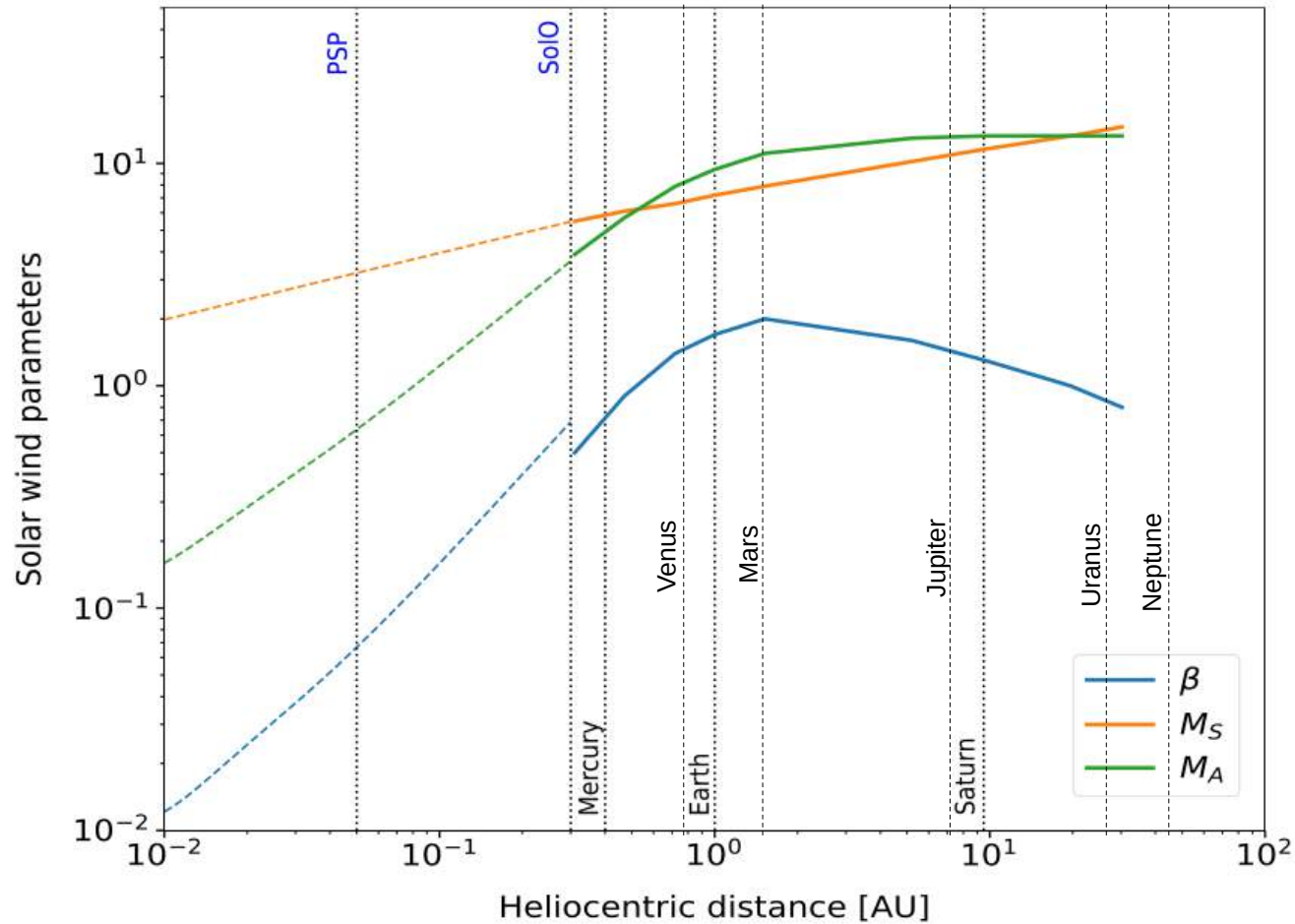
The solar wind: a broad parameter space !



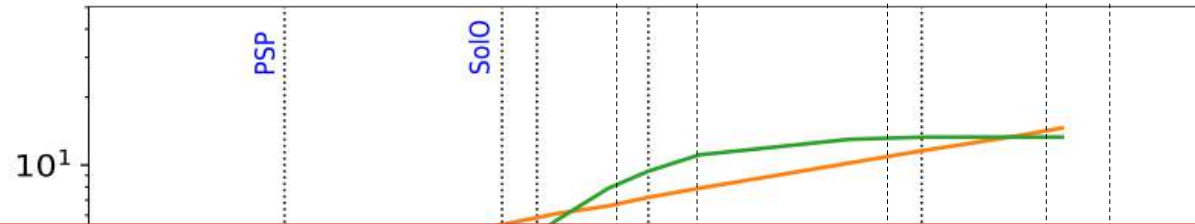
**Solar wind properties
and scales of the
planetary magnetospheres**

Adapted from *Bagenal+2013*

The solar wind: a broad parameter space !

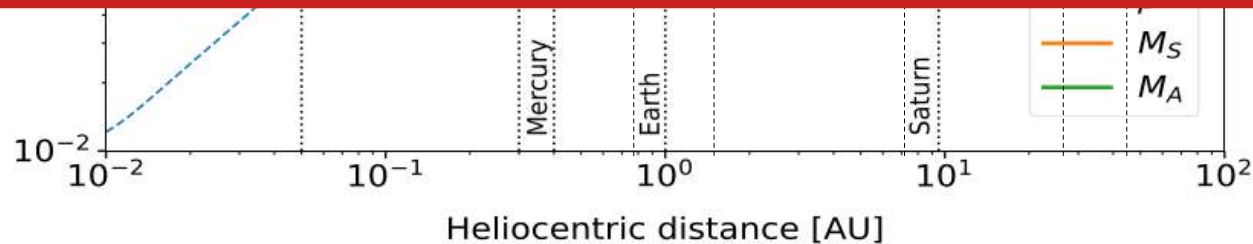


Adapted from
Sahraoui+RMPP, 2020

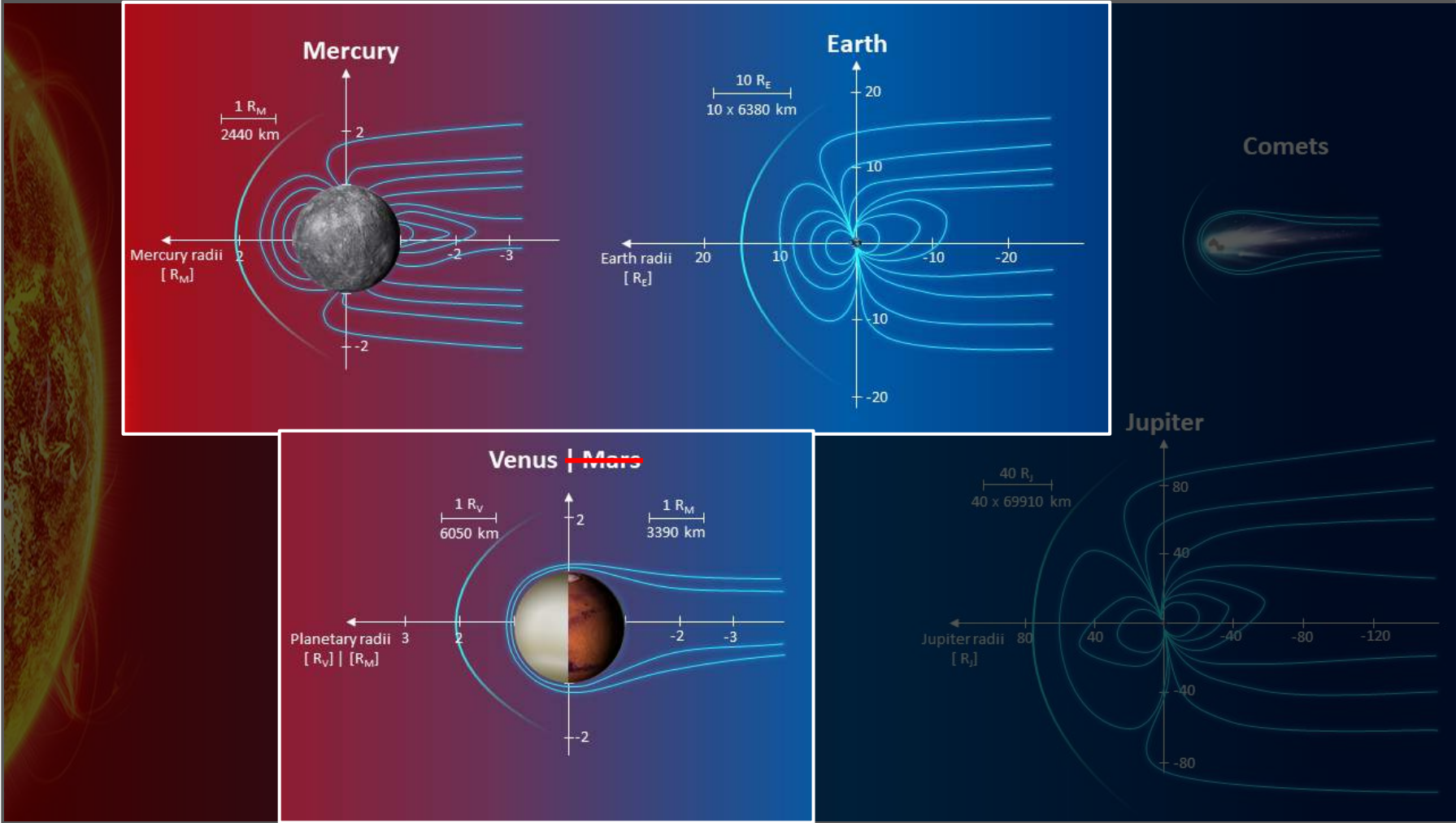


Broad range of scales and the SW parameters:

