JUICE : INSTRUMENTATION TO DO NOVEL SCIENCE

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JUICE Science Themes

- *Emergence of habitable worlds around gas giants*
- *Jupiter system as an archetype for gas giants*

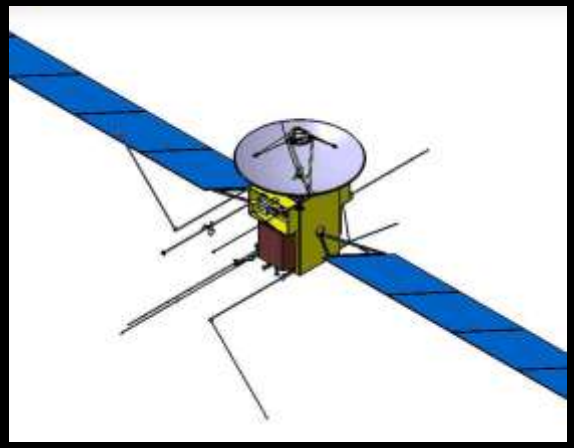
JUICE concept

- *European-led mission to the Jovian system*
- *Emerging from the EJSM-Laplace JGO scenario with two Europa flybys and high-inclination phase at Jupiter*
- *JGO model payload was fully compatible with JUICE objectives and therefore kept*
- *First orbiter of an icy moon*

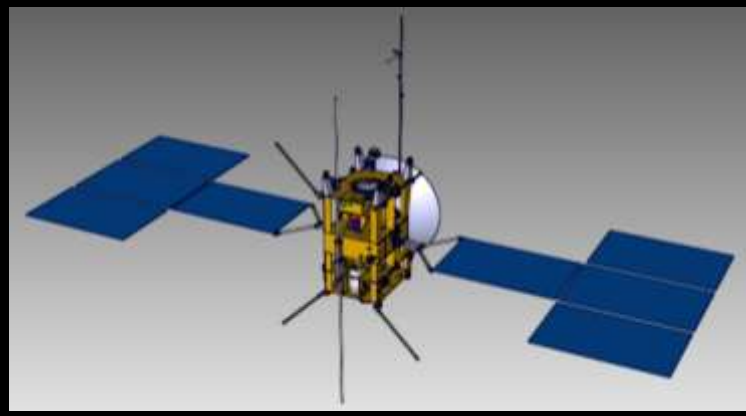
Mission design

- Dry mass ~1900 kg, propellant mass ~2900 kg
- Launcher - Ariane 5 ECA, high Δv : 2600 m/s
- Model payload 104 kg, ~120 – 150 W
- 3-axis stabilized s/c
- Power: solar array 60 – 70 m^2, 640 – 700 W
- HGA: >3 m, fixed to body, X & Ka-band
- Data return >1.4 Gb per 8 h pass (one ground station)

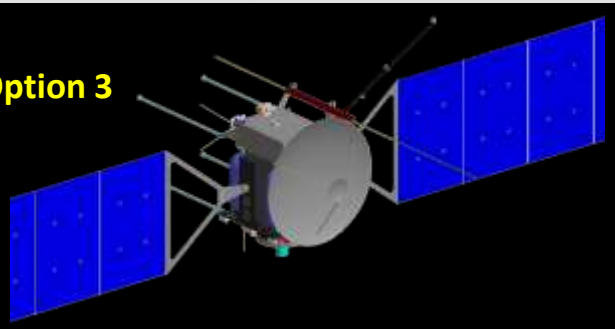
Option 1



Option 2

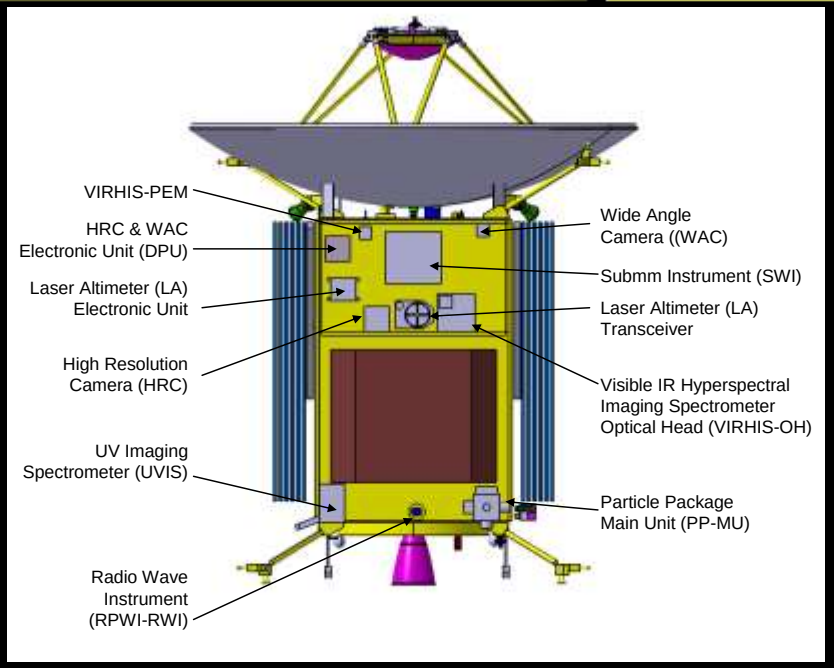


Option 3



Imaging	
Narrow Angle Camera (NAC)	10 kg
Wide Angle Camera (WAC)	4.5 kg
Spectroscopy	
Visible Infrared Hyperspectral Imaging Spectrometer (VIRHIS)	17 kg
UV Imaging Spectrometer (UVIS)	6.5 kg
Sub-mm Wave Instrument (SWI)	9.7 kg
In situ Fields and Particles	
Magnetometer (MAG)	1.8 kg
Radio and Plasma Wave Instr. (RPWI)	11.2 kg
Particle and Plasma Instrument - Ion Neutral Mass Spectrometer (PPI-INMS)	18.2 kg
Sounders & Radio Science	
Laser Altimeter (LA)	11 kg
Ice Penetrating Radar (IPR)	10 kg
Radio Science Instrument (JRST+USO)	4 kg

Total mass: 104 kg



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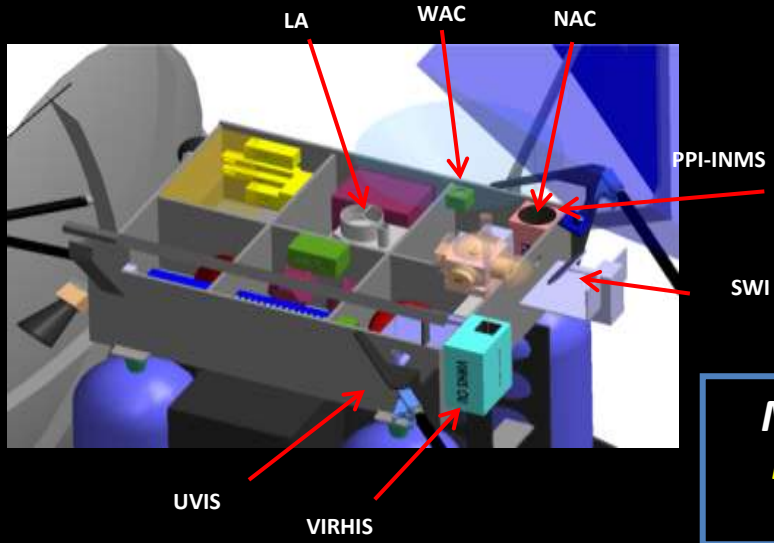

