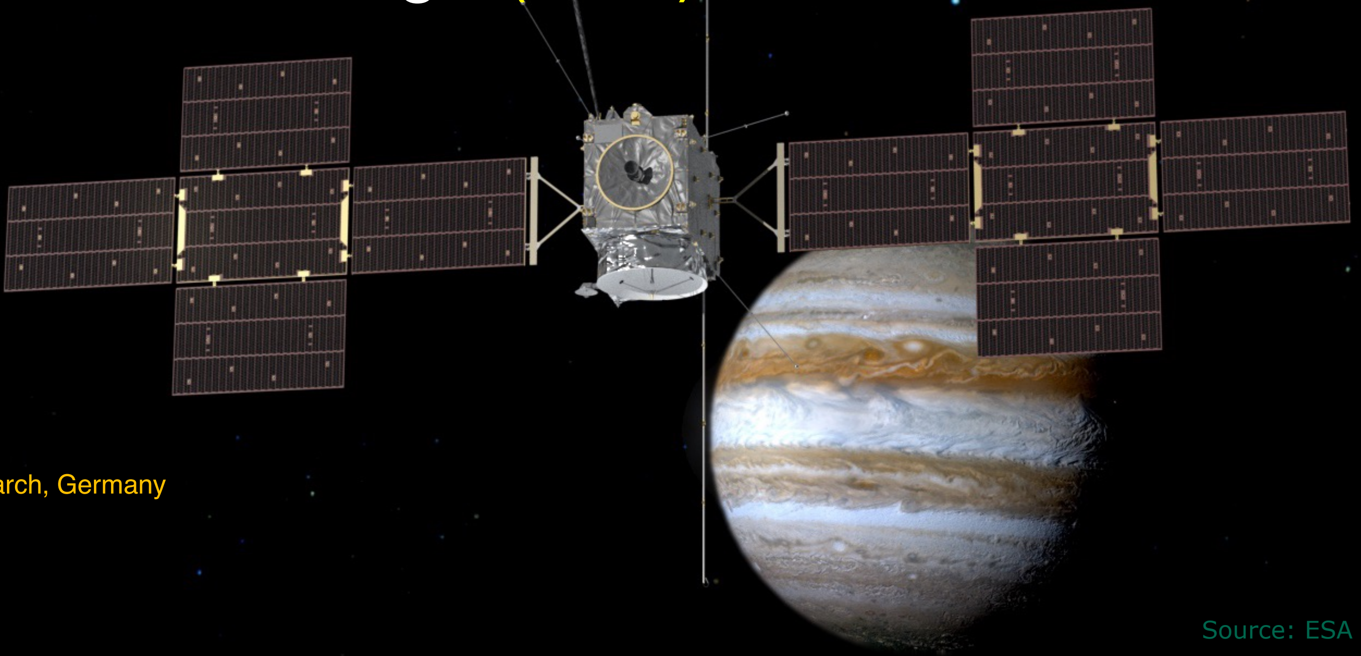
The JUICE mission to Jupiter and the Particle Environment Package (PEP)



Source: ESA

Elias Roussos
Max Planck Institute for Solar System Research, Germany

What is JUICE;

JU.IC.E: JUpiter ICy Moons Explorer

1. The first L-class mission of ESA's Cosmic Vision program

2. Target: Jupiter and its three icy Galilean moons

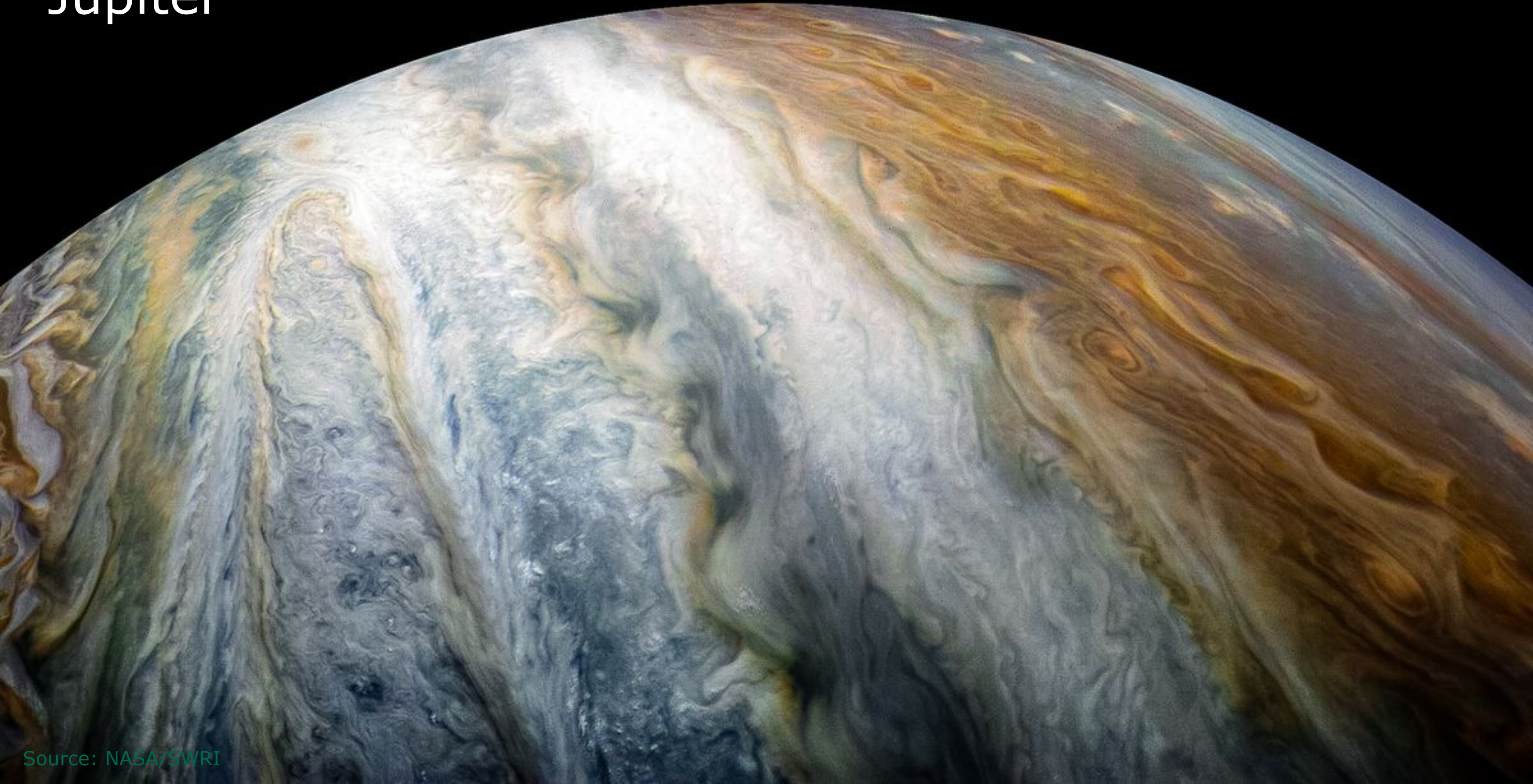
3. Guiding science questions:

    - What are the conditions for the emergence of life in the universe?

    - How does the solar system work?

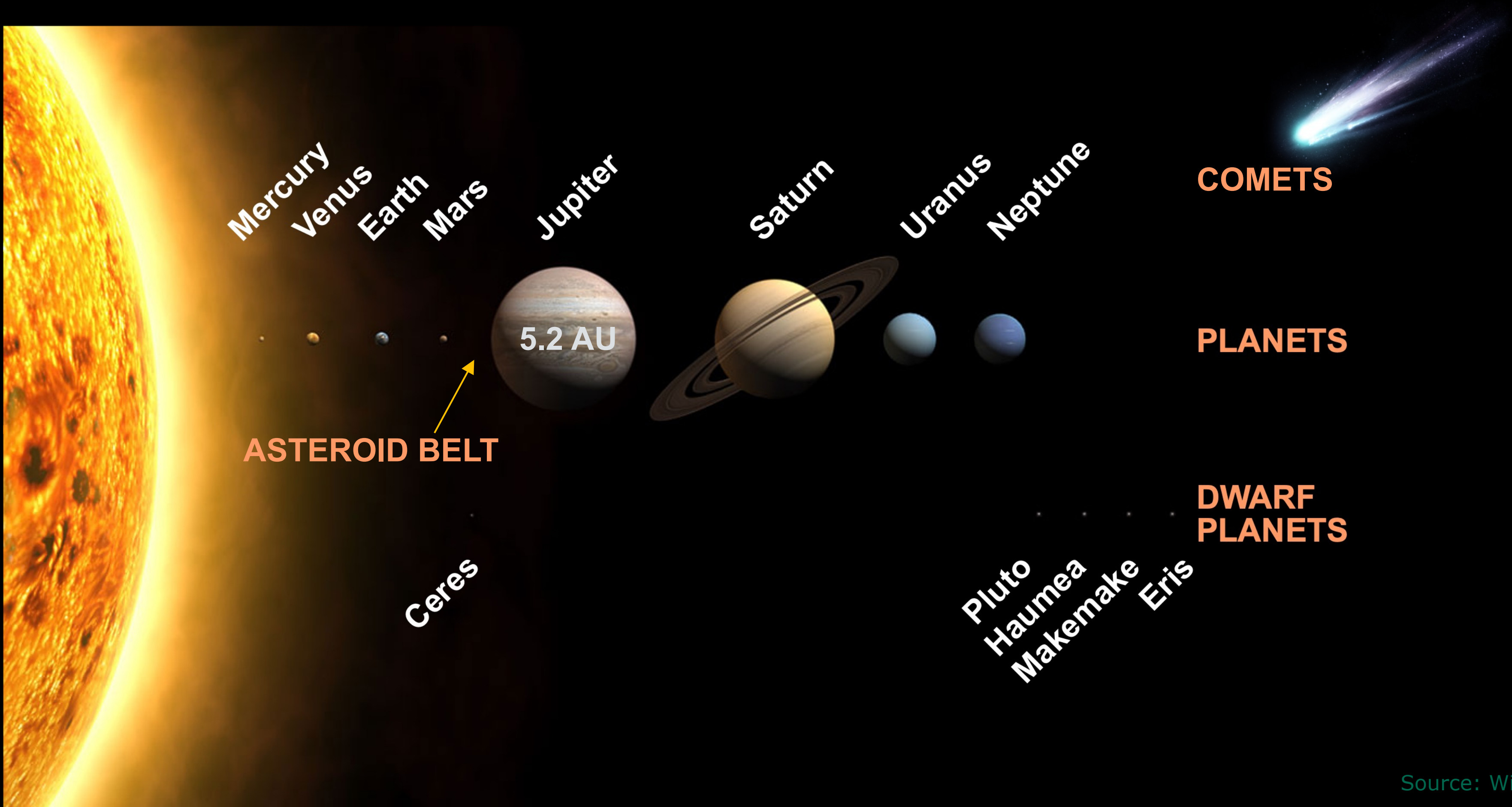
Source: ESA

Jupiter



Source: NASA/SWRI

Our Solar System



Source: Wikipedia

Why Jupiter?