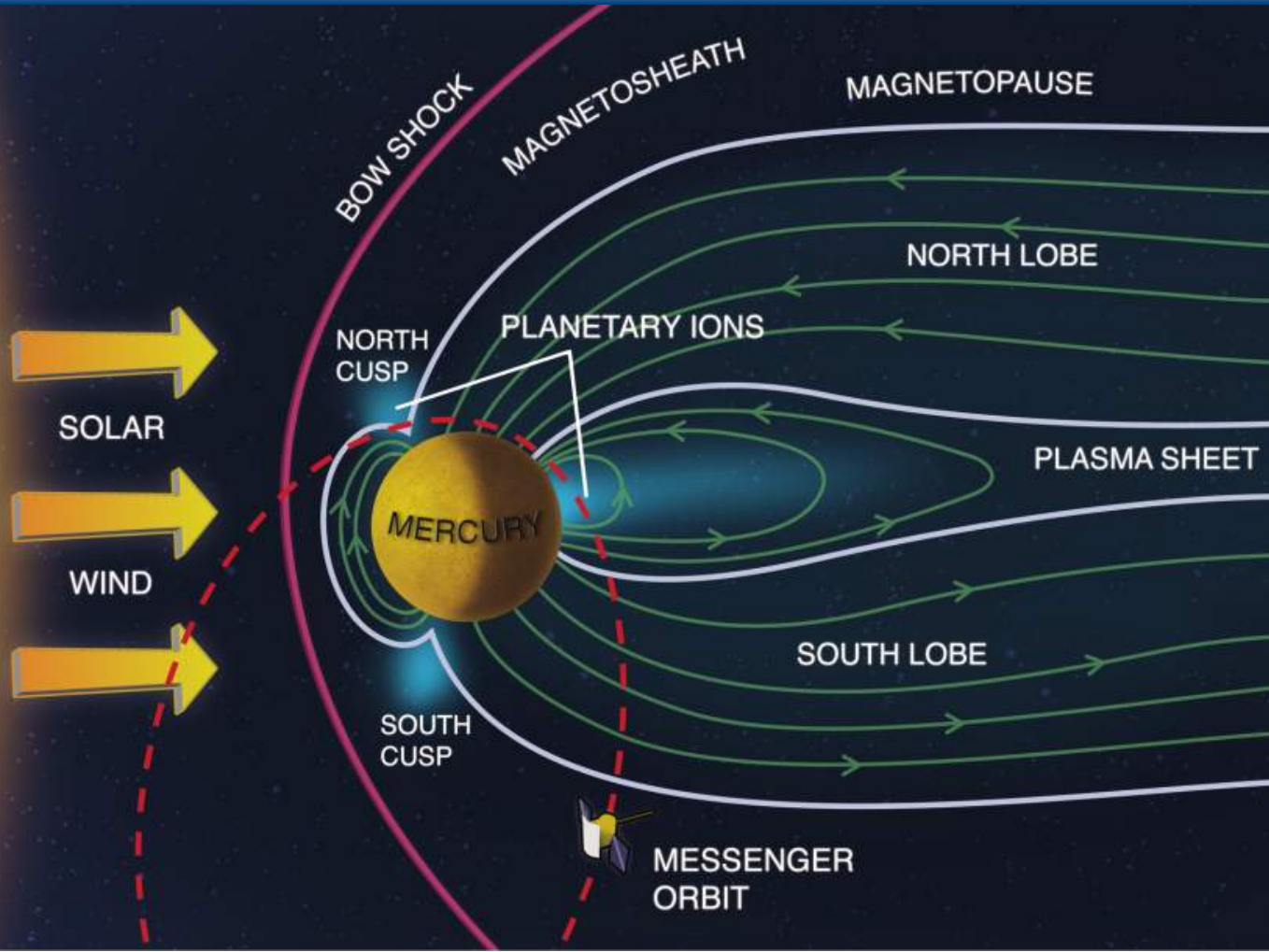
- Different responses of the planetary magnetospheres to the solar wind forcing
- Study fundamental processes in different plasma regimes that can be applicable to astrophysical media that are not accessible for in situ measurements (so far) e.g. ISM [Schekochihin+ApJ, 2009]
- Understanding Solar wind planetary magnetospheres interaction has important implications for exoplanets, habitability and planet-star interactions



Magnetospheres of Venus and Mercury



Mercury: Mini-magnetosphere, the innermost planet of the heliosphere



→ Planetary magnetic field is $<1\%$ of Earth's in strength.

→ **Highly dynamical and compressed magnetosphere.**

→ Populated with solar wind and **planetary heavy ions.**

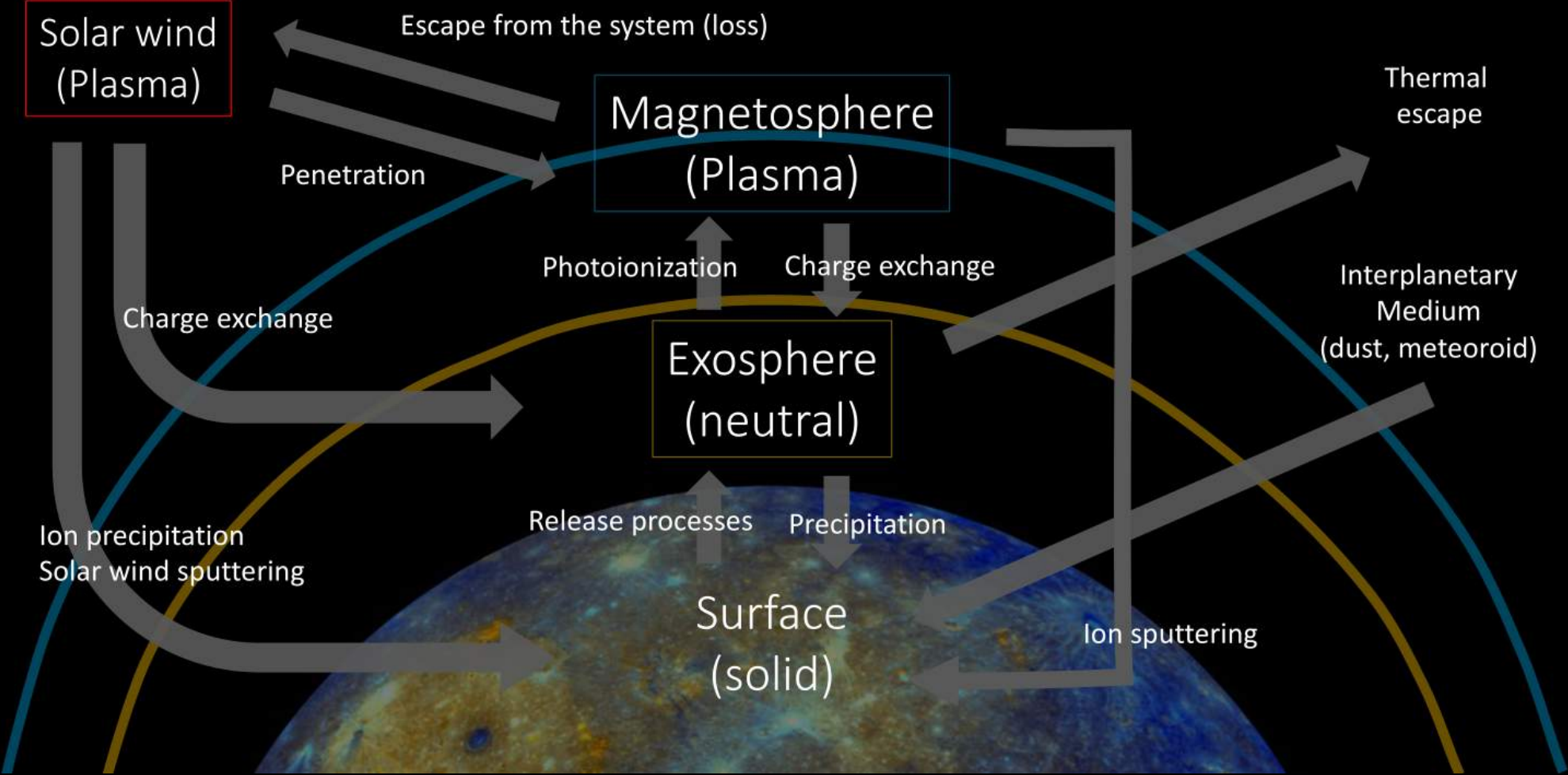
→ No ionosphere/atmosphere; tenuous exosphere.