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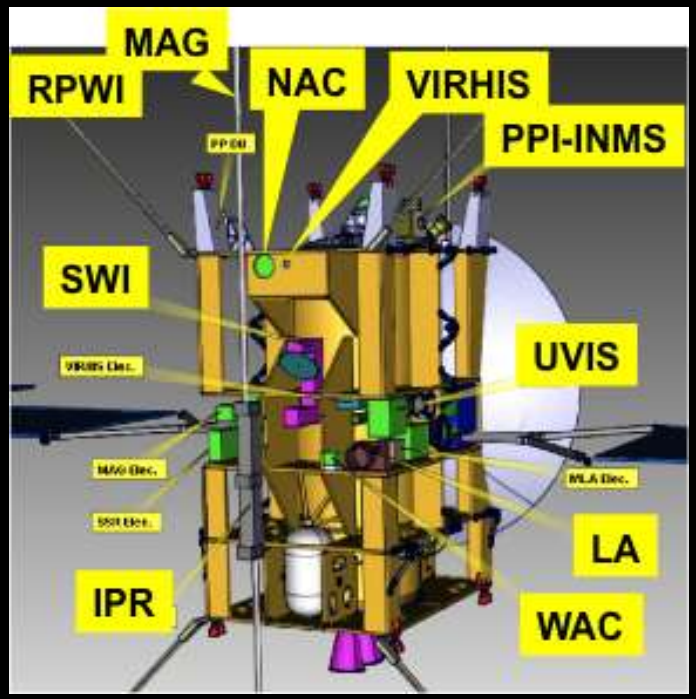


Option 3

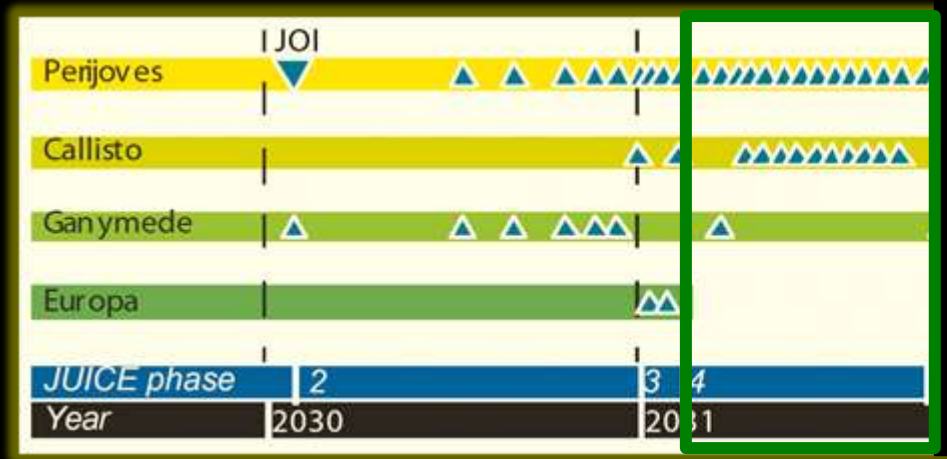
Model payload is based on heritage:

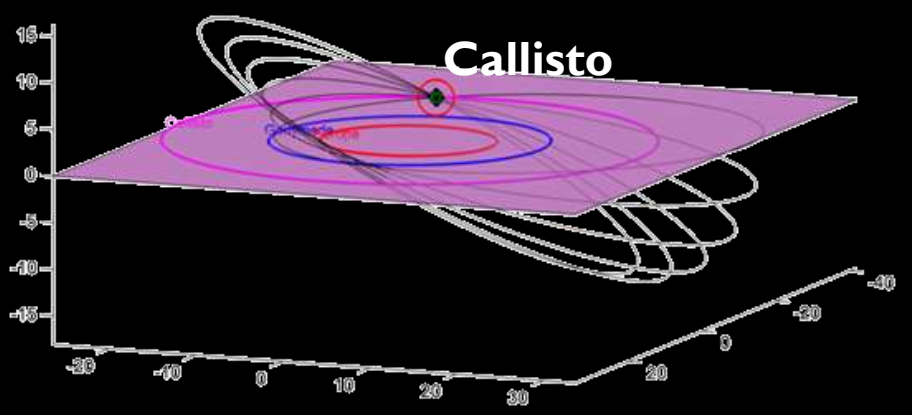
BepiColombo, Juno, Mars Express, Double Star, Venus Express, Rosetta, Dawn, Cassini, etc…

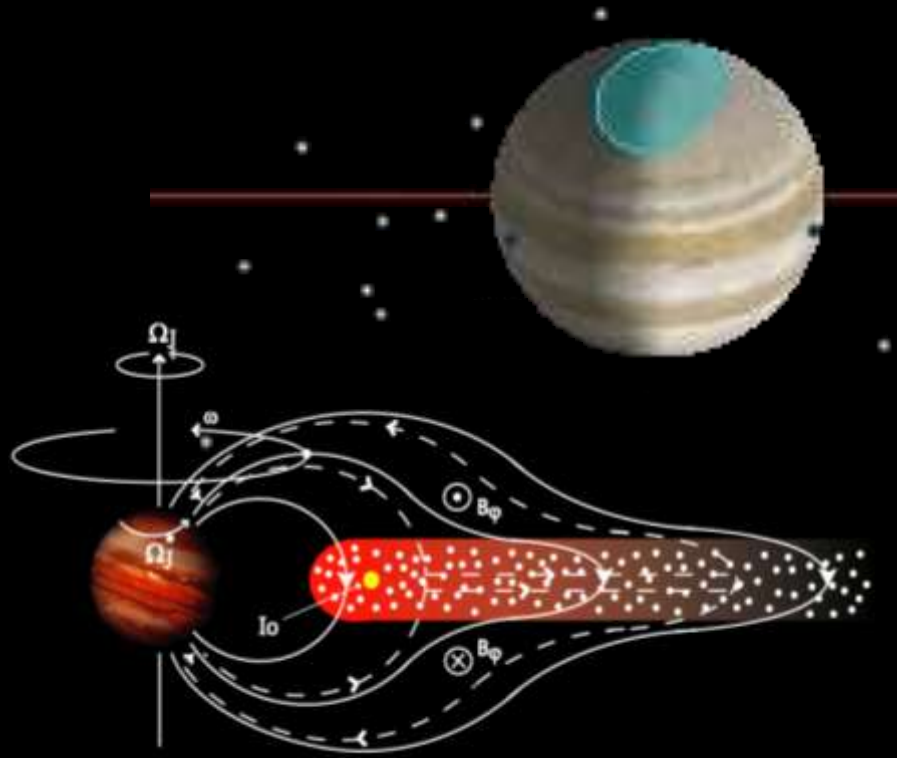
Mission design

Spacecraft Design | Model instruments | Mission phases

Launch	June 2022
Interplanetary transfer (Earth-Venus-Earth_Earth)	7.6 years (8 years)
Jupiter orbit insertion and apocentre reduction with Ganymede gravity assists	11 months
2 Europa flybys	36 days
Reduction of v_{inf} (Ganymede, Callisto)	60 days
Increase inclination with 10 Callisto gravity assists	200 days