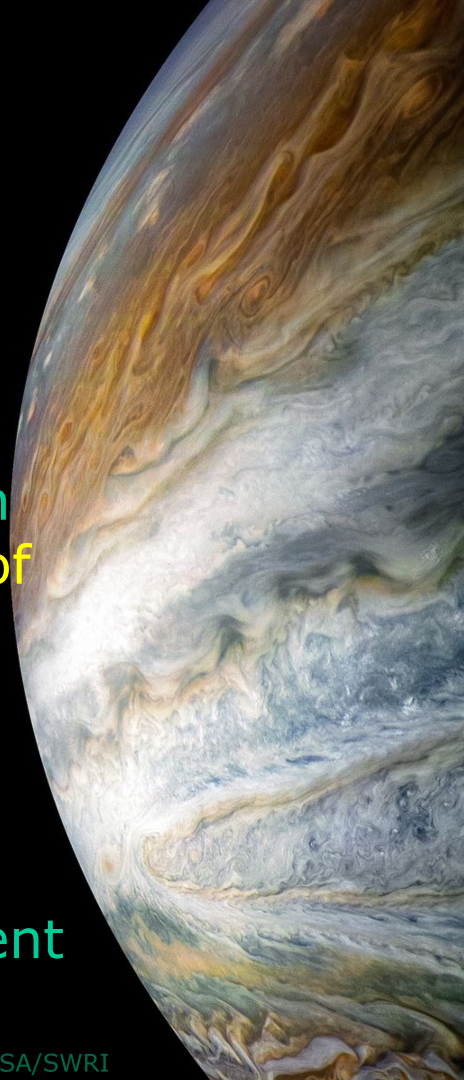
"A planet of superlatives":

The largest and most massive planet
1300 times more massive than the Earth

The strongest magnetic field and the fastest rotation
20000 stronger magnetic dipole moment than that of Earth, 1 jovian day: 9.5 hours

The largest number of natural satellites (95!)
…including four large and very diverse moons

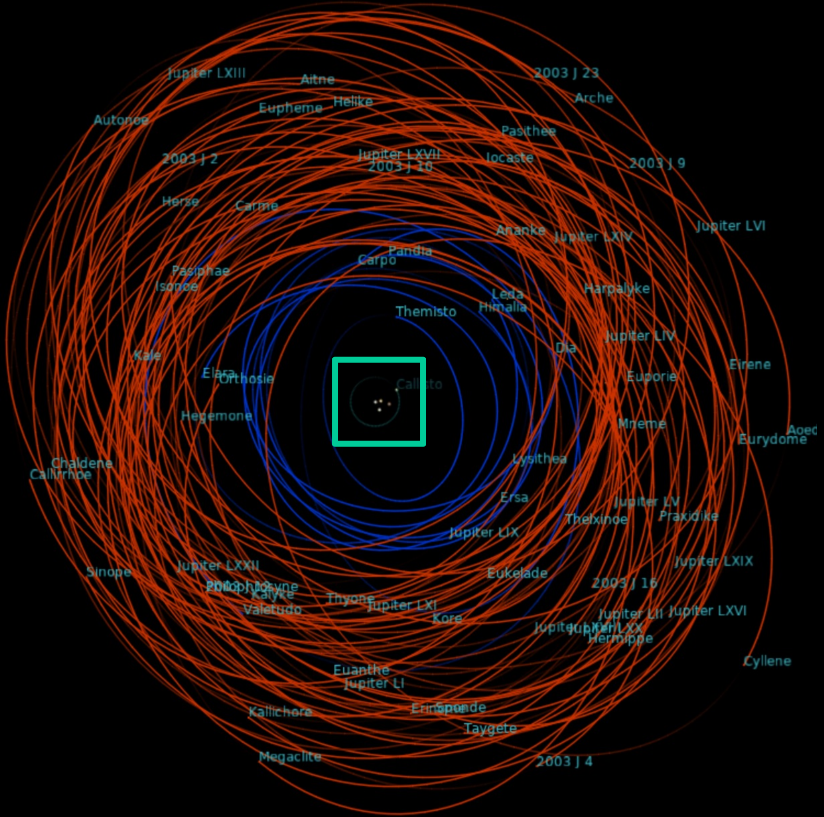
An extreme plasma and particle radiation environment
Best parallel to astrophysical systems



Source: NASA/SWRI

Why Jupiter?

Jupiter's moons & the Galilean satellites



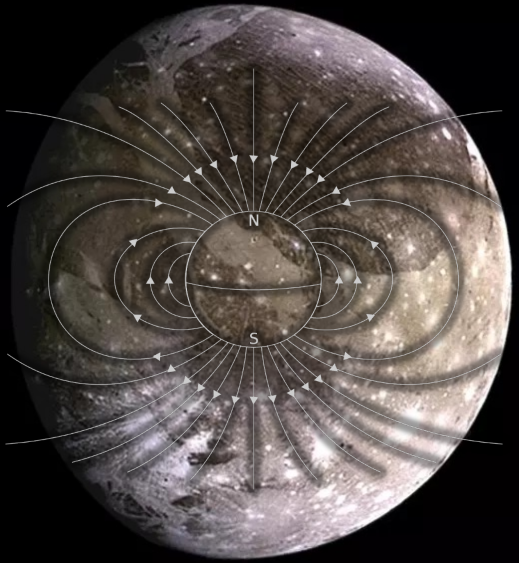
Source: ´Wikipedia

Why Jupiter?

Jupiter’s Galilean moons

Io
(silicate
rock, iron)

Europa
(ice)



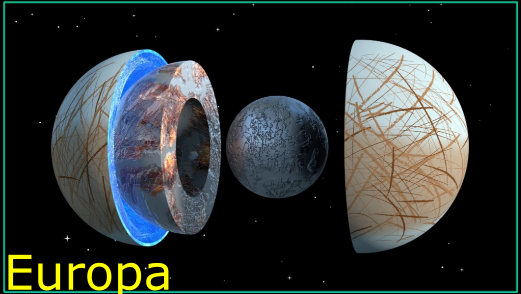
Ganymede
(ice)

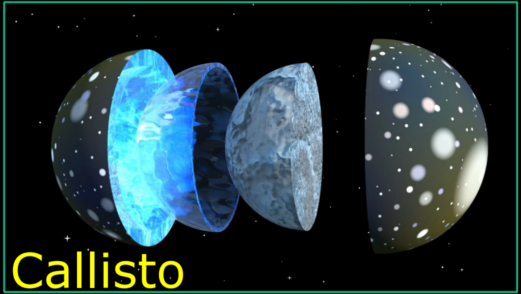
Callisto
(silicate
rock & ice)

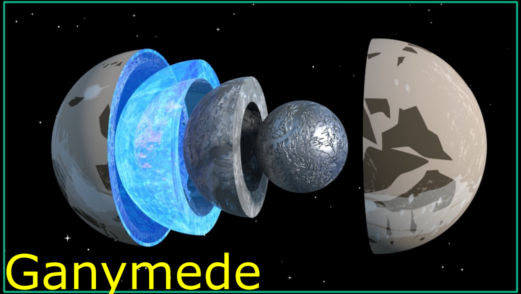
Source: NASA, Wikipedia

Why Jupiter?

Liquid water ocean in the subsurface of the Galilean icy satellites







Source: ESA, NASA

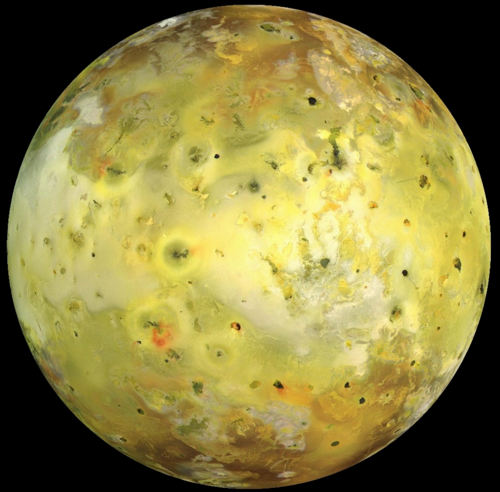
Why Jupiter?

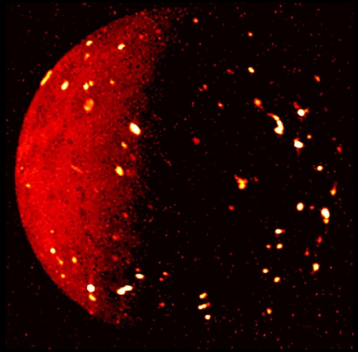
A complex interplay of processes, starting at Io

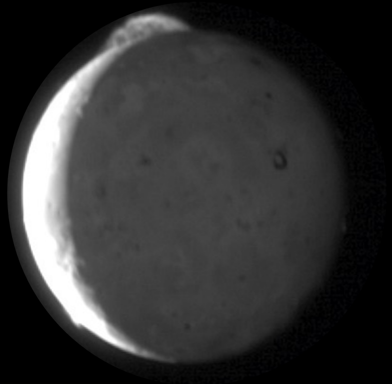
Source: NASA, Wikipedia

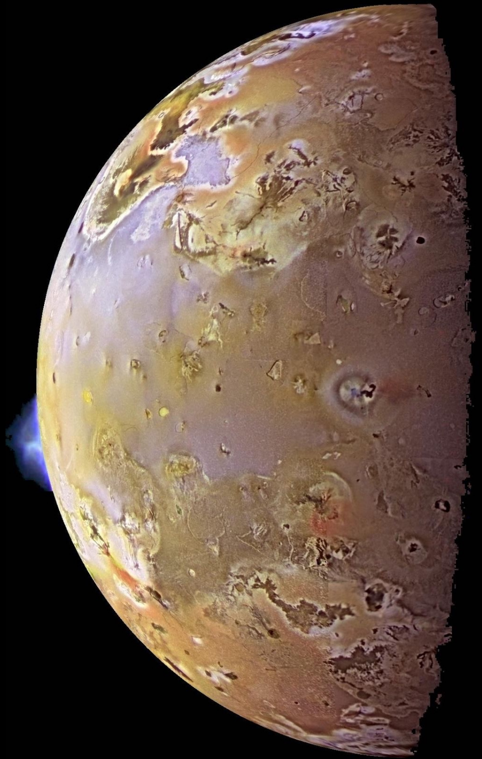
Why Jupiter?

A complex interplay of processes, starting at Io





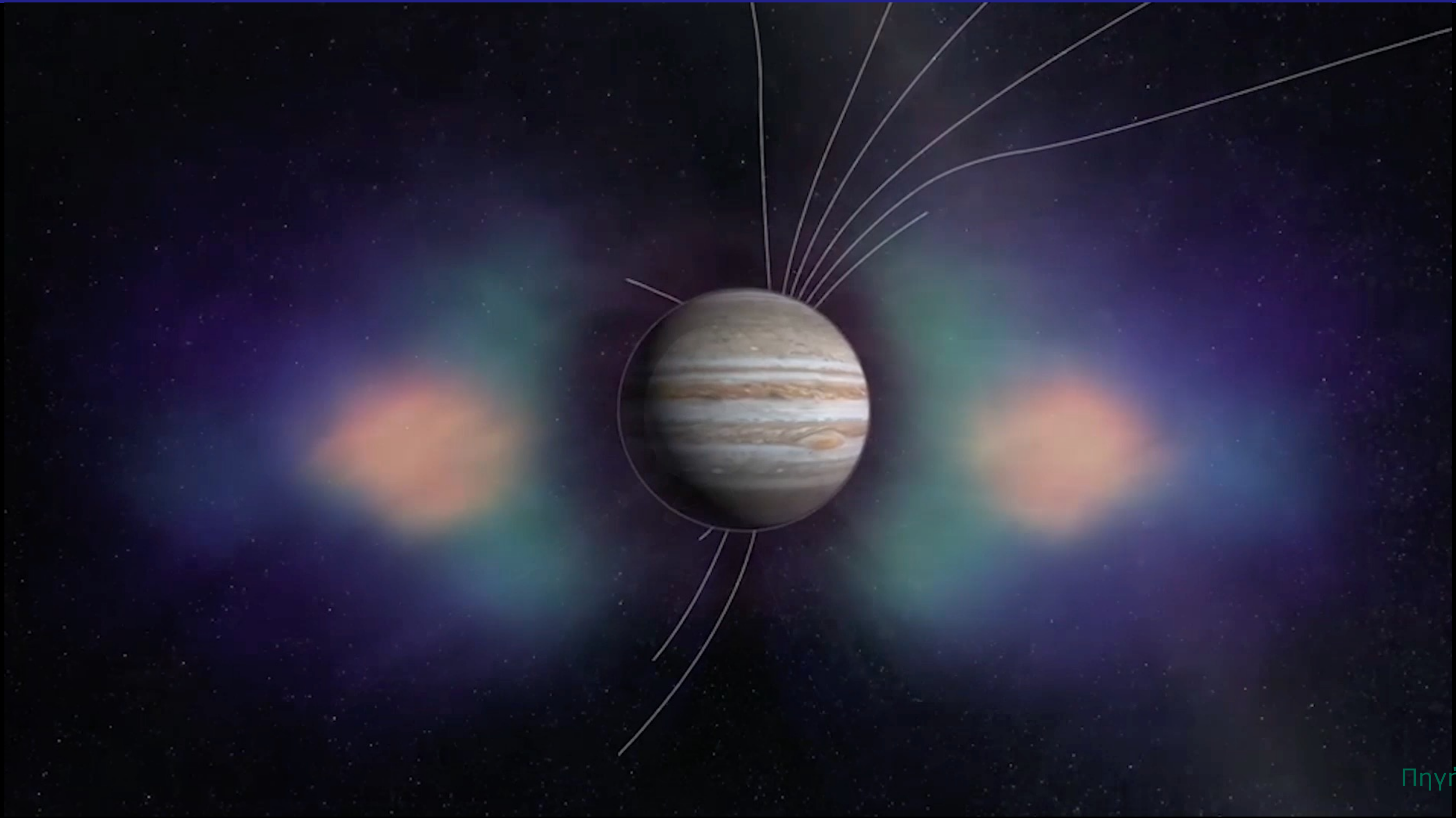




Source: NASA/SWRI

Why Jupiter?