→ **Different coupling system** (large larmor radius of the ions).

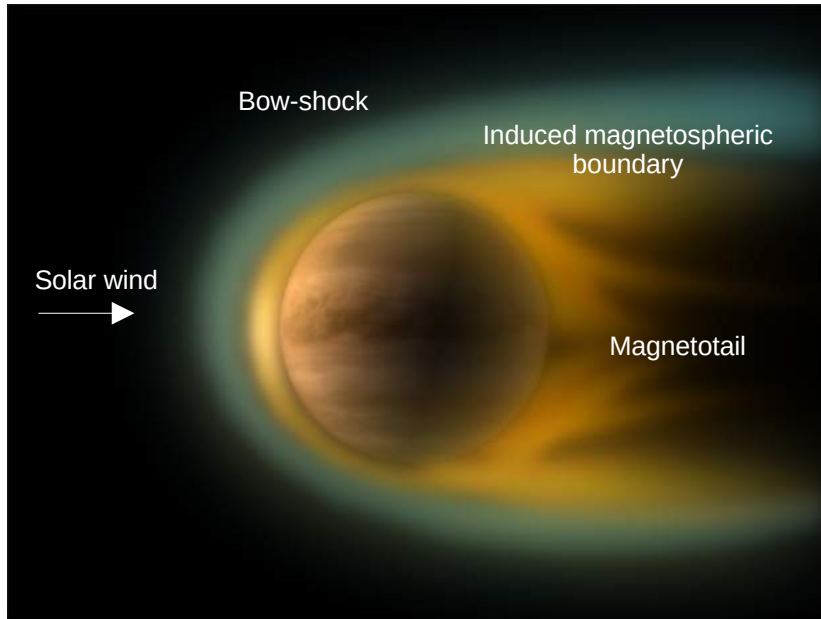
→ Characteristic lengths of the boundary layers \sim Ion inertial length