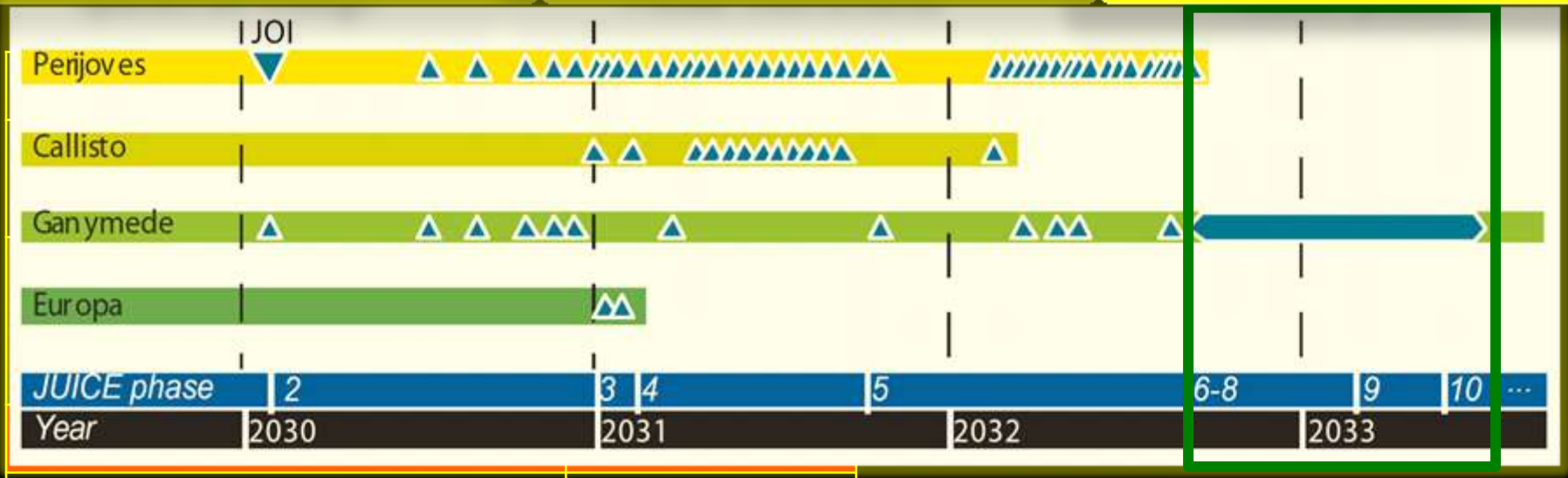




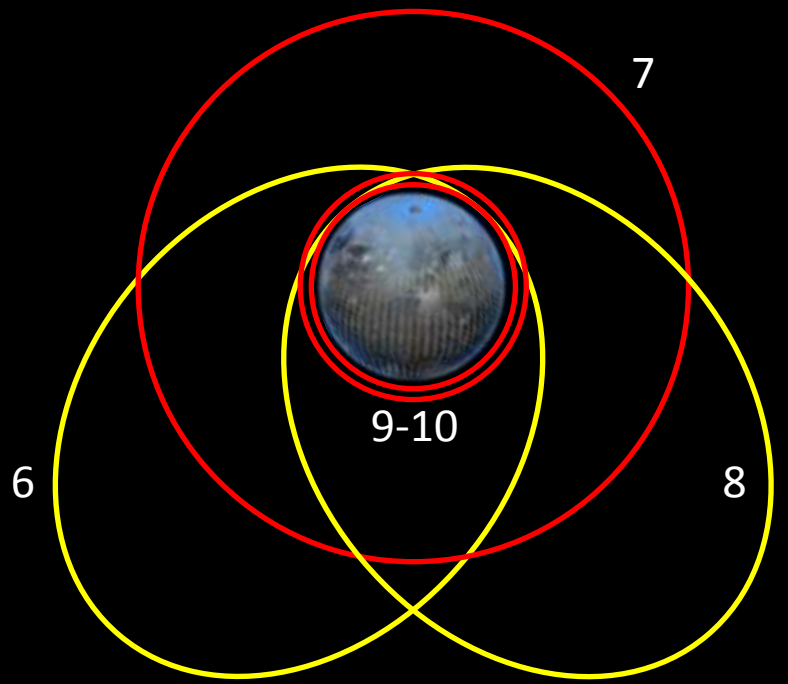


Mission design

Spacecraft Design | Model instruments | Mission phases



Reduction of v_{inf} (Ganymede, Callisto)	60 days
Increase inclination with 10 Callisto gravity assists	200 days
Callisto to Ganymede	11 months
Ganymede (polar) 10,000x200 km & 5000 km 500 km circular 200 km circular	 150 days 102 days 30 days
Total mission at Jupiter	3 years



Exploration of the Jupiter system

JUICE

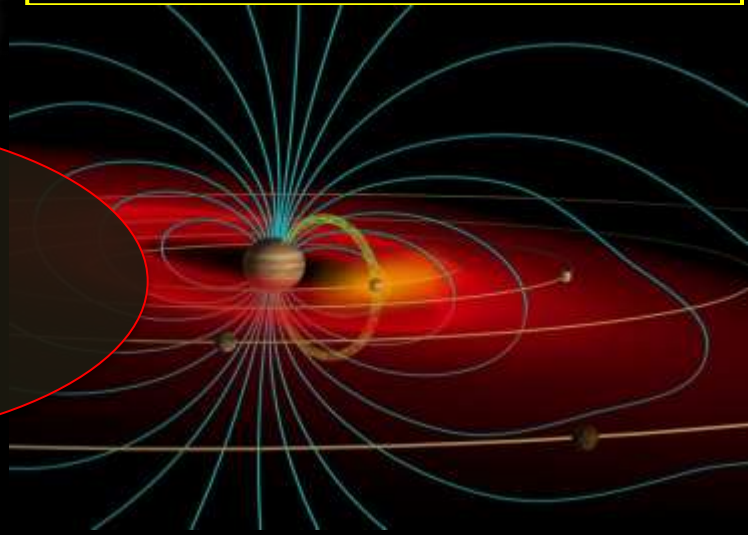
The biggest planet, the biggest magnetosphere, and a mini solar system

Jupiter

- Archetype for giant planets
- Natural planetary-scale laboratory for fundamental fluid dynamics, chemistry, meteorology,...
- Window into the formational history of our planetary system

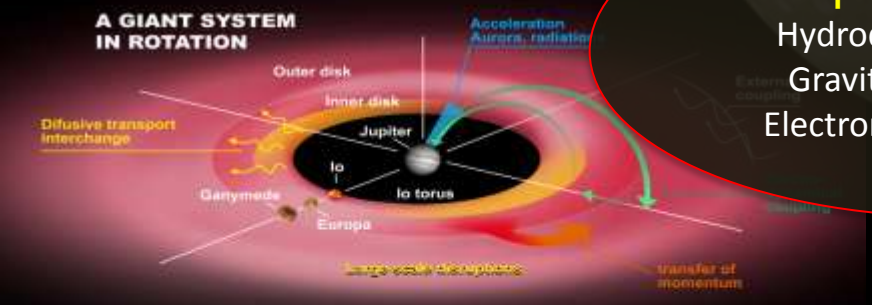
Magnetosphere

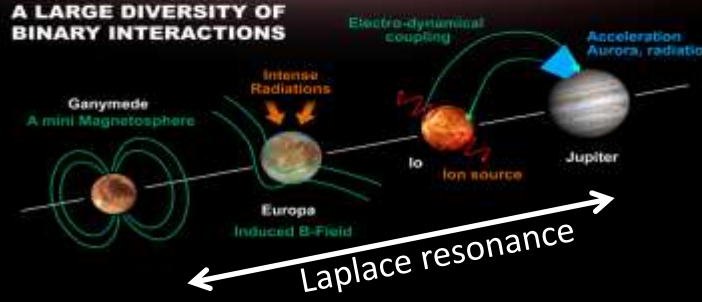
- Largest object in our Solar System
- Biggest particle accelerator in the Solar System
- Unveil global dynamics of an astrophysical object