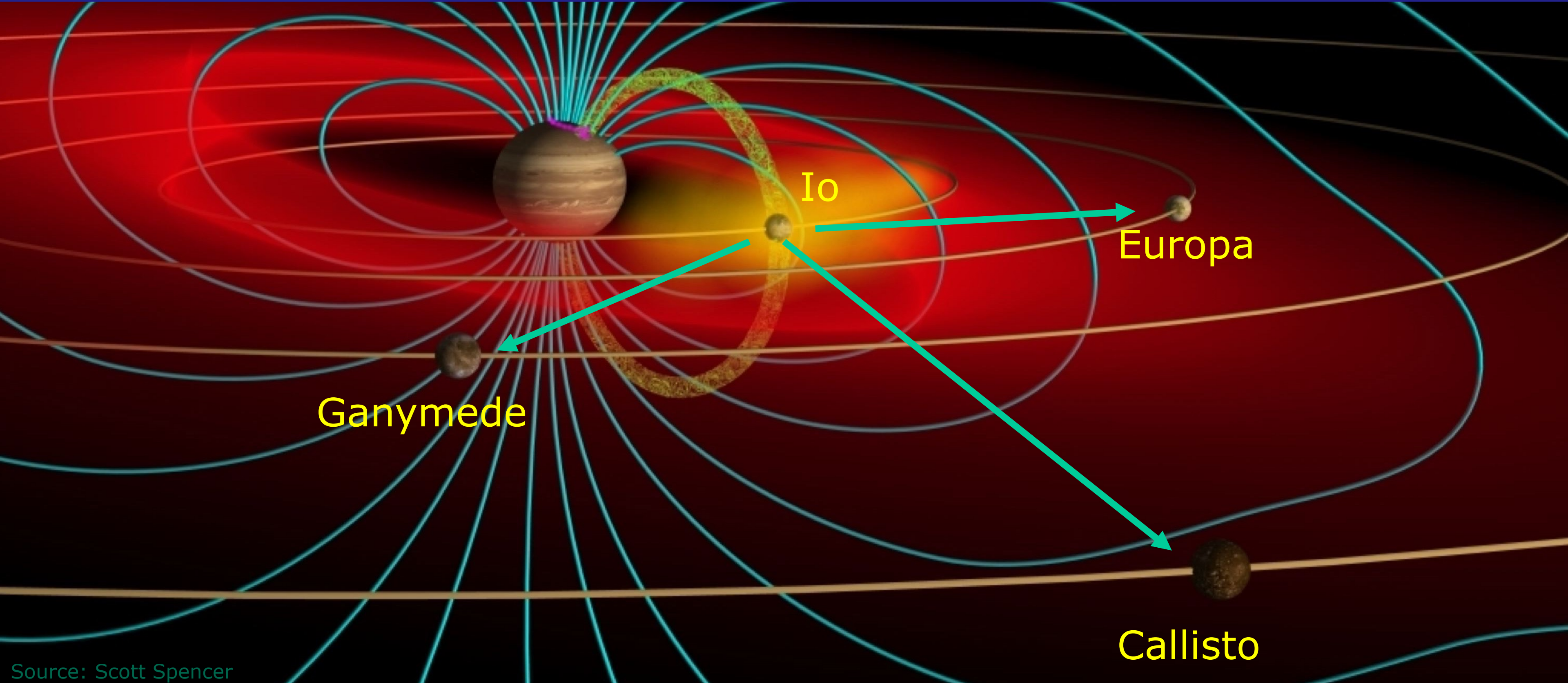
Jupiter's gigantic magnetosphere



Πηγή: Jonothan Nichols

Why Jupiter?

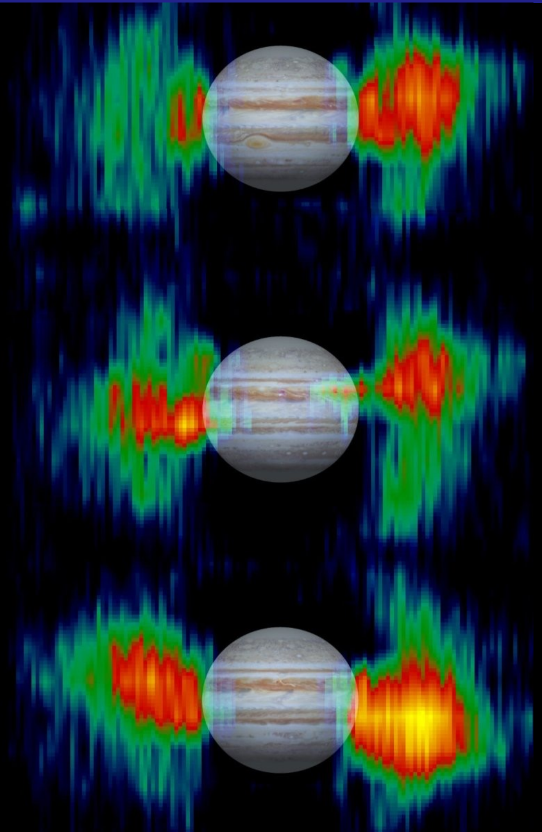
Jupiter’s magnetosphere spreads the impact of Io’s volcanism

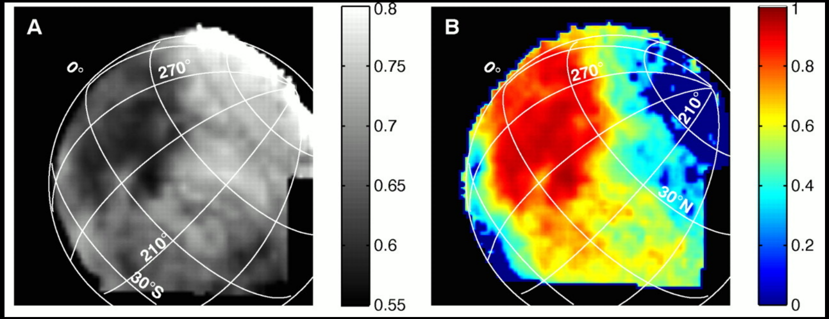


Source: Scott Spencer

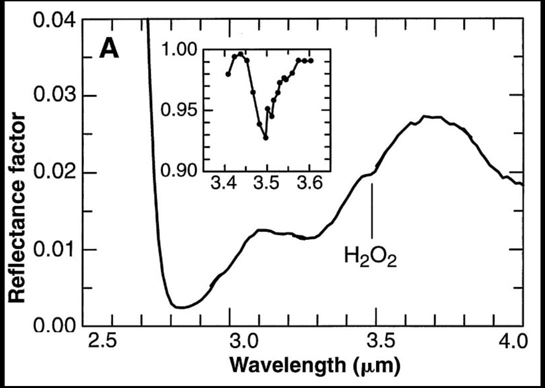
Why Jupiter?

Links between charged particle radiation and astrobiology





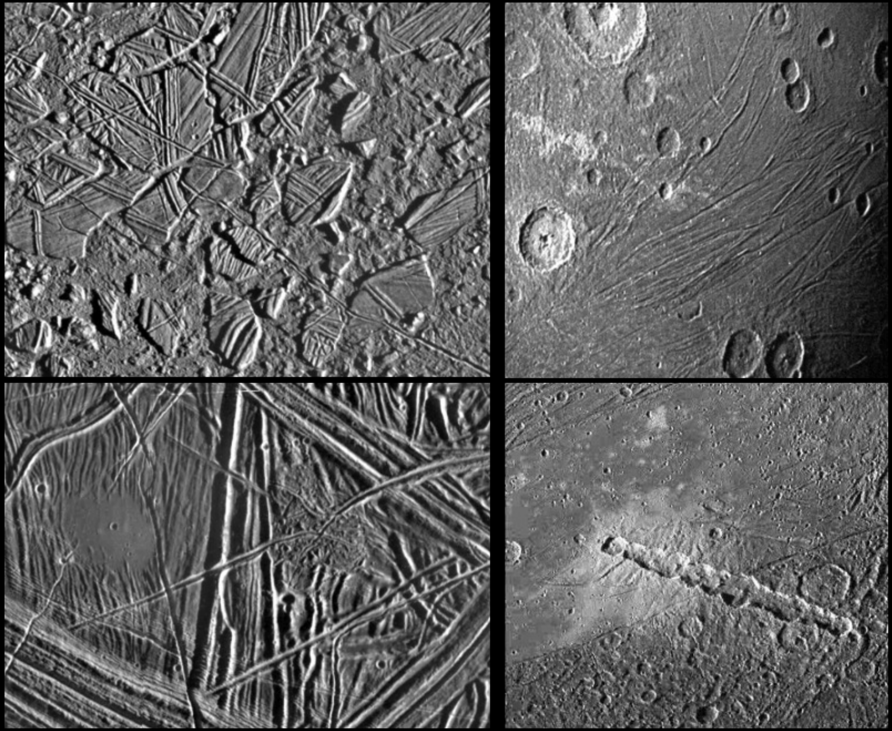
Infrared observations of Europa's surface – detection of salts (McCord et al. 1998)



Detection of Hydrogen Peroxide on Europa's surface (Carlson et al. 1999)

Why Jupiter?

Links between charged particle radiation and astrobiology



Europa Ganymede

Young surfaces indicate mixing of surface and ocean material → salts and hydrogen peroxide delivered to the surface

Why Jupiter? A summary

Ocean worlds

Extreme space weathering environments

Links to astrobiology

A mini ”solar” system in our neighbourhood

Do all Galilean moons harbour subsurface liquid water oceans today?

What are the properties of those oceans?

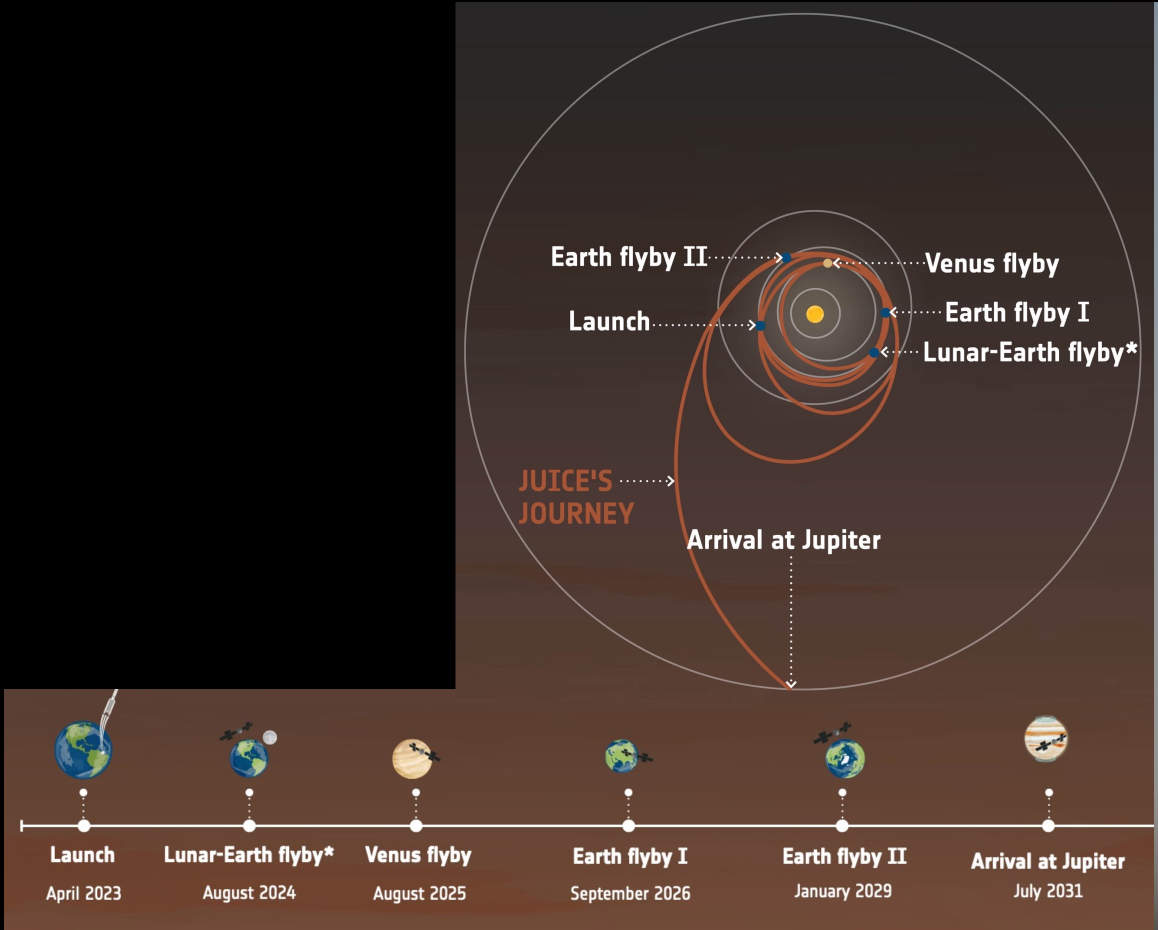
What is the interplay between Jupiter’s space environment and the moons?