→ **Kinetic processes are important!**

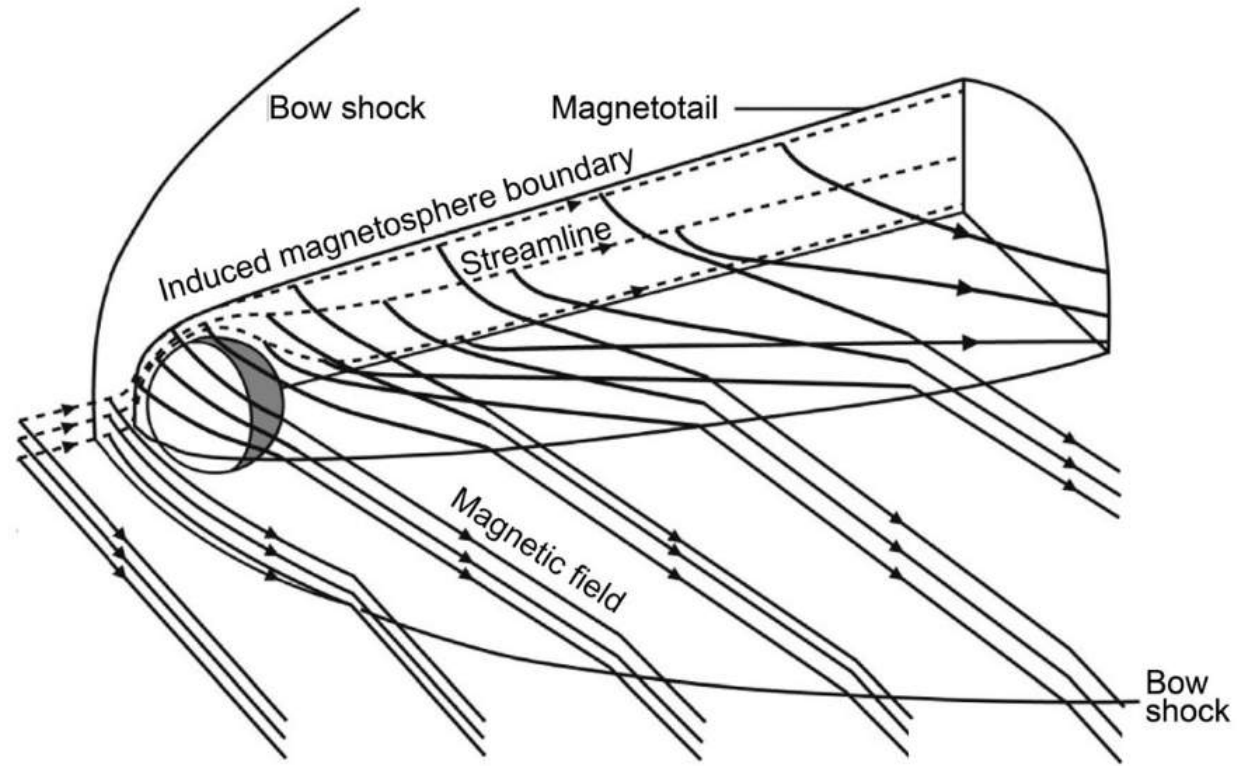
Unique coupled system at Mercury



Venus: Induced magnetosphere



©ESA



Luhmann+1991

The BepiColombo ESA/JAXA mission

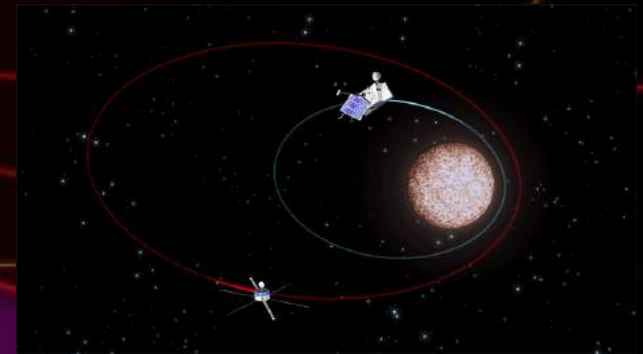


Launch: October 2018
In orbit: December 2025
Science: 2026-2027



Mio
Mercury
Magnetospheric
Orbiter

MPO
Mercury Planetary
Orbiter



BepiColombo's cruise phase



Launch of Ariane 5



October 2018

Earth flyby



10 April 2020

1st Venus flyby



15 October 2020

2nd Venus flyby



11 August 2021

1st Mercury flyby



1 October 2021

2nd Mercury flyby



23 June 2022

3rd Mercury flyby



20 June 2023

4th Mercury flyby



5 September 2024

5th Mercury flyby



2 December 2024

6th Mercury flyby

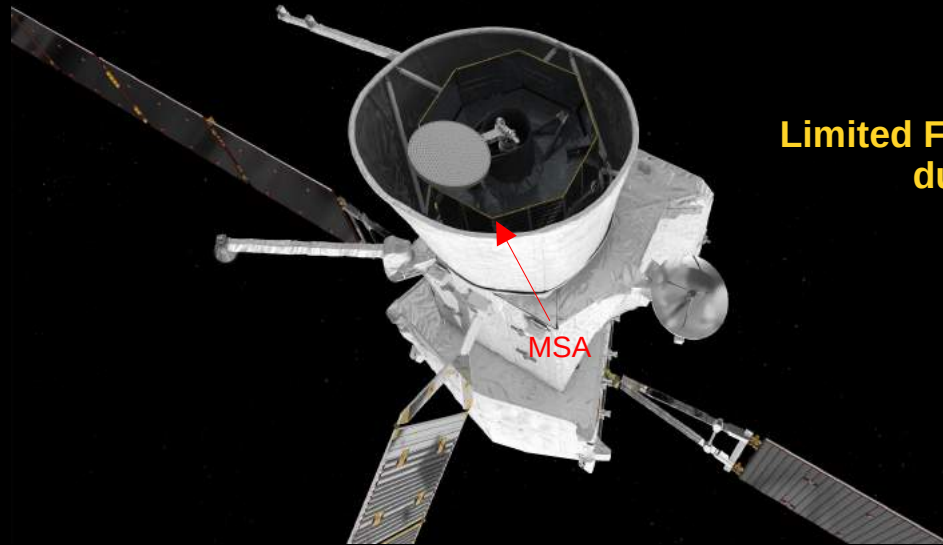


9 January 2025

Arrival at Mercury

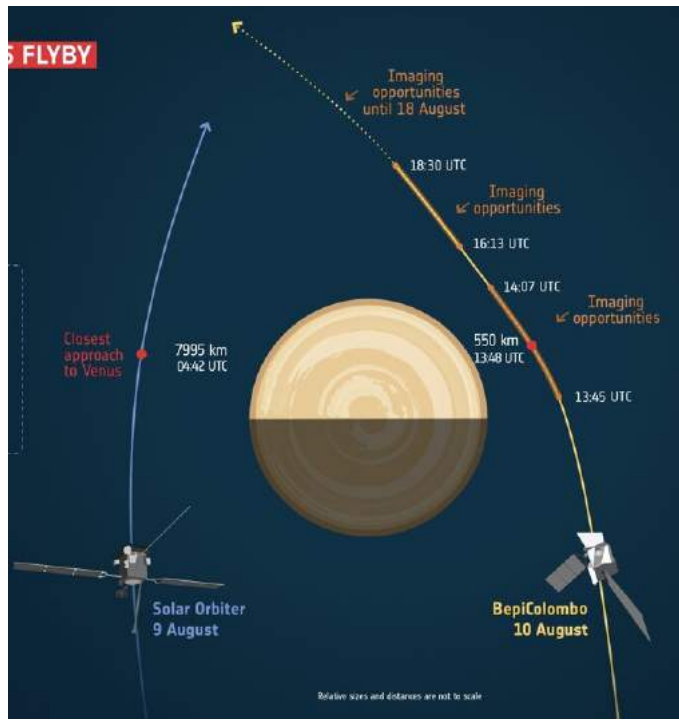


5 December 2025

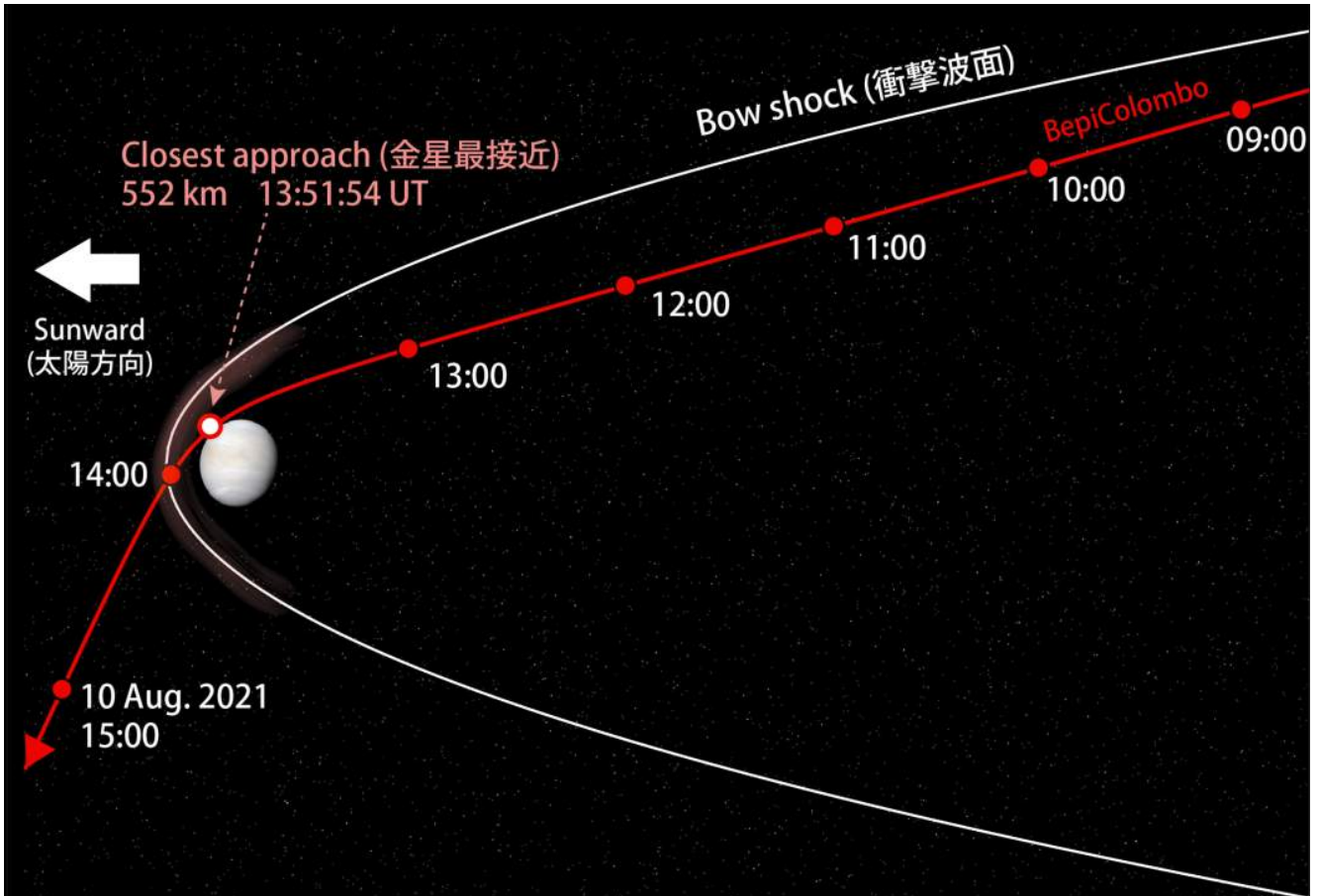


Limited Field-of-View of MSA during cruise!

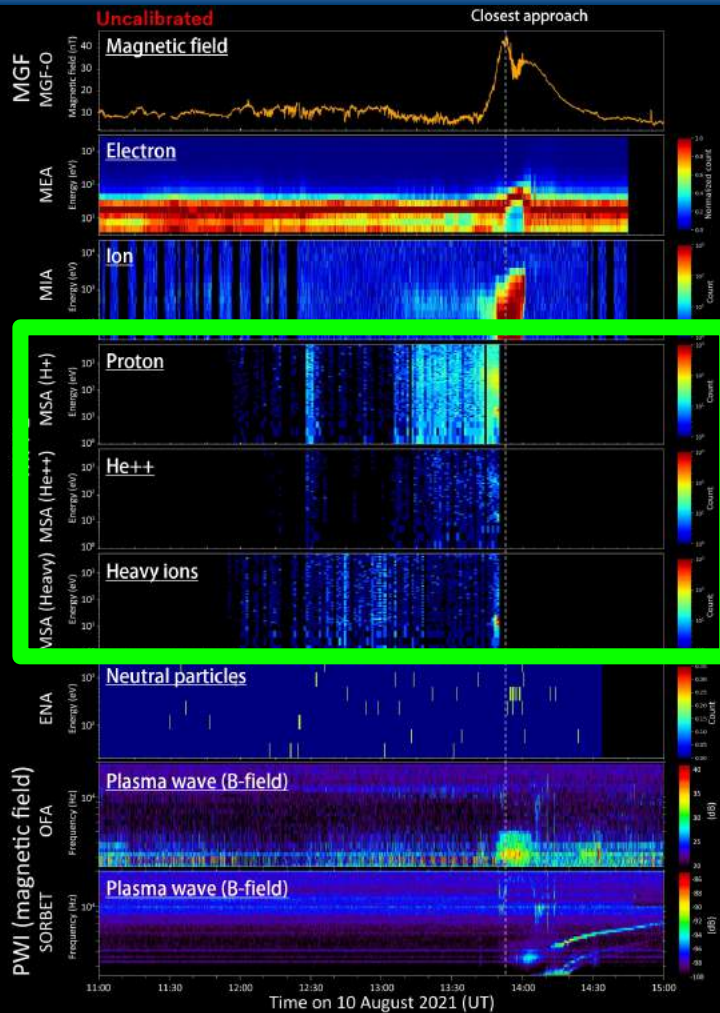
Double Venus flyby: Solar Oribter on August 09 2021



Person et al., Nature Communication, 2023.