Coupling processes

Hydrodynamic coupling
Gravitational coupling
Electromagnetic coupling





Satellite system

- Tidal forces: Laplace resonance
- Electromagnetic interactions to magnetosphere and upper atmosphere of Jupiter

Exploration of the habitable zone

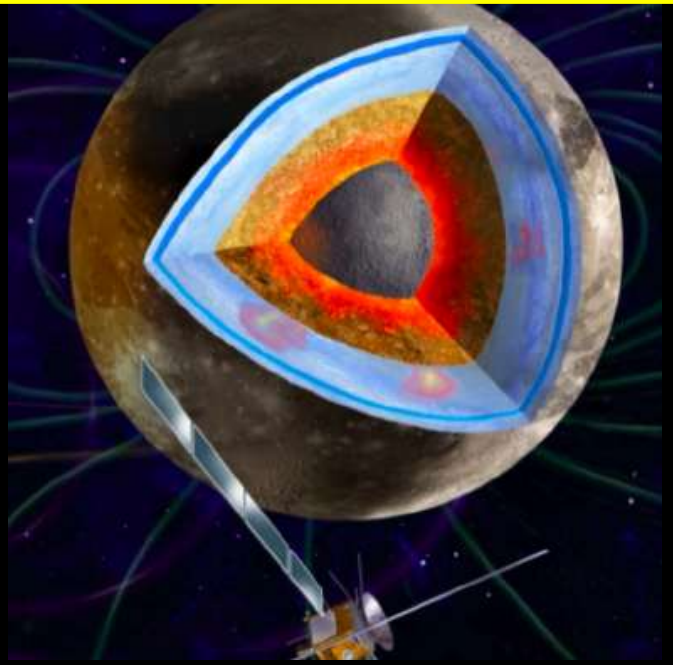
JUICE

Three large icy moons to explore

Ganymede

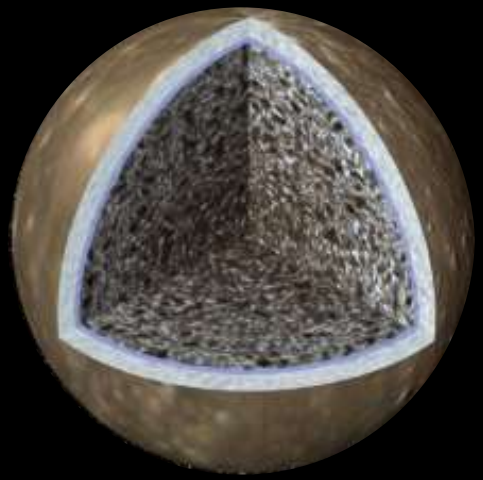
- Largest satellite in the solar system
- A deep ocean
- Internal dynamo and an induced magnetic field – unique
- Richest crater morphologies

- Archetype of waterworlds
- Best example of liquid environment trapped between icy layers



Callisto

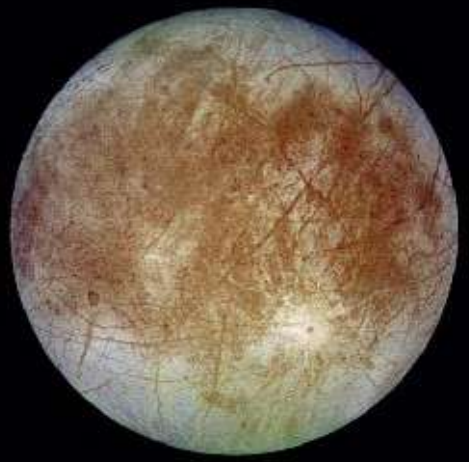
- Best place to study the impactor history
- Differentiation – still an enigma
- Only known example of non active but ocean-bearing world
- The witness of early ages



Europa

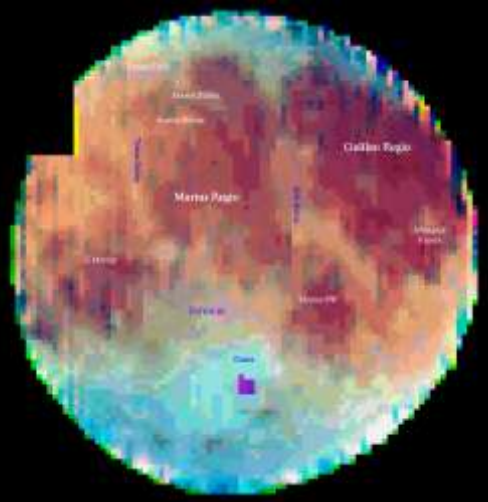
- A deep ocean
- An active world?

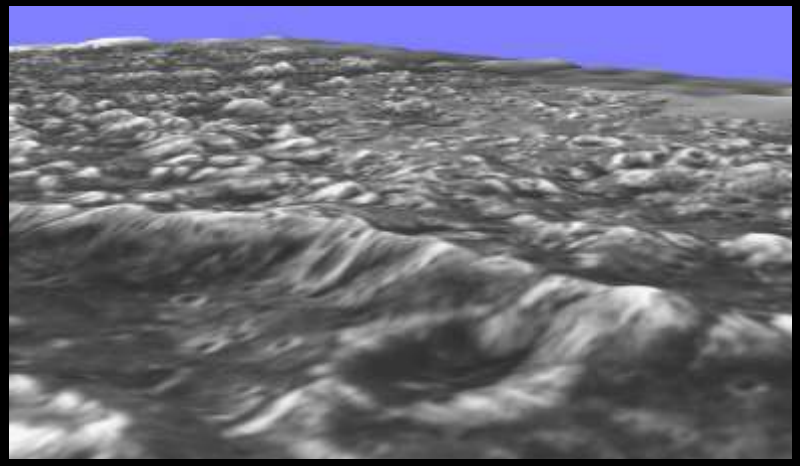
- Best example of liquid environment in contact with silicates