Is the ocean environment of the icy moons suitable for hosting life?

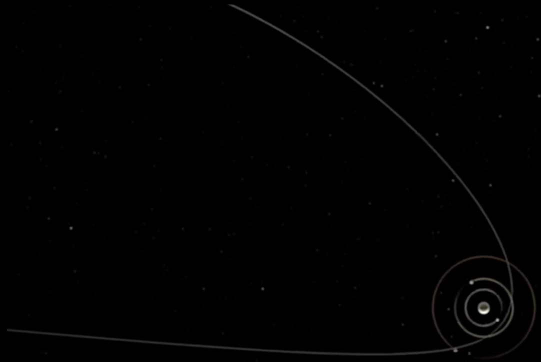
Jupiter’s icy moons are in the spotlight, but they cannot be studied in isolation from Jupiter and its space environment

Source: NASA/SWRI

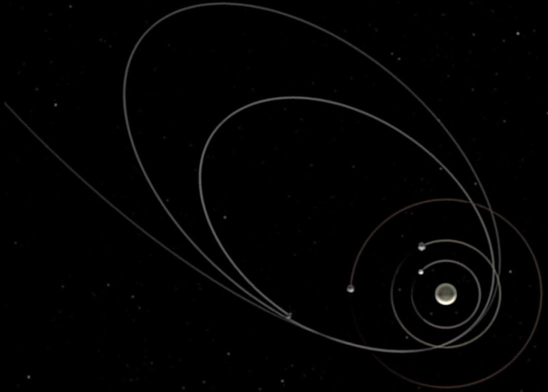
JUICE: mission profile



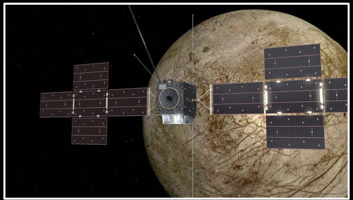
JUICE mission profile



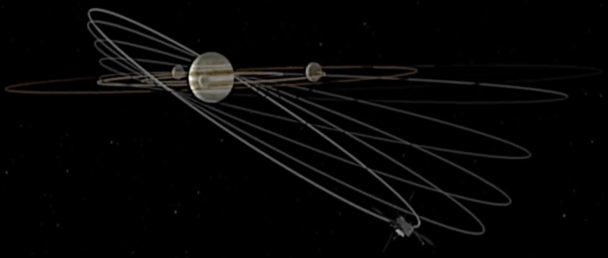
July 2031: Jupiter Orbit insertion



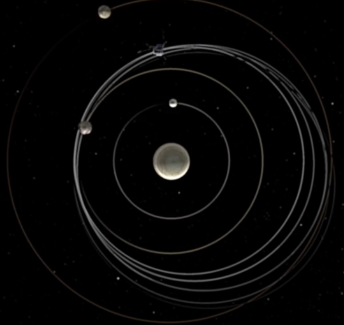
2031-2032: Orbit reduction



+35 moon flybys
2x Europa
12x Ganymede
21x Callisto

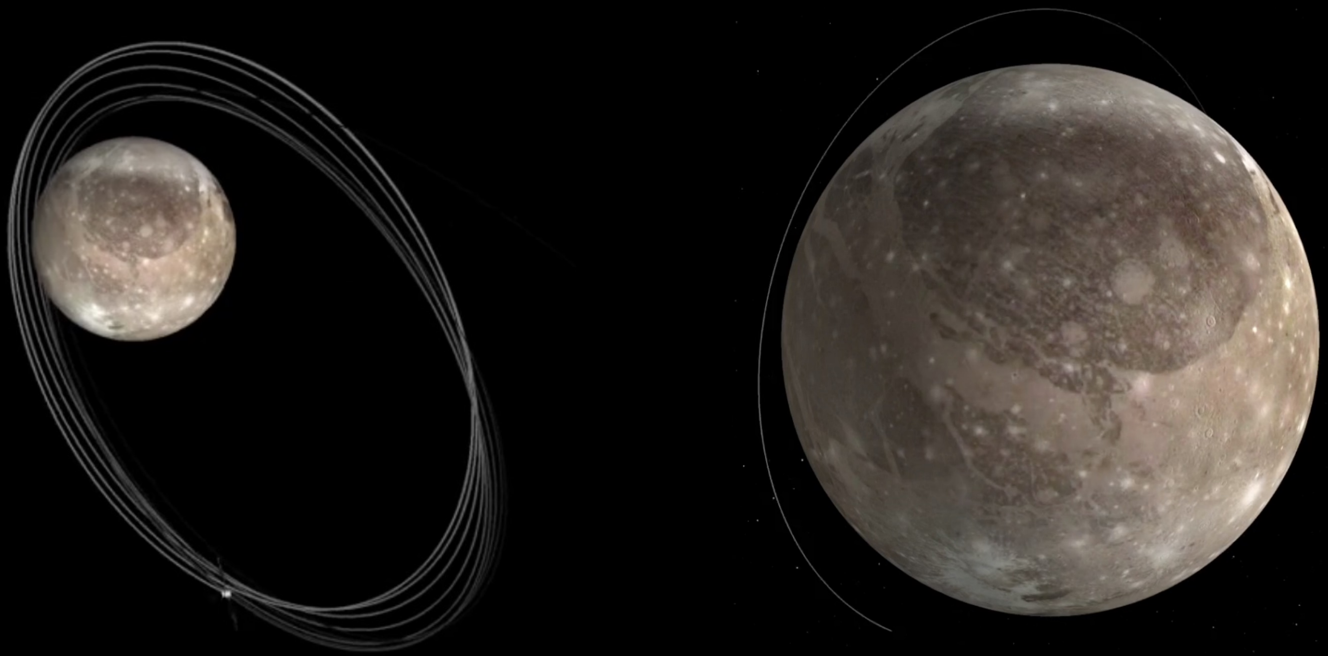


2032: High inclination phase



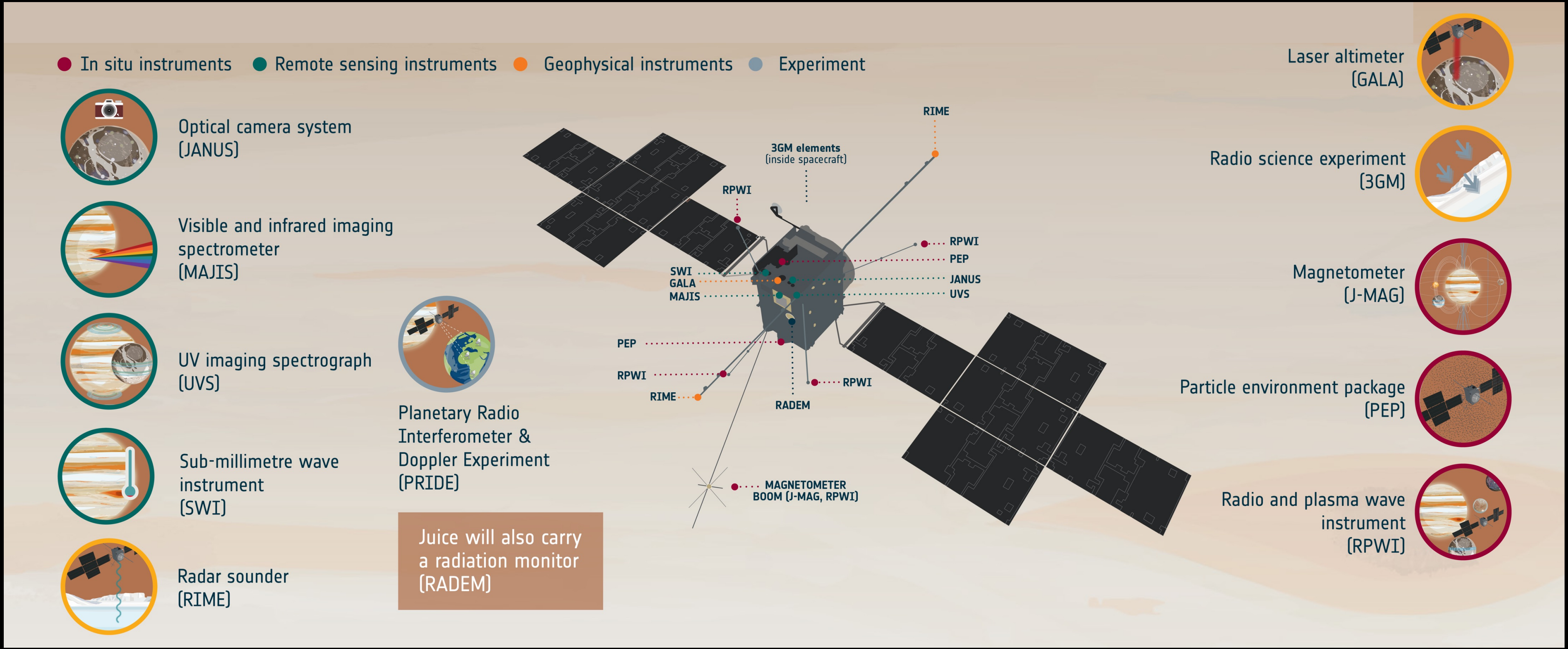
2033-2034: Back to the equator

JUICE mission profile



2034-2035: Ganymede orbit phase, first ever planetary moon orbiter

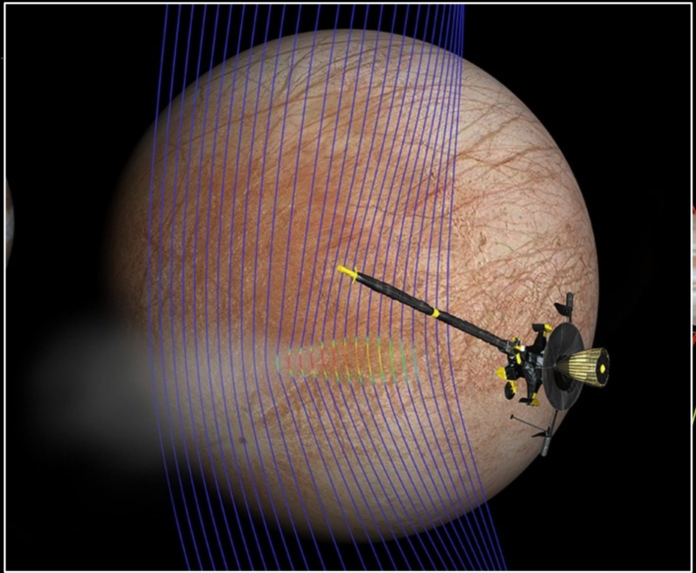
The experiments on JUICE



10 + 3 experiments: remote sensing, sounding, in-situ sampling

Source: ESA

Example: Detecting subsurface oceans



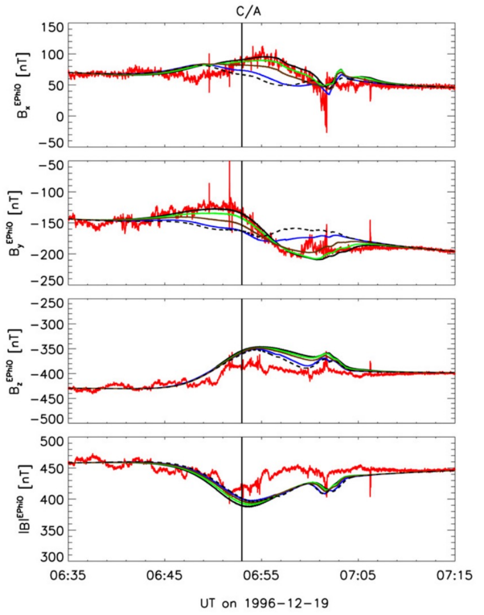
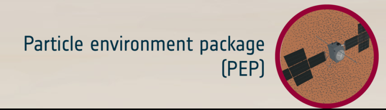


Fig. 5. Observed and modeled magnetic field for the E4 flyby in the EPhiO coordinate system. From top to bottom: B_x, B_y, B_z, B_m. The red curve shows the measured field (Kivelson et al., 1997). The dashed black curve shows the predicted field when no induction is included in our model. The predicted field by including induction is shown for the ocean conductivities σ_{oc}: 100 mS/m (blue), 250 mS/m (brown), 500 mS/m (green), and 5 S/m (black). The assumed thickness of the crust is 25 km and the assumed thickness of the ocean is 100 km.