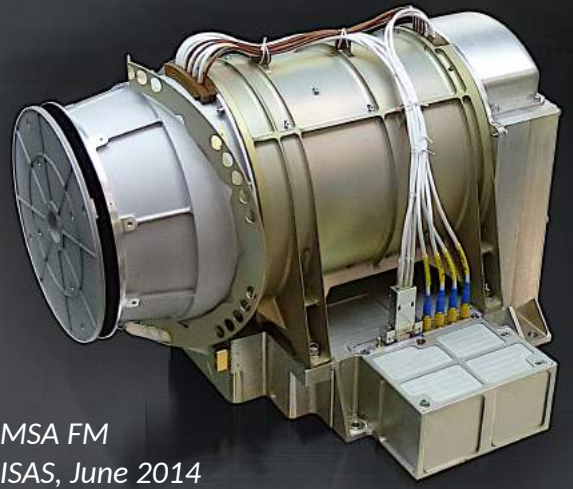


BepiColombo's 2nd Venus flyby on August 10, 2021 and ion observations

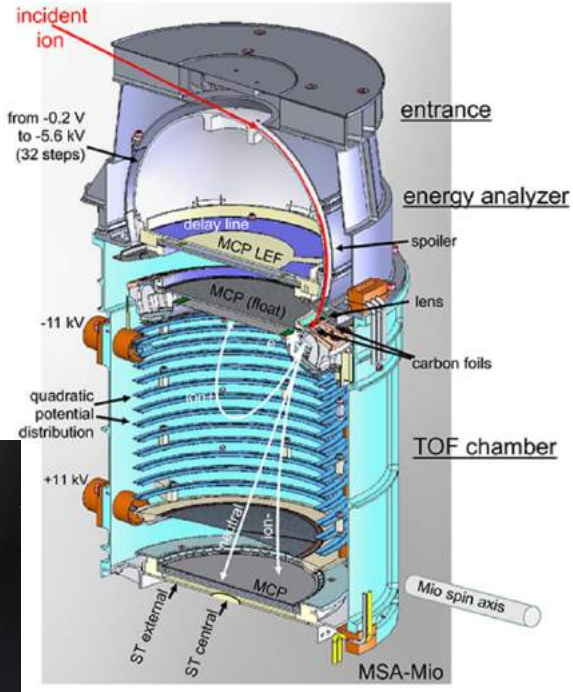


→ Part of the Mercury Plasma Particles Experiment, (PI: Yoshifumi Saito, ISAS/JAXA, Co-PI: D. Delcourt LPP/France)

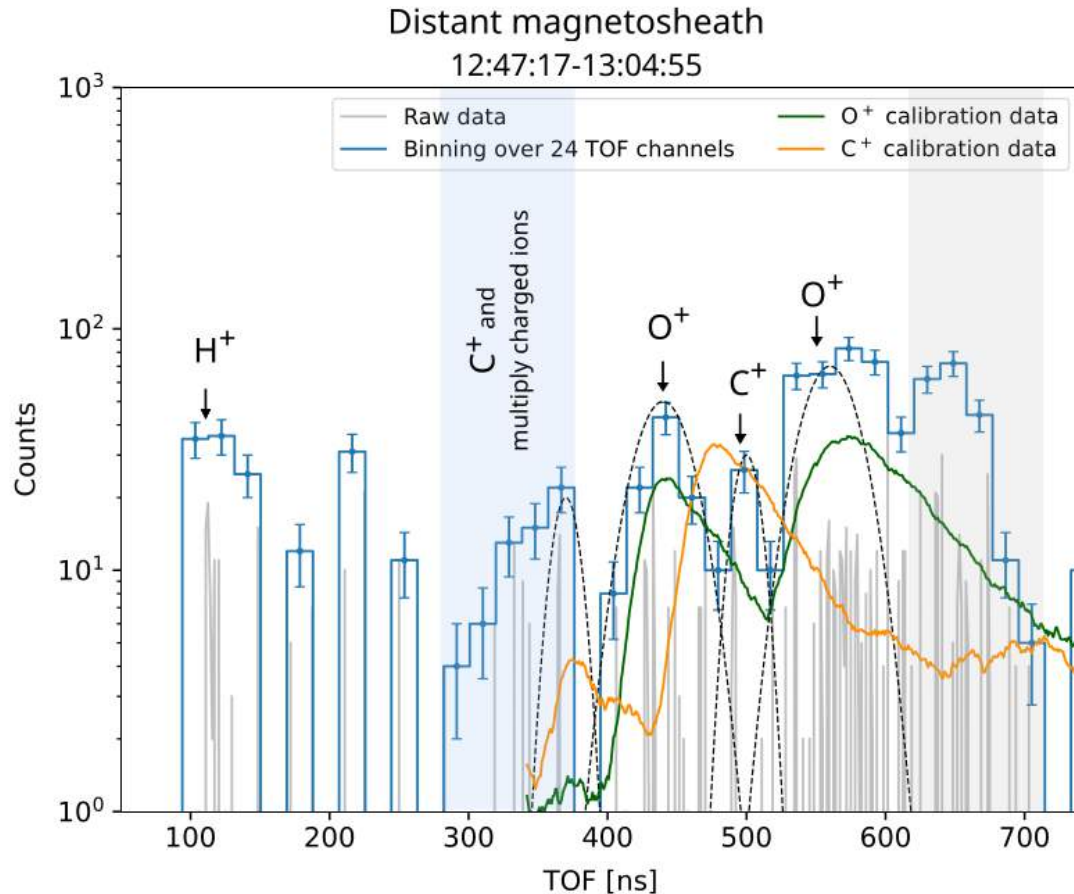
→ 3D ion distributions with high mass resolution