Exploration of the habitable zone

Characterise Ganymede as a planetary object and possible habitat





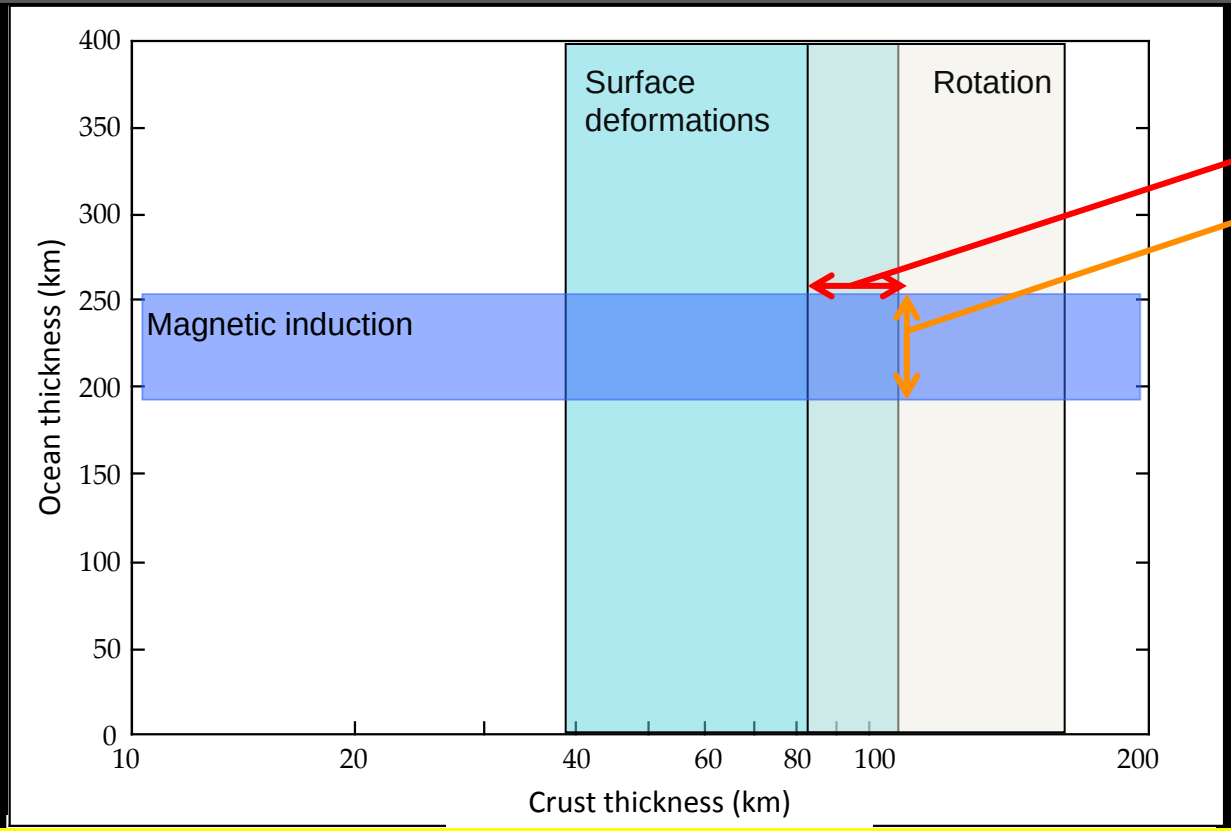
Galileo Regio

JUICE OBJECTIVES

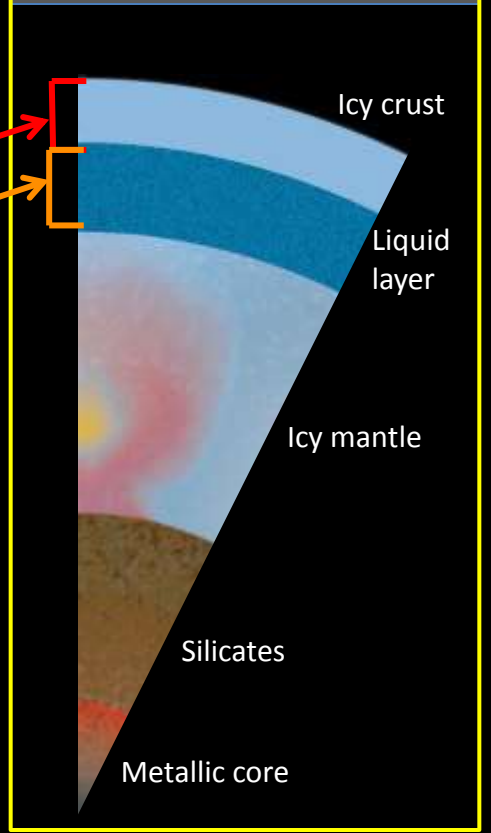
- Characterise the ice shell, the extent of the ocean and its relation to the deeper interior
- Determine global composition, distribution and evolution of surface materials
- Understand the formation of surface features and search for past and present activity
- Characterise the local environment and its interaction with the Jovian magnetosphere

Characterise Ganymede as a planetary object and possible habitat

1. Extent of the ocean and its relation to the deeper interior



Internal structure



JUICE measurements

- Periodic surface deformations from eccentric orbit
- Variations in the rotation -> thickness of the crust
- Magnetic induction -> ocean thickness

Instrument Packages

- In situ Fields and Particles
- Imaging
- Sounders and Radio Science

Characterise Ganymede as a planetary object and possible habitat

2. Composition, distribution, and evolution of surface materials

What are the surface chemical compounds ?

Remote sensing

Spatial coverage

- **>50% at 2-3 km/px**
- **100 m/px on a few %**
- **10 m/px where needed**

Spectral coverage

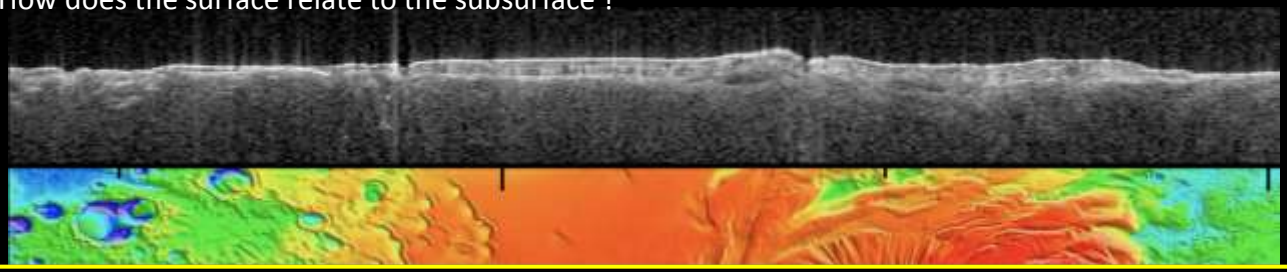
- **4 times better than Galileo NIMS**
- **Close to lab data quality when needed**

Exogeneous /endogeneous ?

Volatiles

Ions and Neutrals

How does the surface relate to the subsurface ?