Galileo E4 flyby:
Schilling et al. (2007)



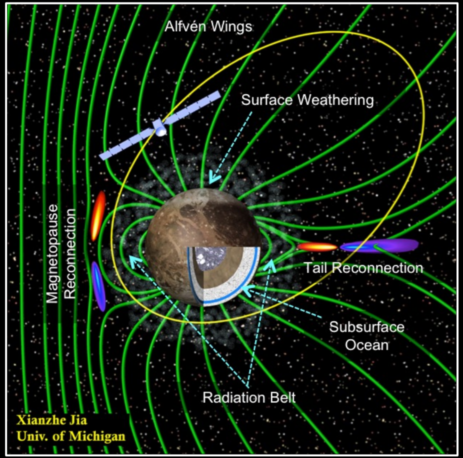
Source: ESA, NASA,
C. Cochrane

The Particle Environment Package

(PI: Stas Barabash, IRF, Sweden)

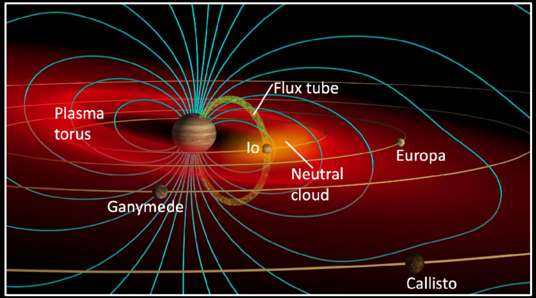
PEP Science Goals

1. How do the icy Galilean moons (Europa, Ganymede, Callisto) interact with the complex and diverse environments of Jupiter's corotating magnetosphere?

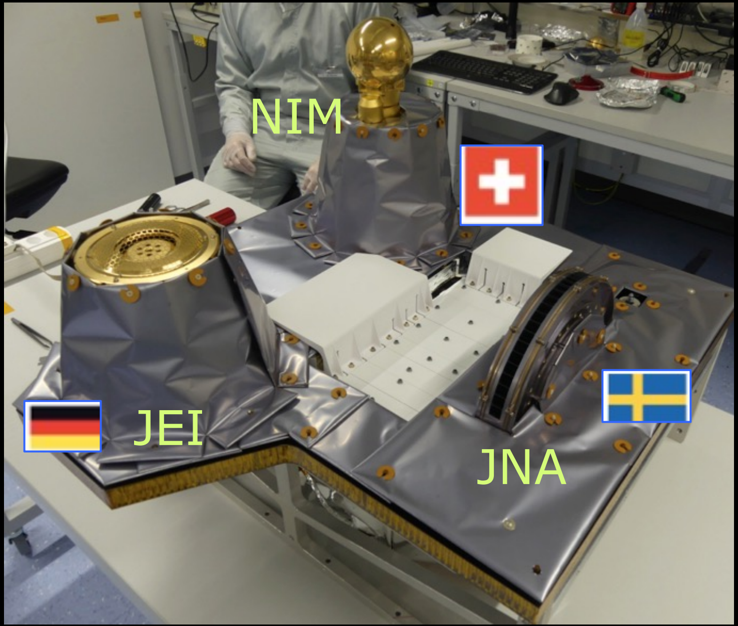


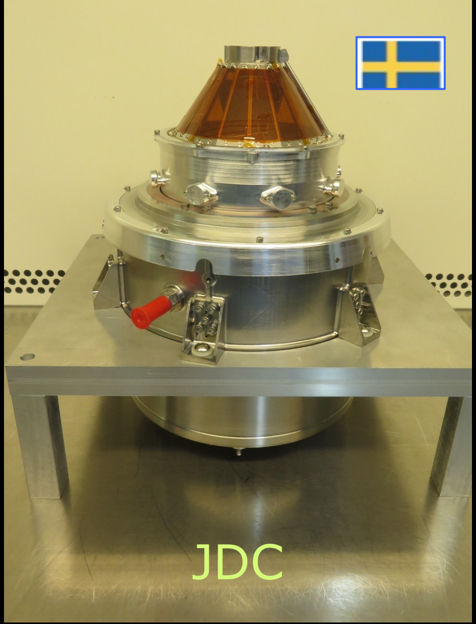
2. What are the mechanisms under which material is released to the jovian magnetosphere by active and inert moons?

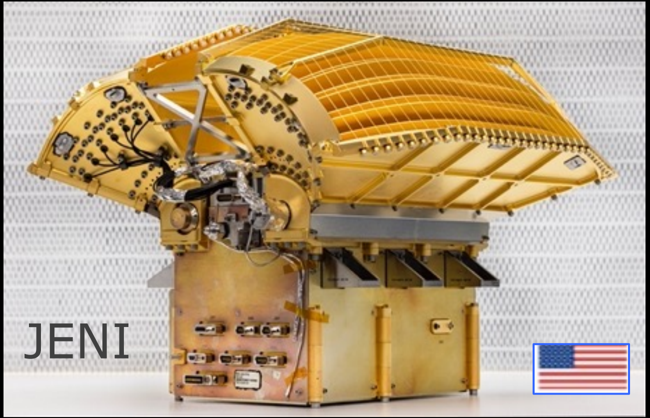
3. How do internal and external solar wind drivers cause such energetic, time variable and multi-scale phenomena in the Jovian magnetosphere

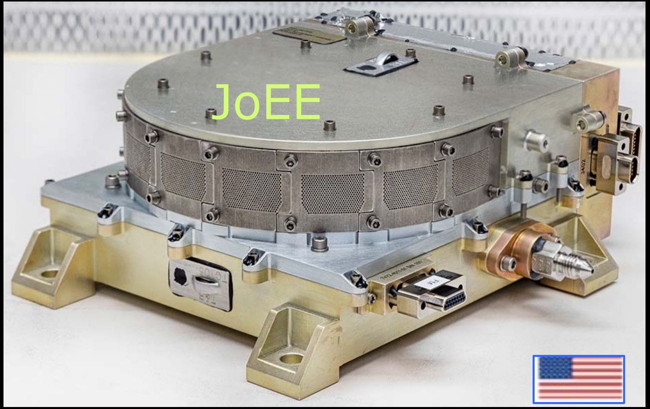


Particle Environment Package (PEP)







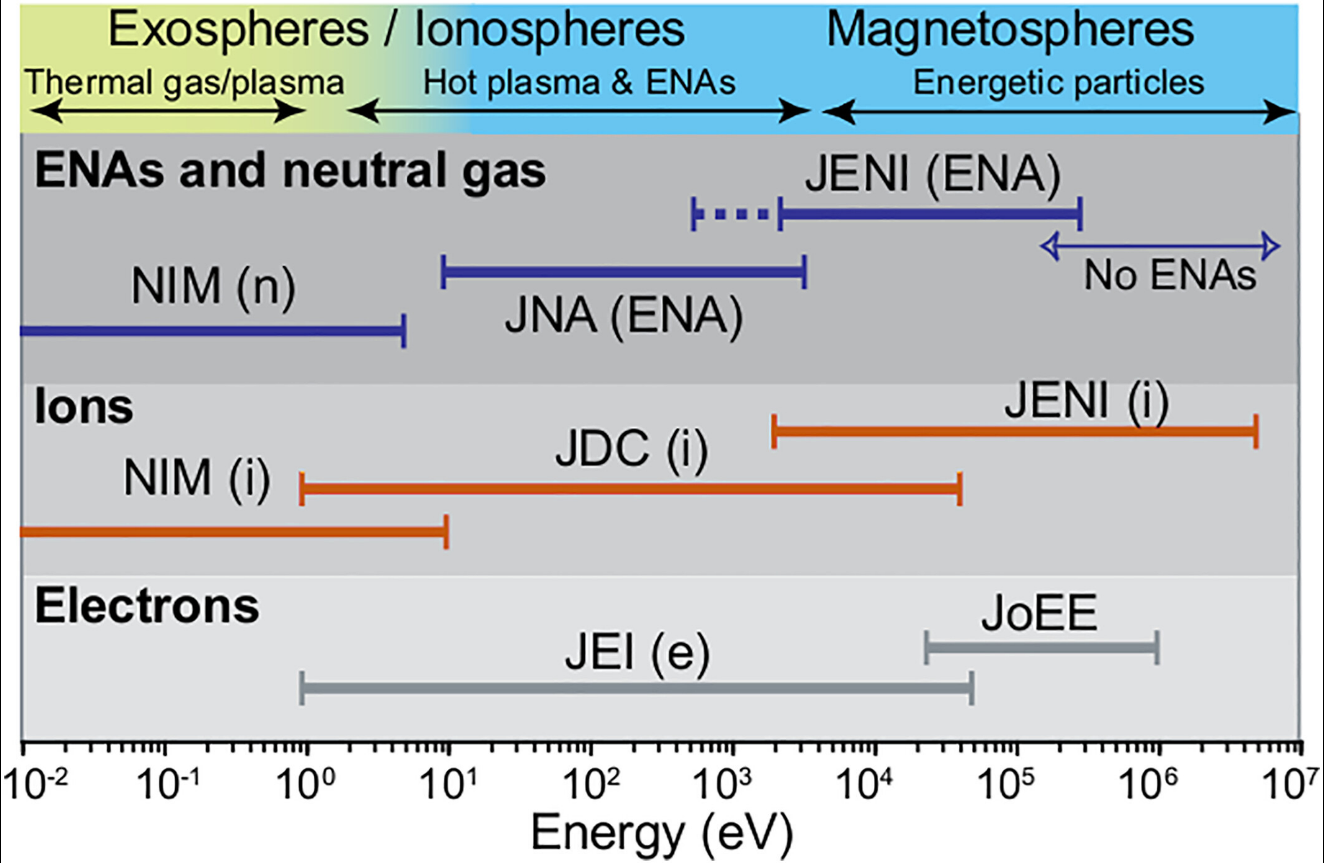


PEP: 6 instruments in one experiment!