MSA FM
ISAS, June 2014

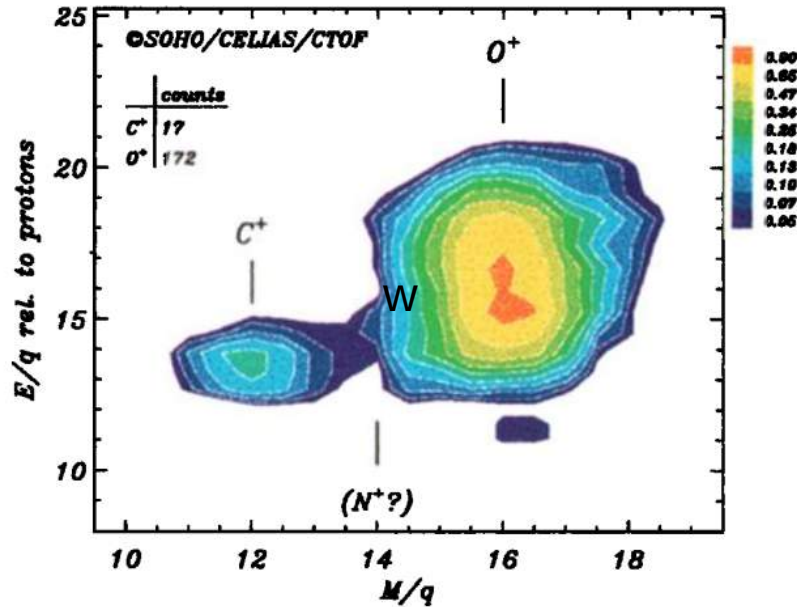


Delcourt et al., JGR, 2016

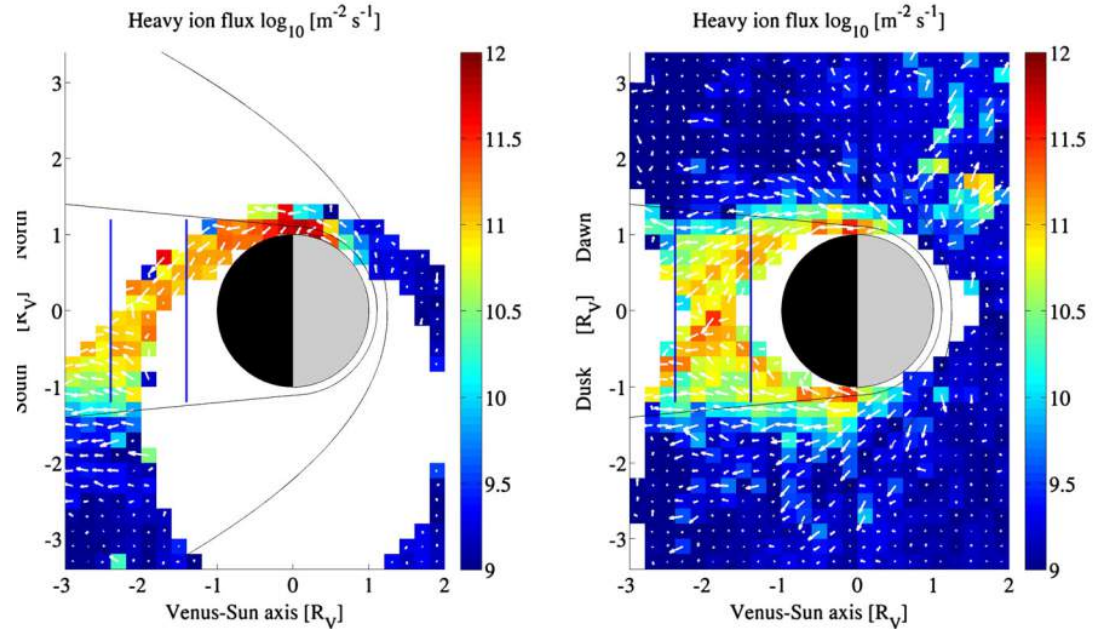


- **Evidence of Oxygen and Carbon ions in the flank of Venus magnetosphere in the vicinity of the MPB.**
- The observed abundance of C⁺ with respect to O⁺ at most 30%
- Surplus of O⁺ inconsistent with only CO group ions source (additional H₂O ?)
- Average total flux $\sim 4 \pm 1 \times 10^4 \text{ cm}^{-2}\text{s}^{-1}$

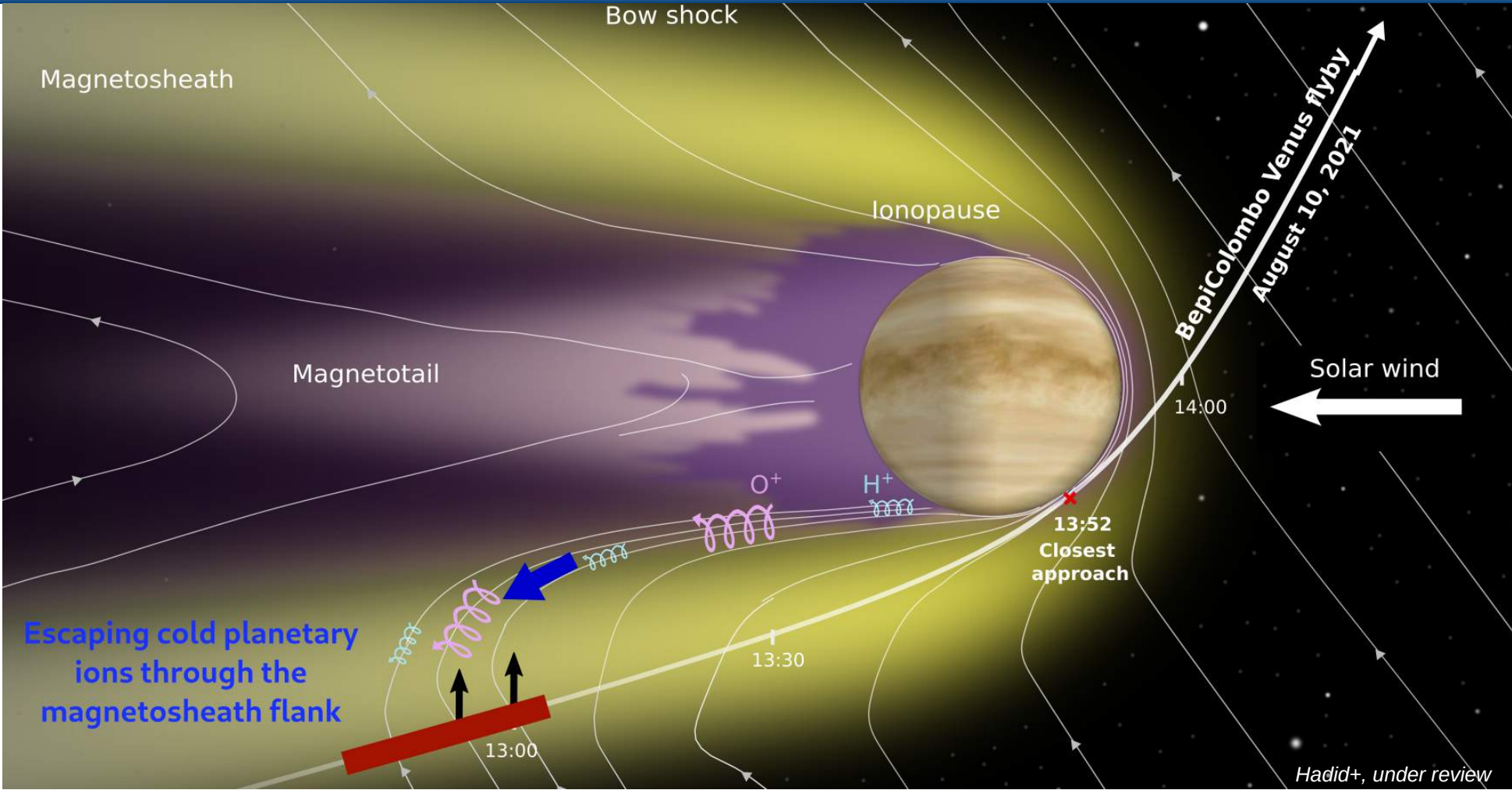
In the ionotail of Venus around 100 R_v by the SOHO spacecraft → $\sim 10^3 \text{ cm}^{-2}\text{s}^{-1}$
 [Grünwaldt et al., GRL, 1997]