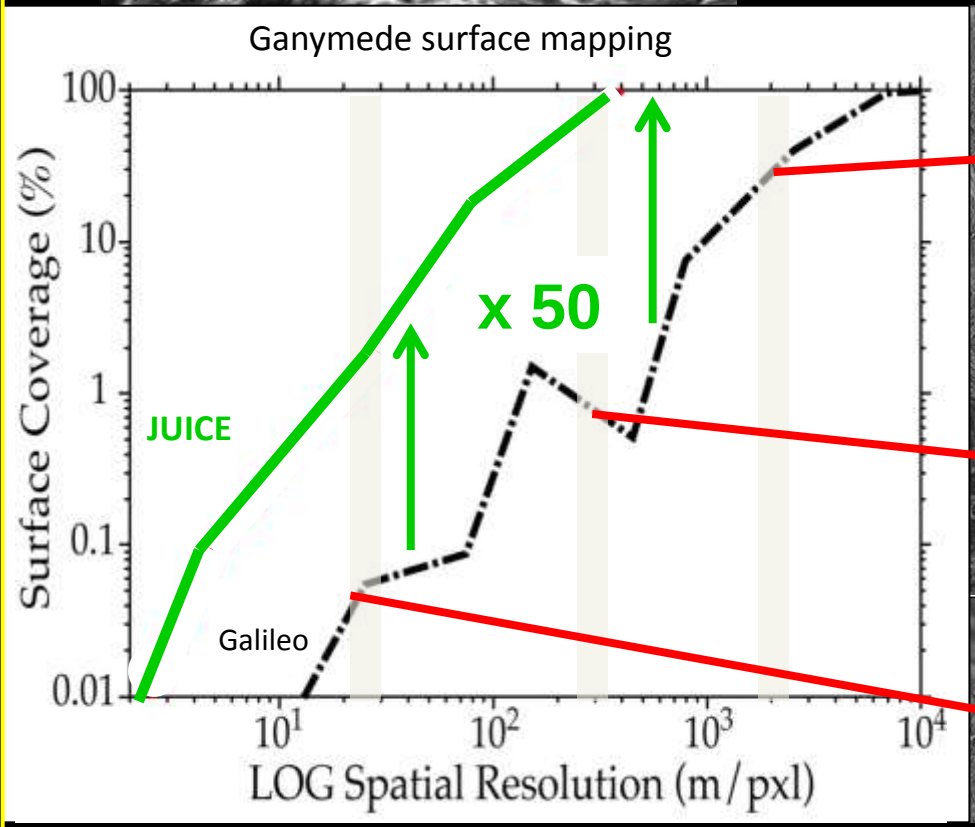


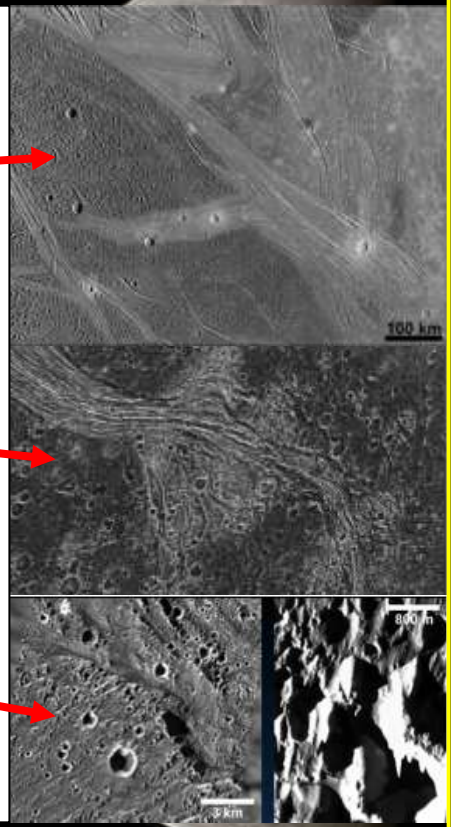
Instrument Packages

- Spectroscometer
- Imaging
- In situ Neutral Particles
- Radar sounder

Characterise Ganymede as a planetary object and possible habitat

3. Formation of surface features and search for past and present activity





Bright terrain: Rift-like tectonism, icy volcanism

Measurements

- Global imaging at 200-400 m/px
- High Resolution target areas
- Topography/ morphology
- Subsurface exploration
- Compositional relationships

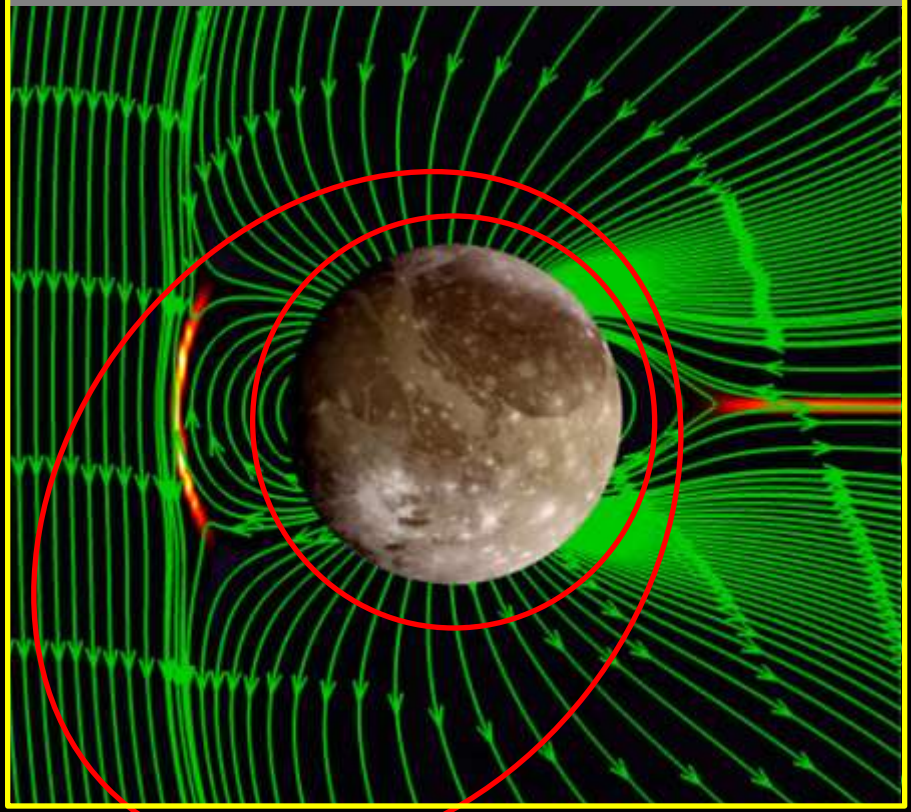
Instrument Packages

- Imaging
- Spectrometers
- Sounders

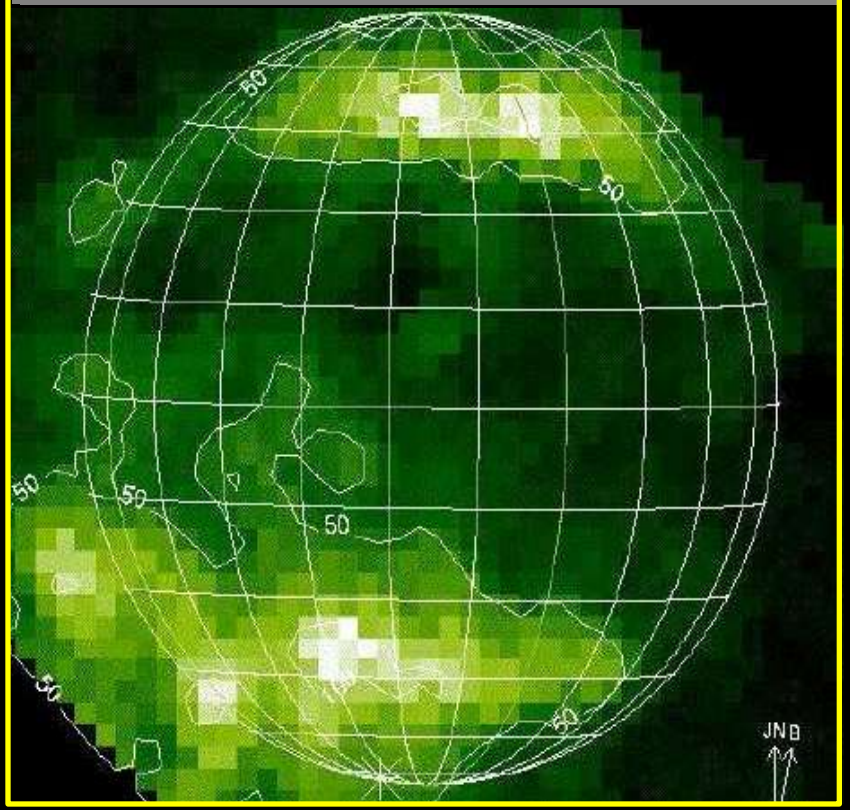
Characterise Ganymede as a planetary object and possible habitat