PEP-Lo (Europe): JEI, JNA, JDC, NIM
PEP-Hi (USA): JENI, JoEE

Source: MPS, IRF, JHUAPL, Univ. Bern

PEP Energy and Species coverage



Neutral, positive and negative particles

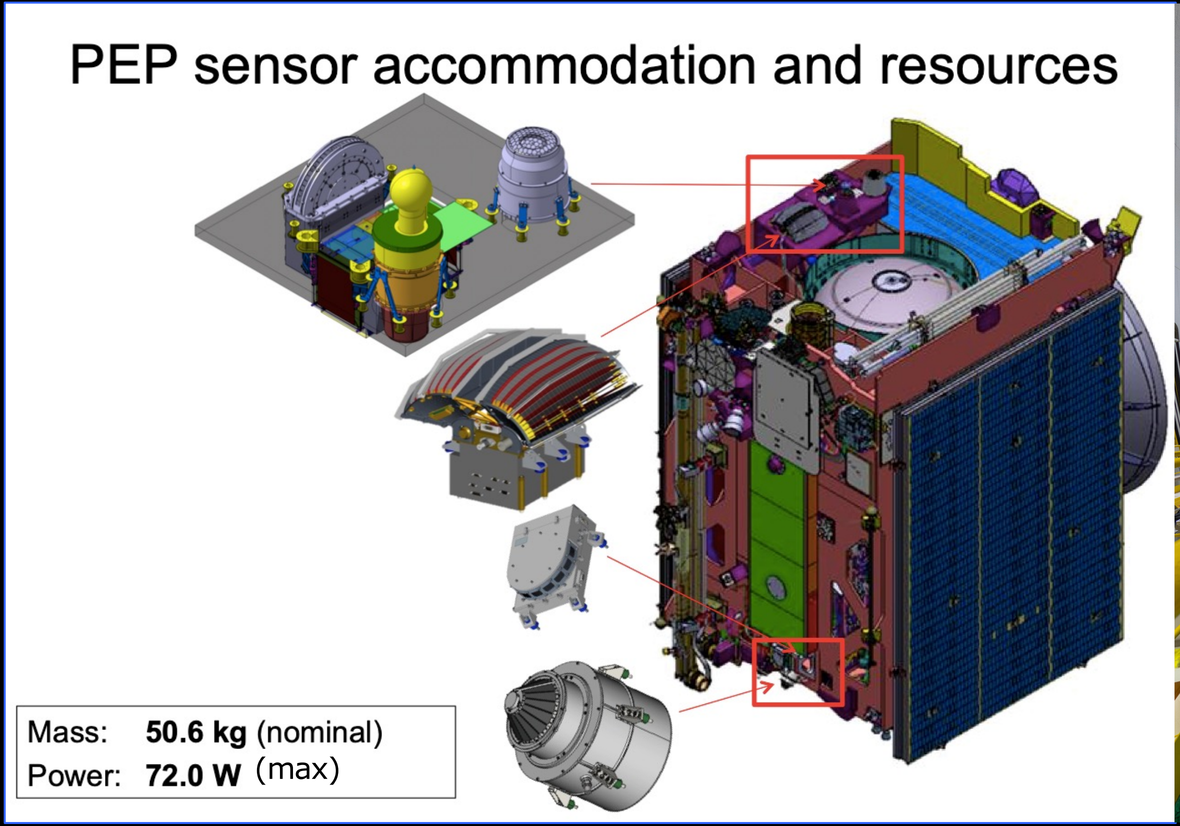
8-9 decades in energy

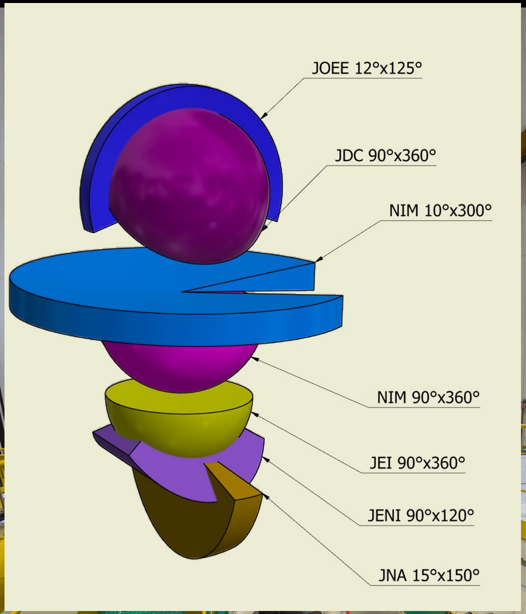
Energy & mass spectroscopy

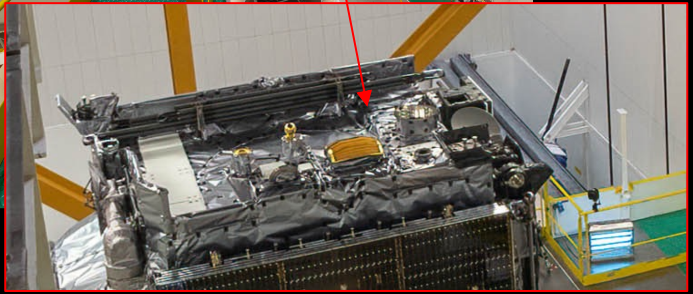
In-situ + Remote sensing

Most sensors measure more than one particle species or states

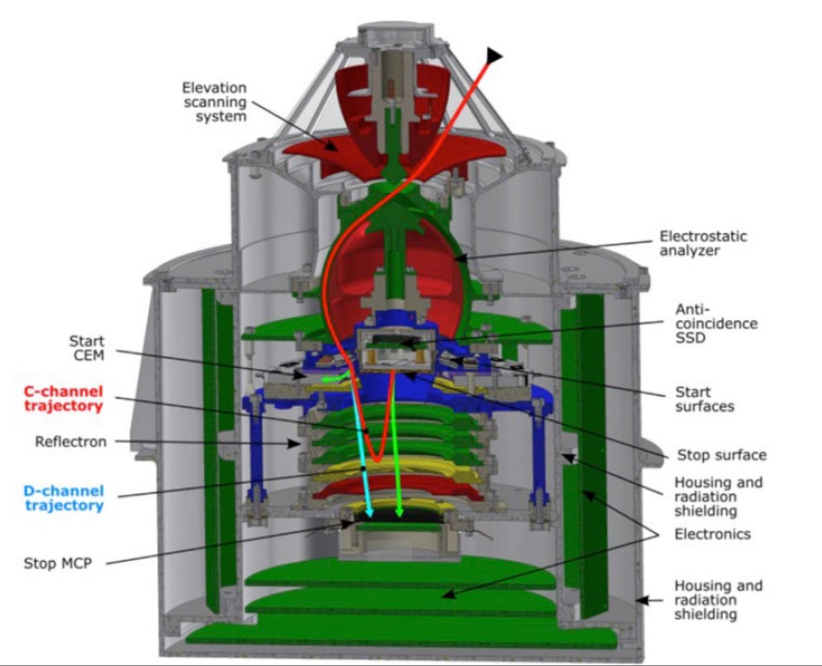
Particle Environment Package Accomodaton (PEP)

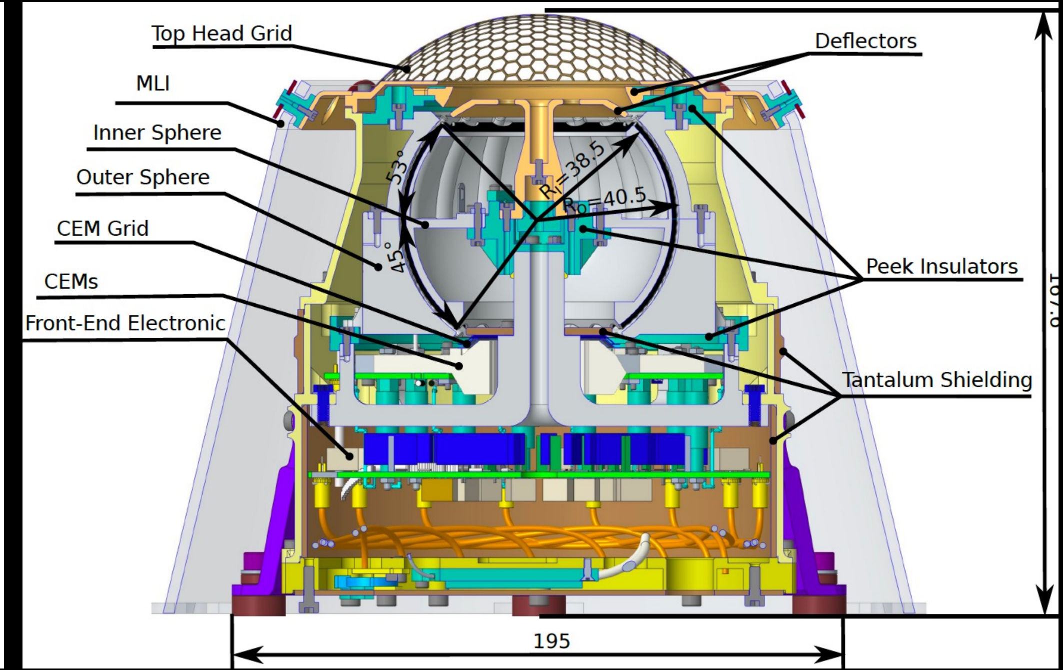






PEP: JDC/JEI ("Plasma Spectrometers": 10 eV – 40 keV)



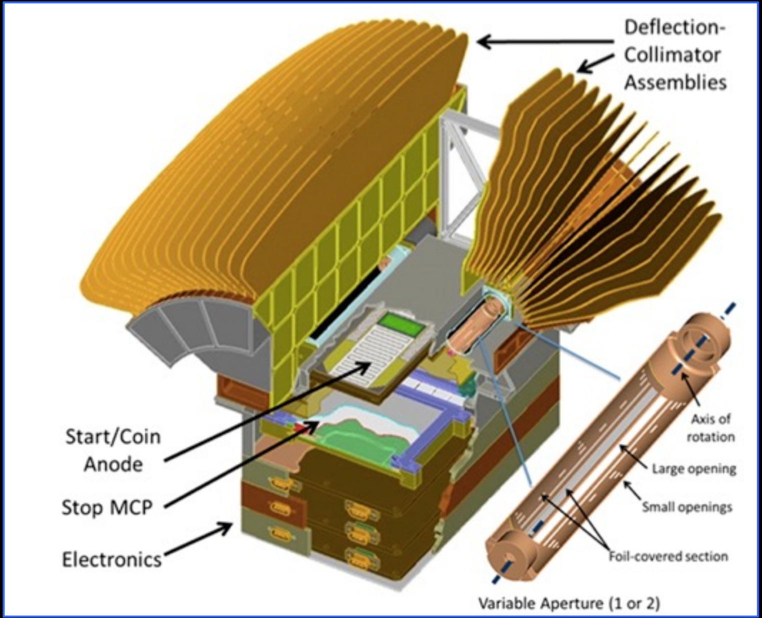


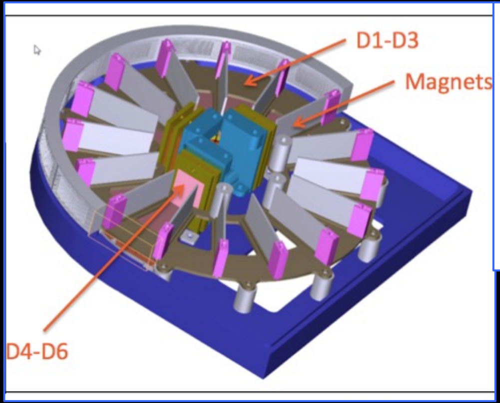
Technique: Electrostatic analyser (both) + TOF (JDC)

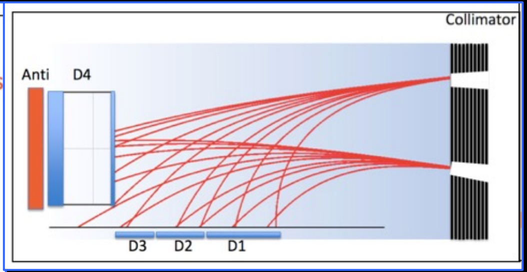
Species: Electrons & ions (both) + Mass composition (JDC)

Detectors: Channeltrons (both) + MCP (JDC) + SSD (JDC)

PEP: JENI/JoEE ("Energetic particles": 10 keV – 2 MeV)