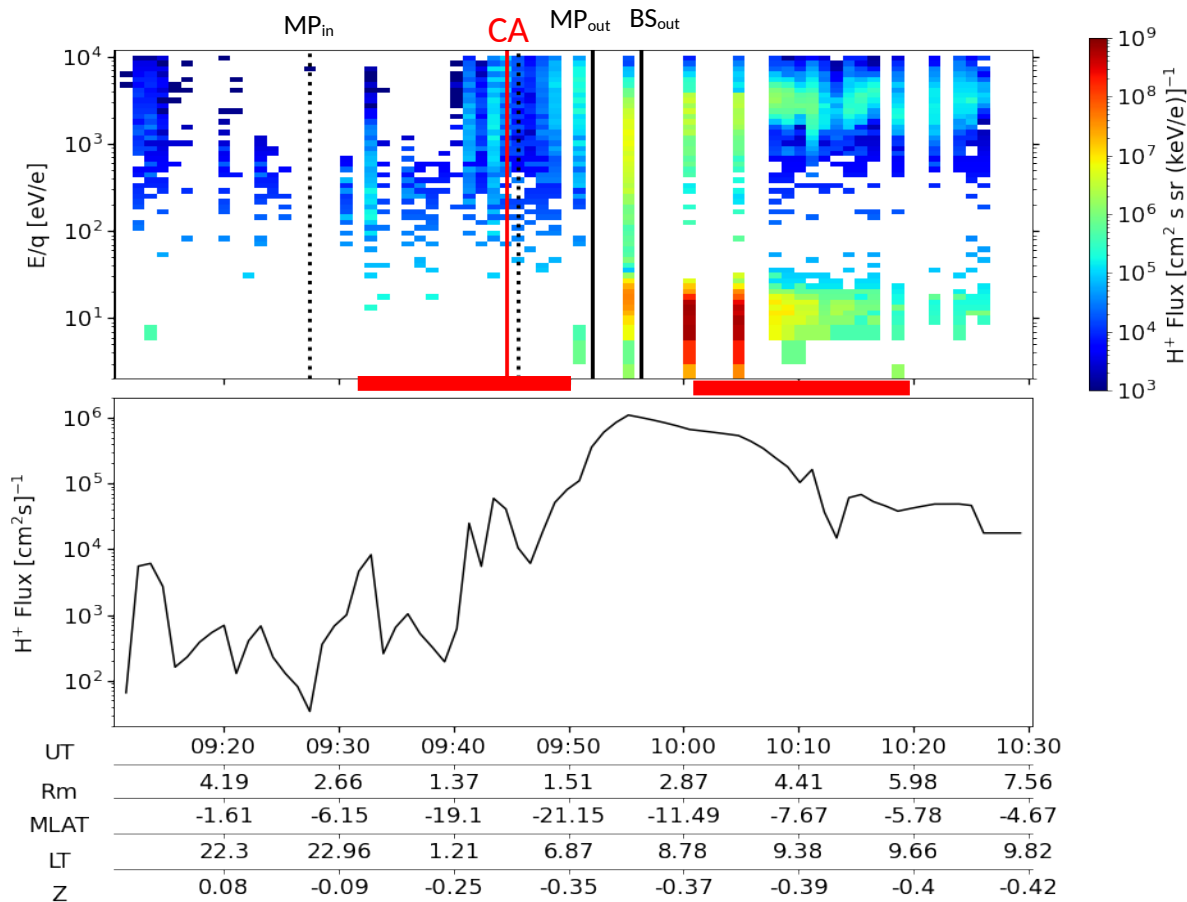
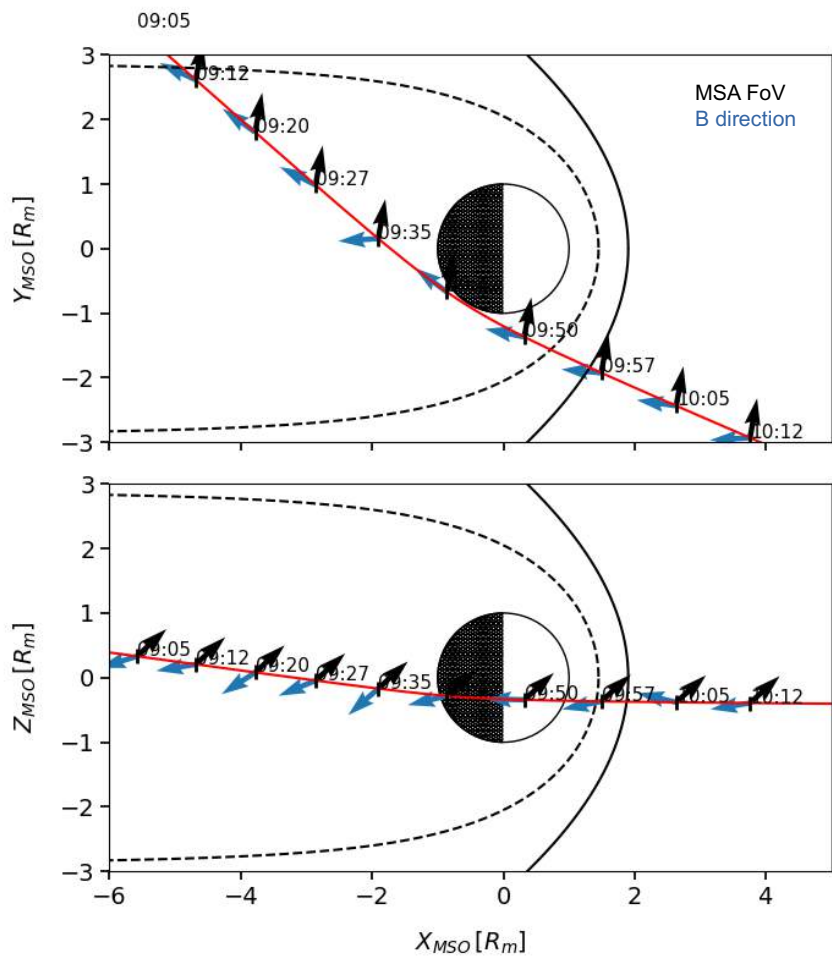
In the magnetosheath flank of Venus around 2 R_v by the VEX spacecraft → $\sim 10^5 \text{ cm}^{-2}\text{s}^{-1}$
 [Nordström et al. JGR, 2013]

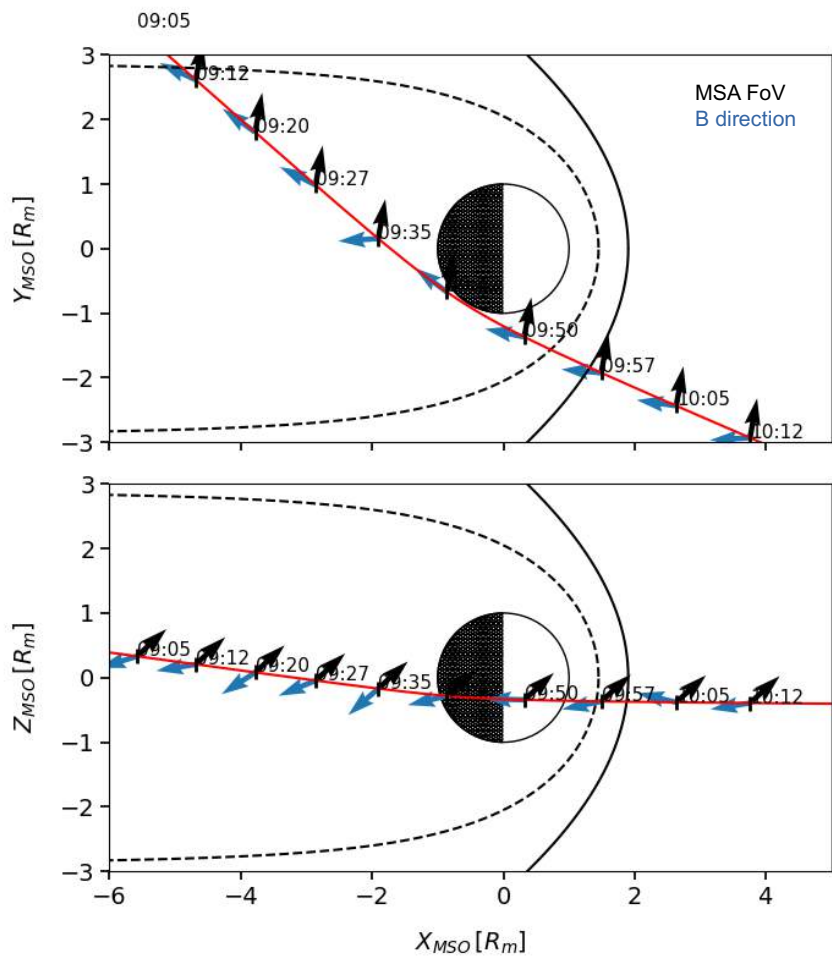


Planetary heavy oxygen and carbon ions



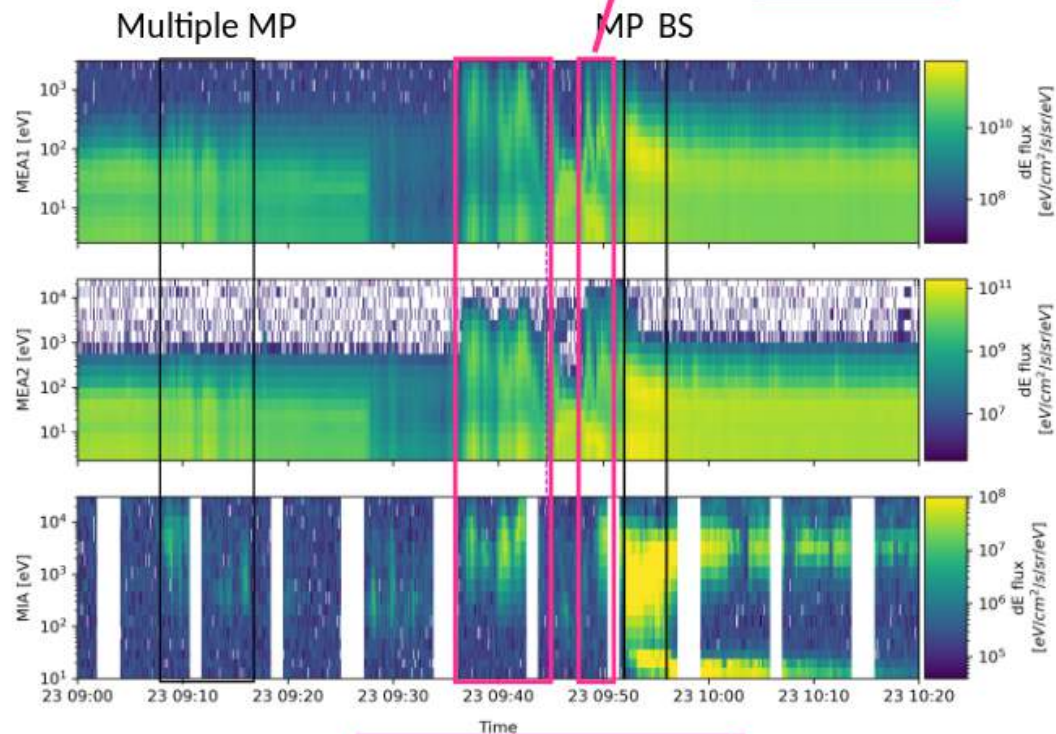
BepiColombo 2nd Mercury flyby: June 23 2022