4. Characterise the local environment

Dipole magnetic field and mini-magnetosphere



Coupling to Jupiter's magnetosphere



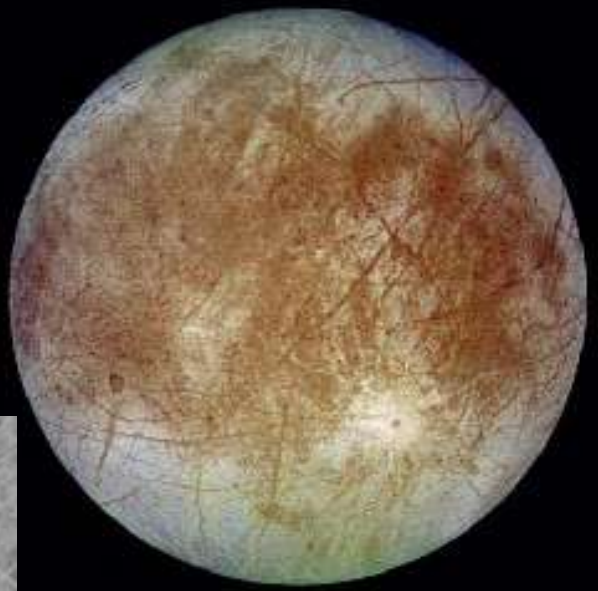
- In situ Fields and Particles
- Imaging
- Spectroscopy
- Radio science

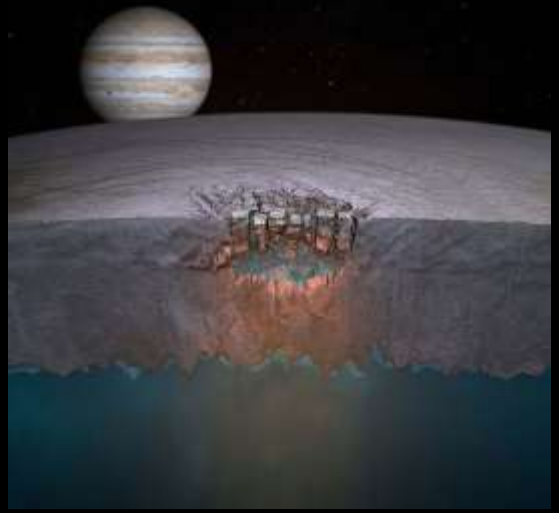
Exploration of the habitable zone

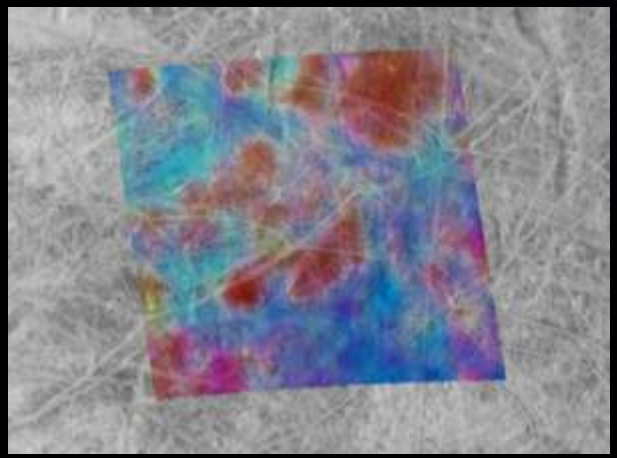
Explore Europa recently active zones

JUICE will tell us:

- If liquid reservoirs exist
- If the salinity is comparable to our oceans
- How thick the crust is in chaos regions
- If the moon is still active
- Potentially where we could land in the future







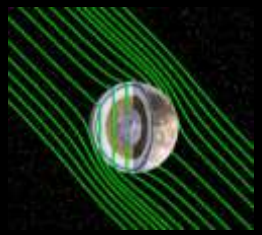
Europa				
Year	2030	2031	2032	2033

Explore Europa recently active zones

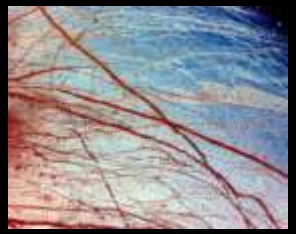
Flyby strategy:

- In-situ observations
- Imaging
- Infrared observations
- Ice penetrating radar
- altimetry

Will result in :