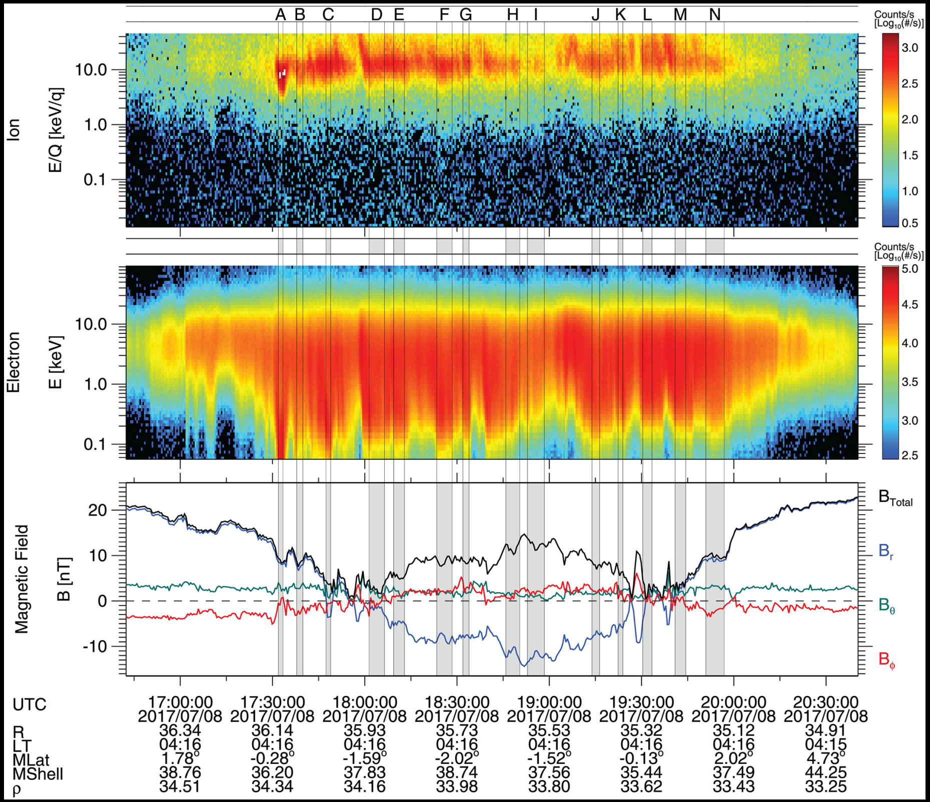


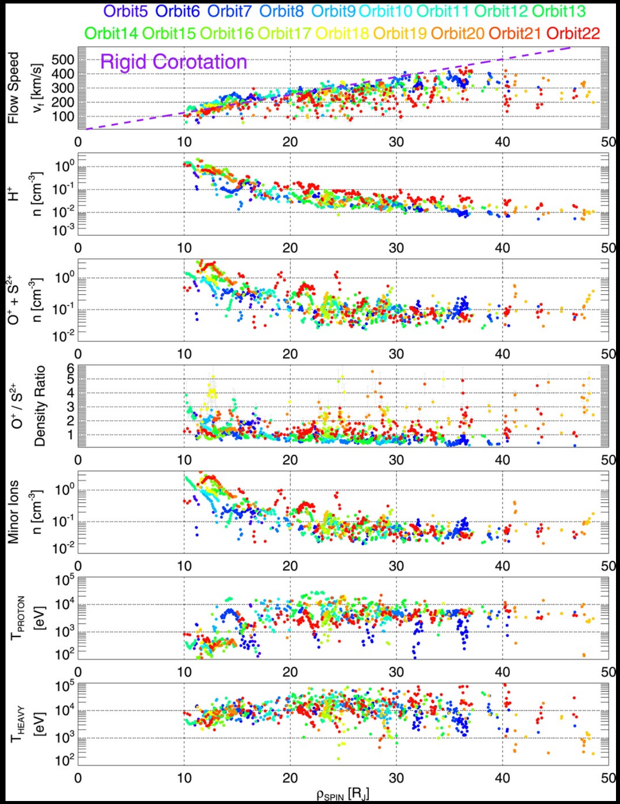




Technique: Energy Loss SSD (both), TOF (JENI), Magn. Deflection (JoEE)
Species: Electrons & ions (both) + Mass composition (JENI)
Detectors: SSD (both) + MCP (JENI)

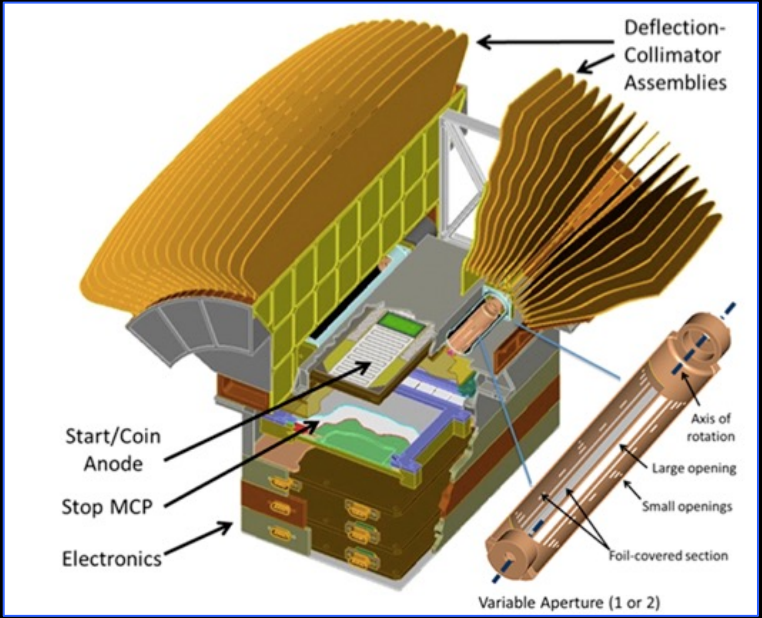
PEP: In-situ charged particle spectrometr products

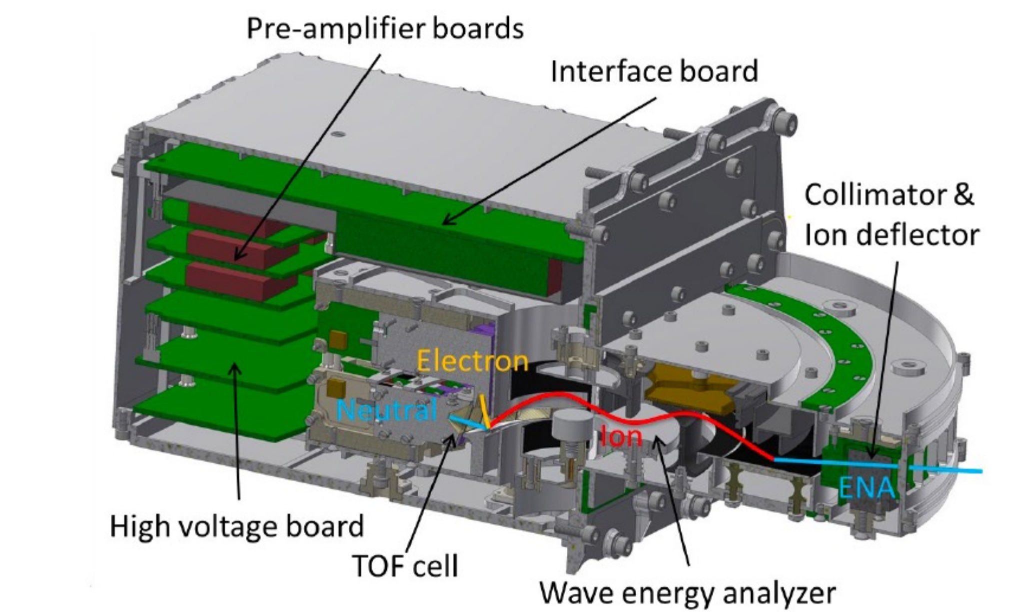




Juno JADE observations (Kim et al. 2019, 2020)

PEP: JENI/JNA (“ENAs”: 100 eV – 300 keV)



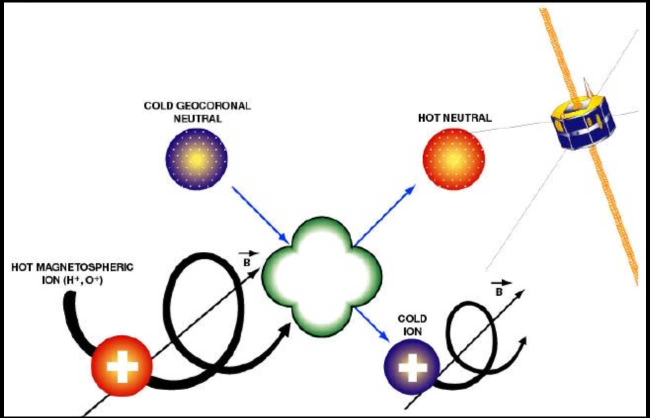


Technique: TOF (both), Electr. Deflection (both), Energy loss SSD (JENI), Charge Conversion (JNA)

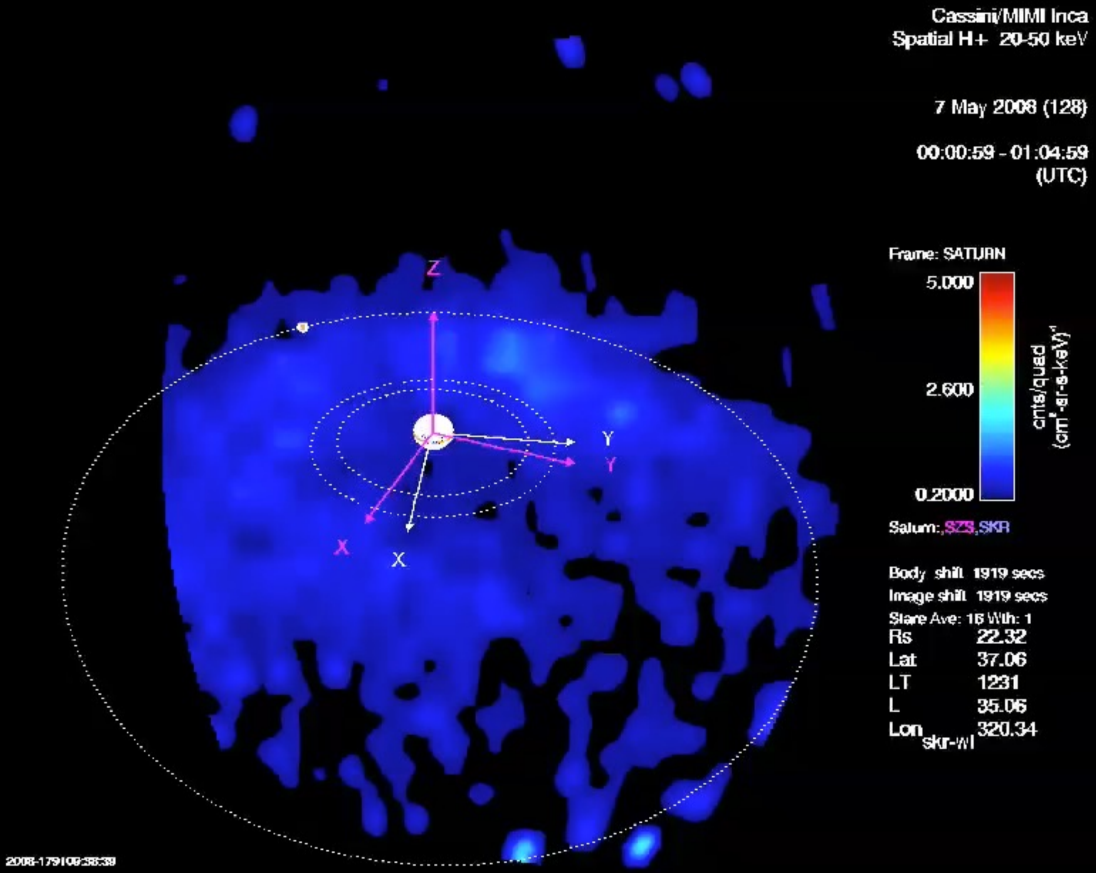
Species: Energetic Neutral Atoms (H, O, S) when deflectors on

Detectors: SSD (JENI), MCP (JENI), Channeltrons (JNA)