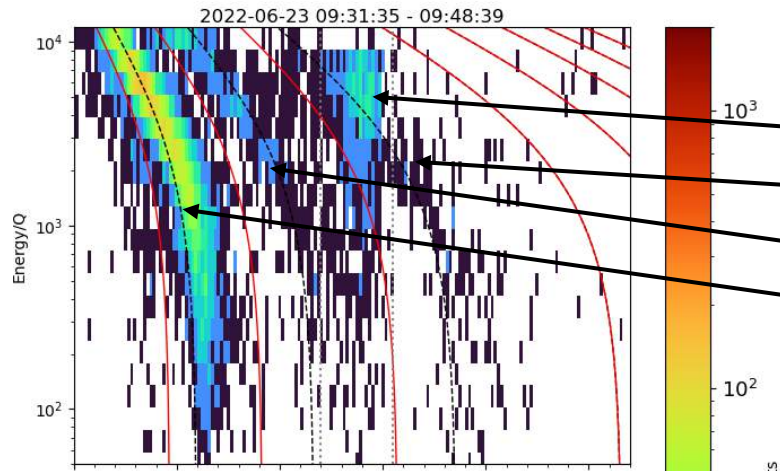


Premières observations des électrons à
Mercure (instruments MEA)

First-ever!
Inverted-V

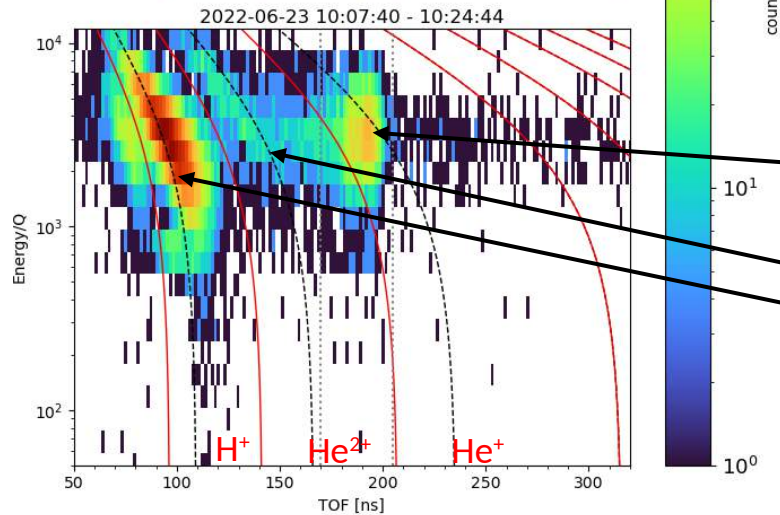


High-energy electrons
(~ keV range)



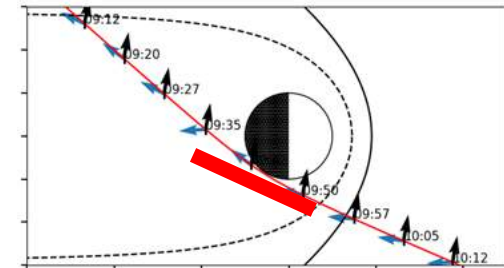
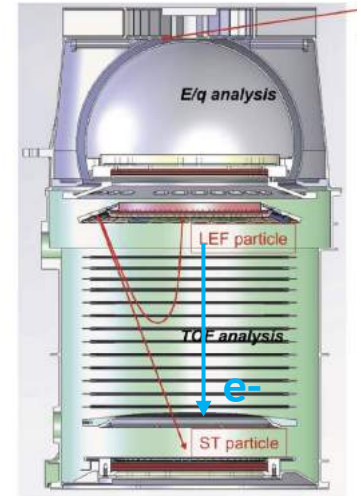
Around CA (09:31 - 09:48 UT)

- * LEF protons (isochronous)
- * He⁺
- * He²⁺
- * protons

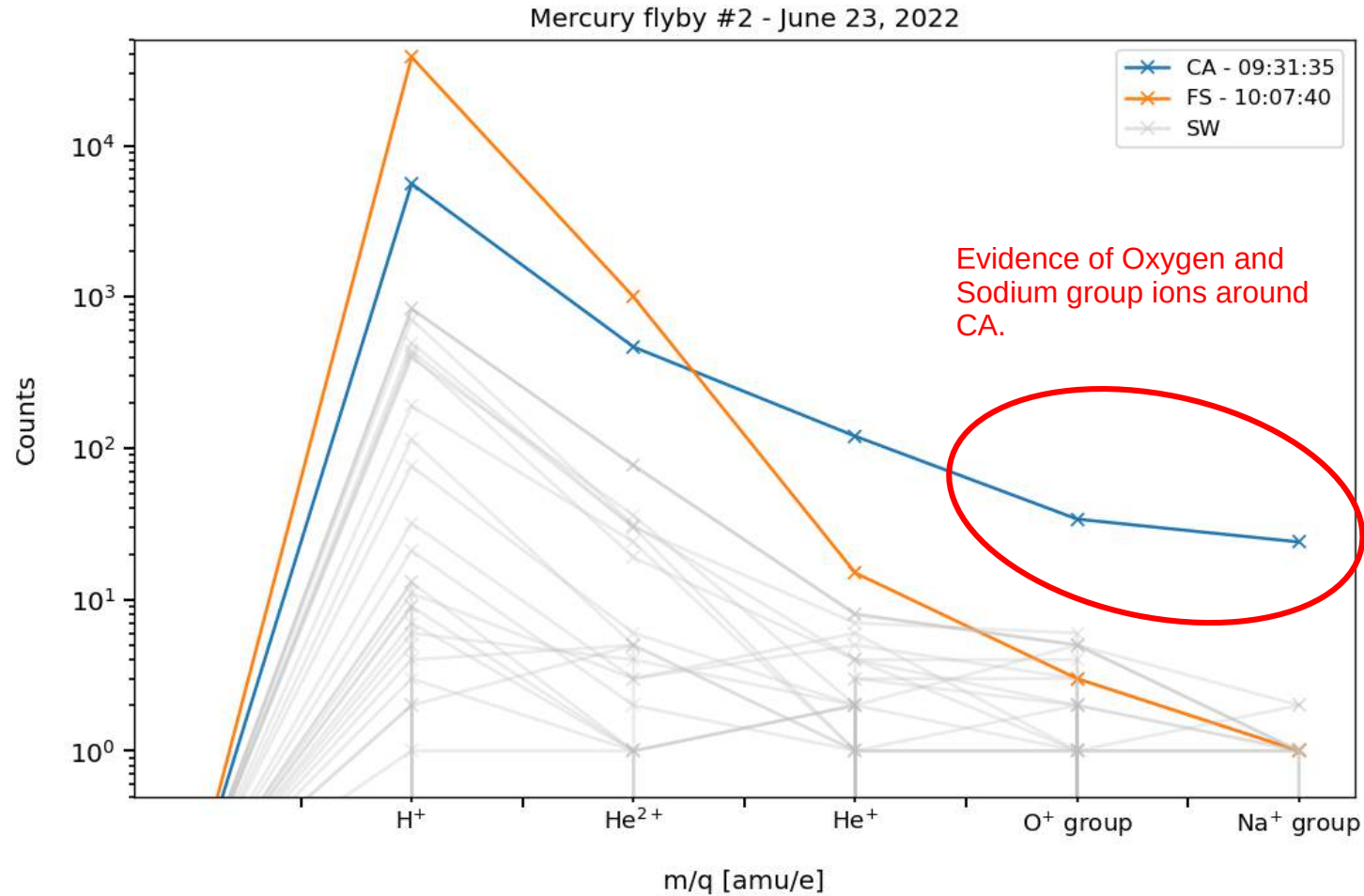


Upstream (10:07 - 10:24 UT)

- * LEF protons (isochronous)
- * He⁺
- * He²⁺
- * protons



Evidence of planetary heavy ions ($m/q \geq 16$)



MSA measurements during BepiColombo Mercury flyby #2 (June 23 2022) reveal :

In the inner magnetosphere

- ✓ Evidences of He^{2+} and He^+ ions of planetary origin in addition to H^+ population (~ 6 keV)
- ✓ Below 1 keV, He^+ dominate over He^{2+}

Upstream of the magnetosphere

- ✓ Evidences of H^+ reflected from bow shock
- ✓ Main population has bulk energy of ~ 3 keV (diffused ion population ? [Glass et al. in prep])
- ✓ H^+ flux decrease away from bow shock

BepiColombo Mercury #3 flyby: June 19-20 2023