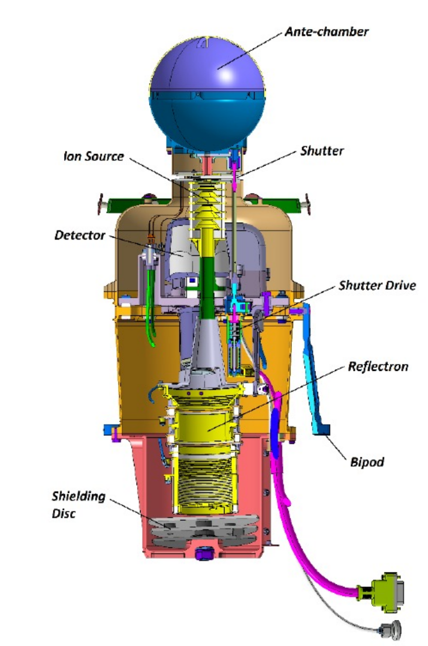
PEP: JENI/JNA ("ENAs": 100 eV – 300 keV)

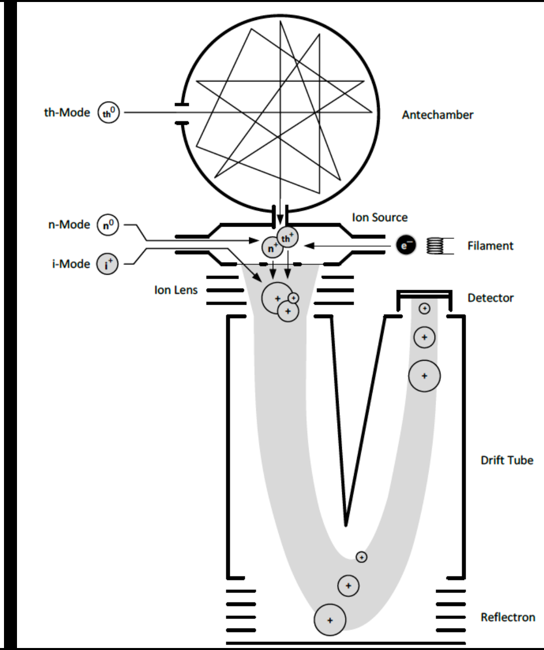


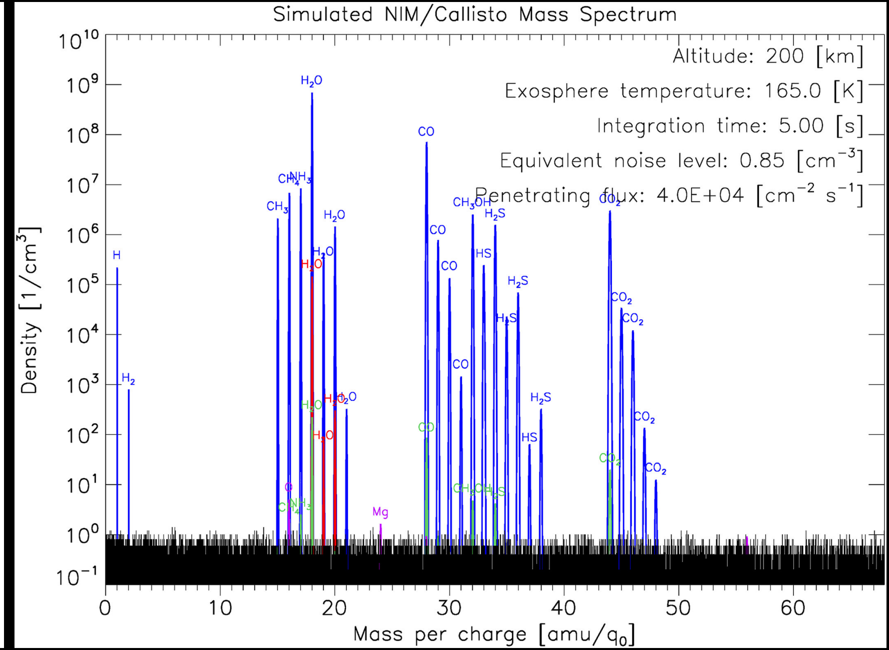
Charge exchange process



PEP: NIM (Thermal neutrals & ions <10 eV)

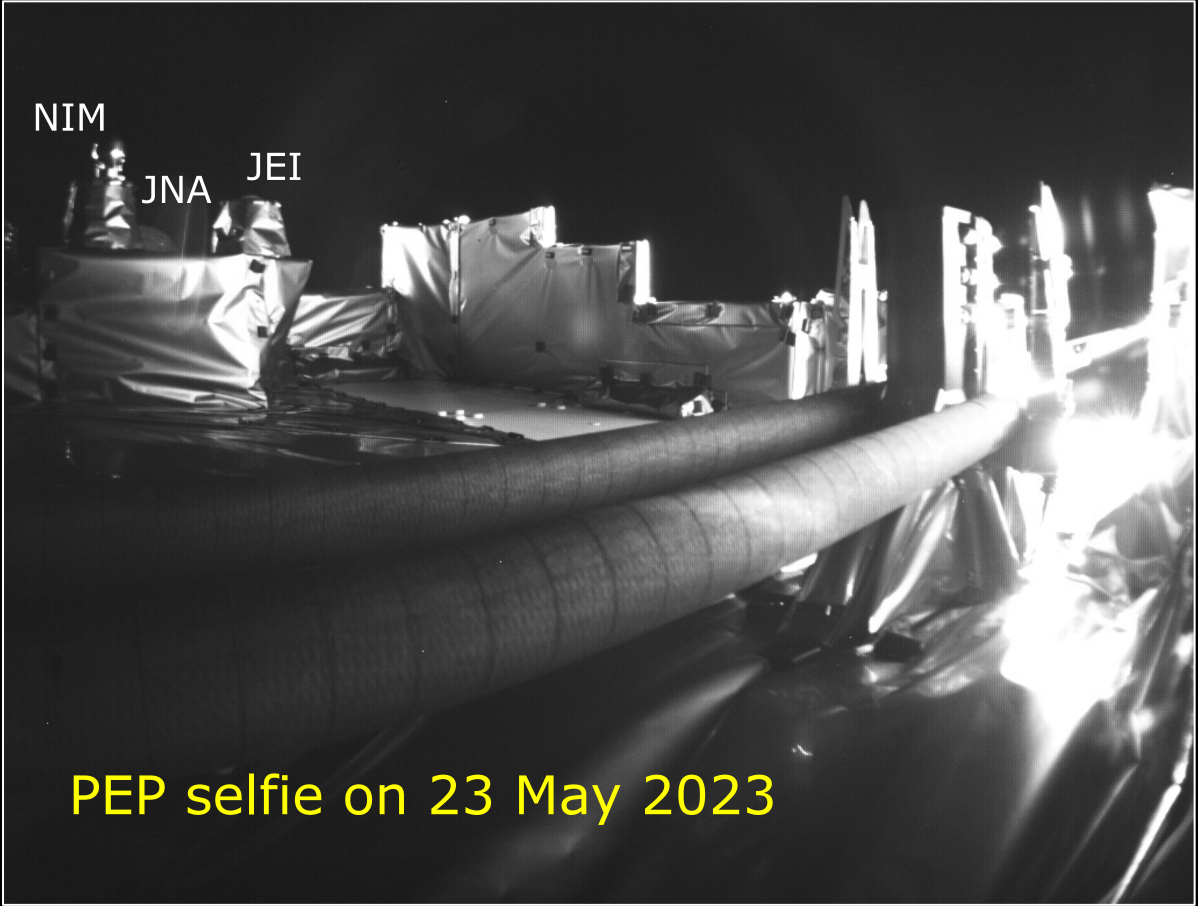






Technique: TOF, Ionization of neutrals, post-acceleration
Species: 1-1000 amu, M/ΔM>800, including molecules
Detectors: MCP

PEP: First light & Status

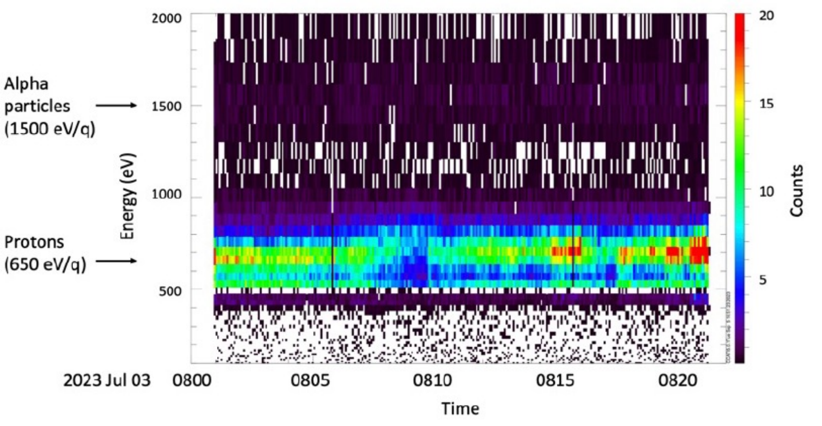


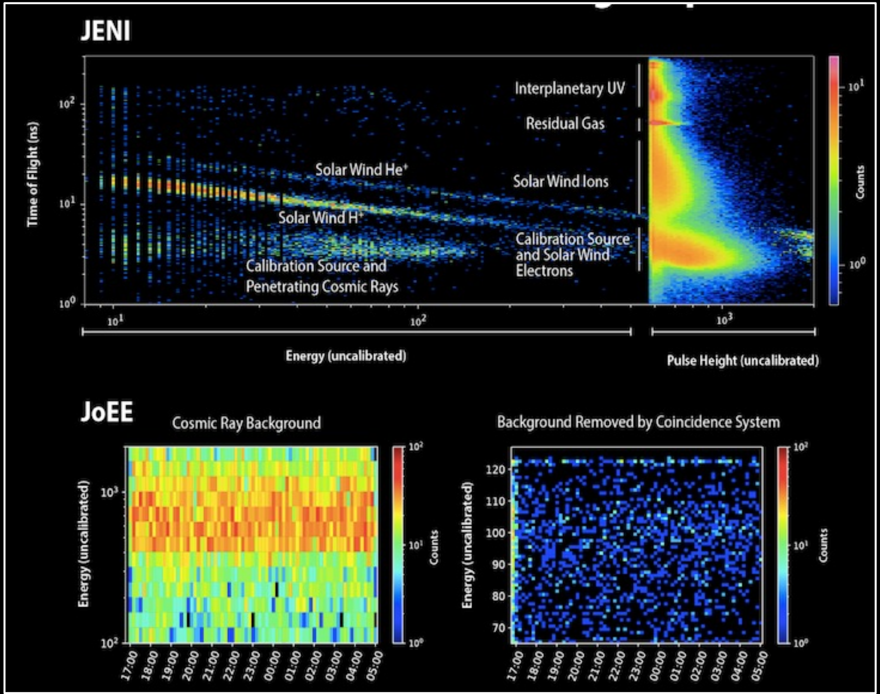
1st stage of PEP commissioning successful

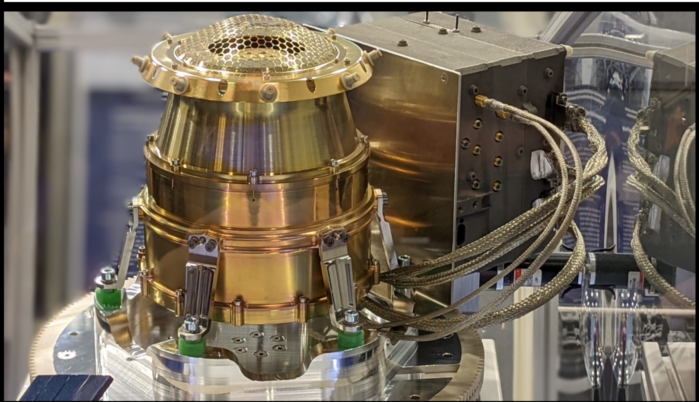
First data acquired by three sensors (JENI, JoEE, JEI)

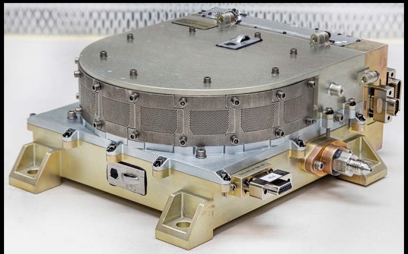
Ongoing commissioning process for the next years (due to s/c outgassing and use of HV)

PEP: First “light”









Thank you!

Particle Environment Package: JNA

Building the Jovian Neutrals Analyzer for the JUICE mission to Jupiter

2018 - 2020

Πηγή: IRF