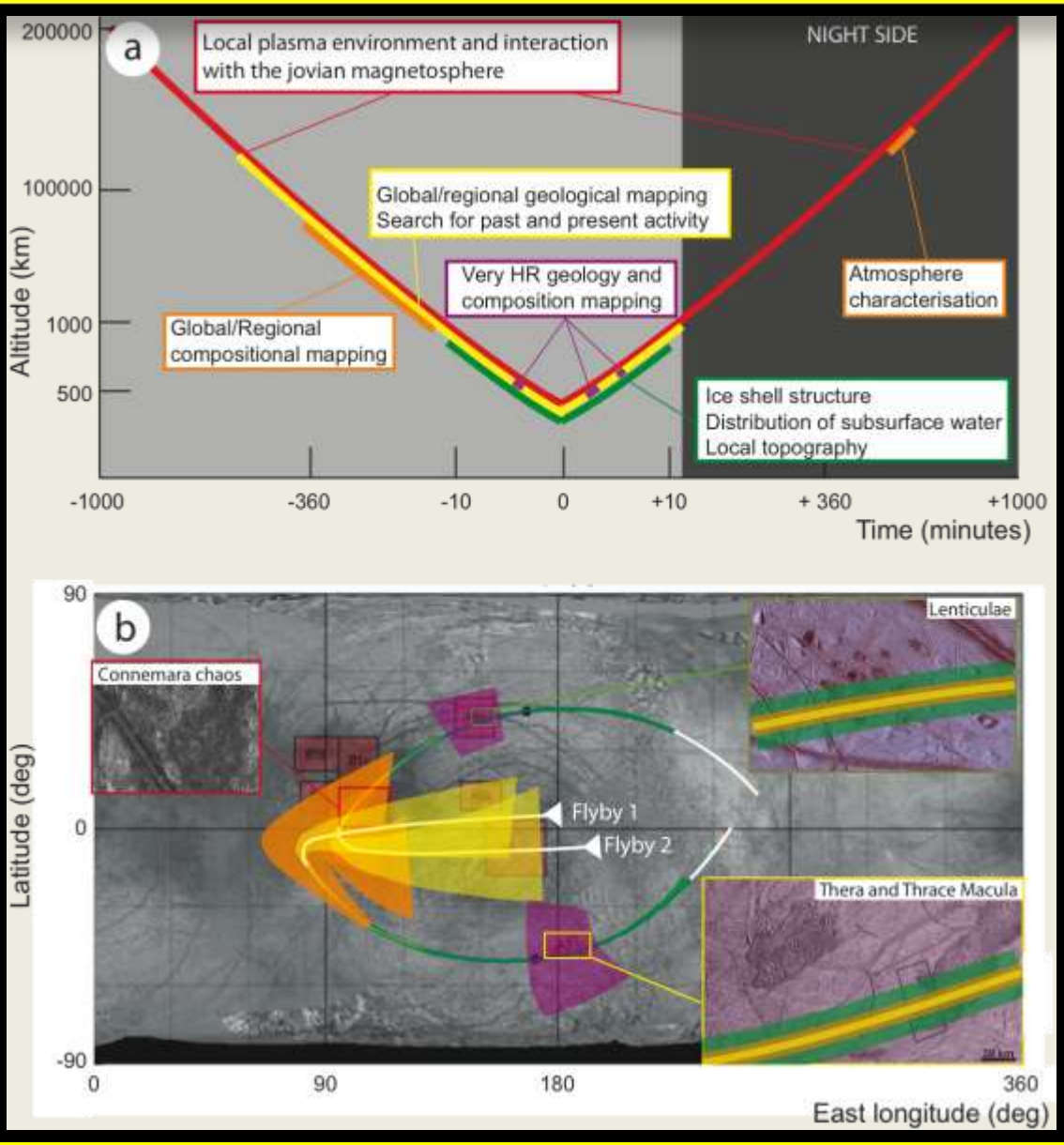


Characterisation of induced field



Composition and geology of areas of high interest

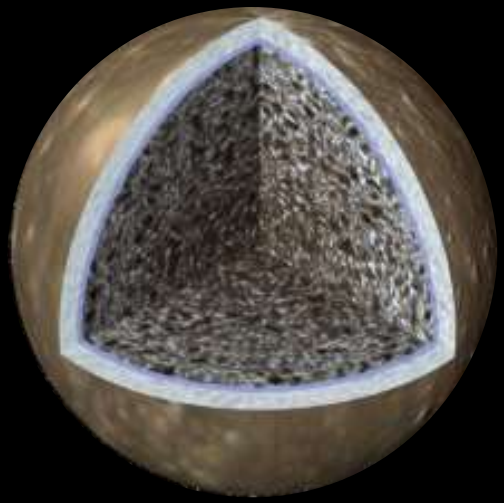
First subsurface exploration of recently active regions

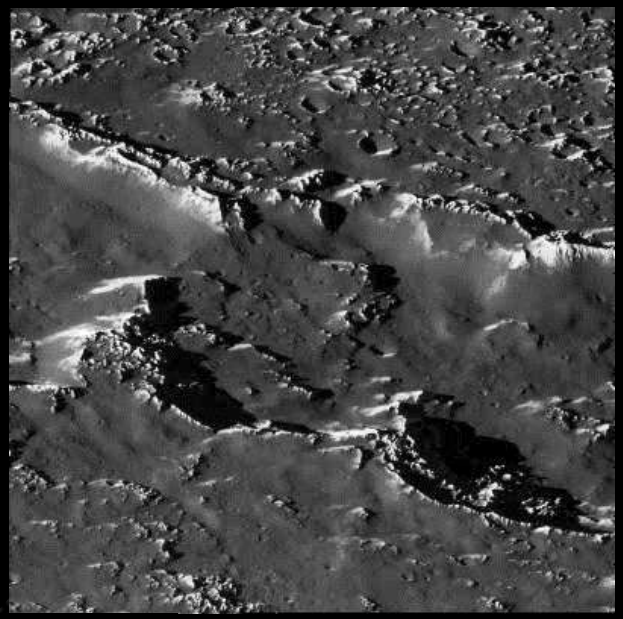


Europa				
Year	2030	2031	2032	2033

Exploration of the habitable zone

Study Callisto as a remnant of the early Jovian system





JUICE OBJECTIVES

- Characterise the outer shells, including the ocean
- Determine the composition of the non-water ice material
- Study the past activity including the differentiation processes

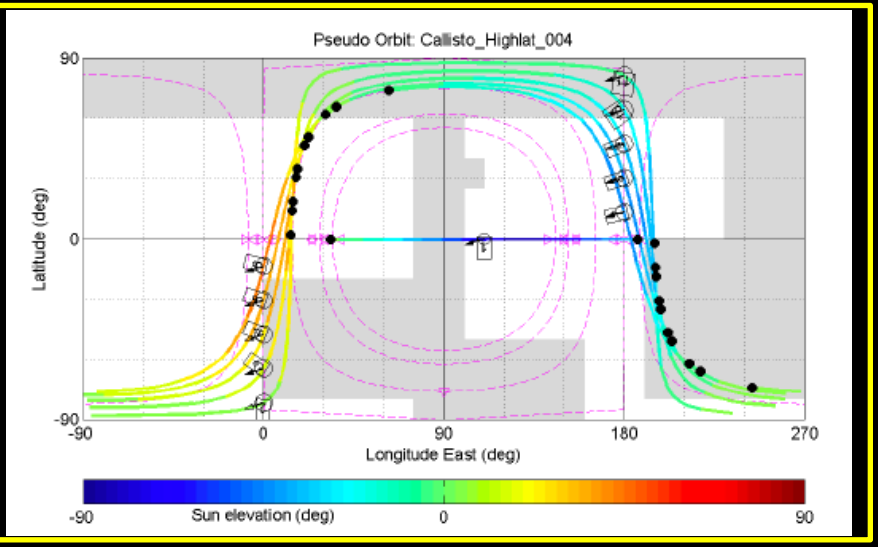
Study Callisto as a remnant of the early Jovian system

Flyby strategy:

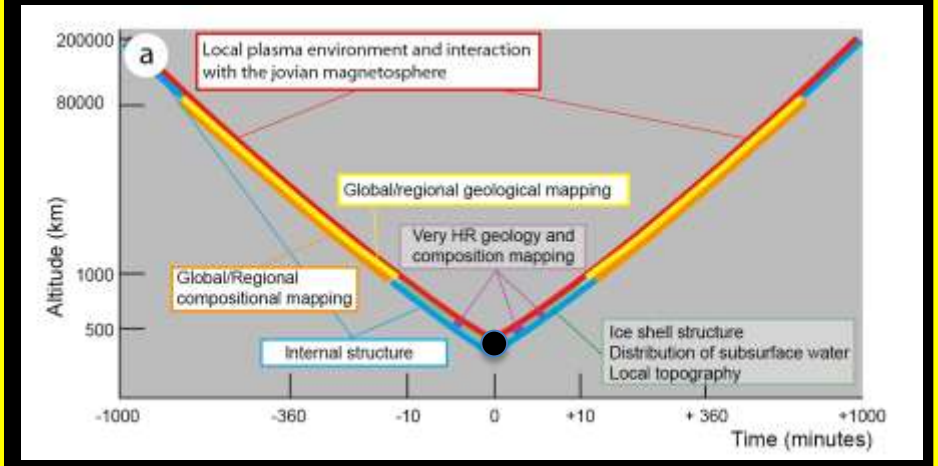
- Radio science and altimetry
- In-situ observations
- Imaging & spectro-imaging
- Ice penetrating radar

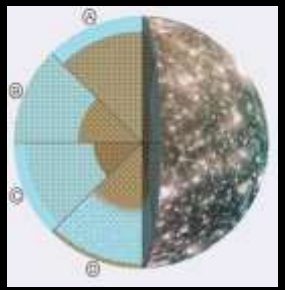
Will result in :

- Degree of differentiation
- Global/regional surface aging
- First subsurface exploration
- Characterisation of the liquid layer
- Exosphere/Ionosphere composition
- Global/Regional composition and geology

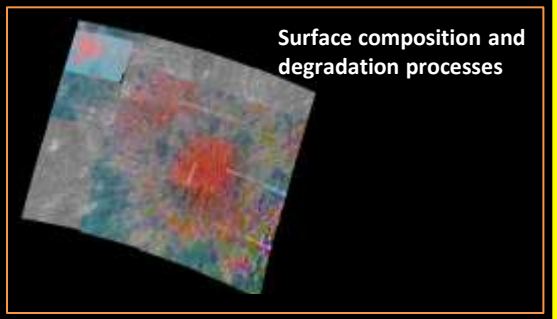


Observation strategy





Structure and internal differentiation

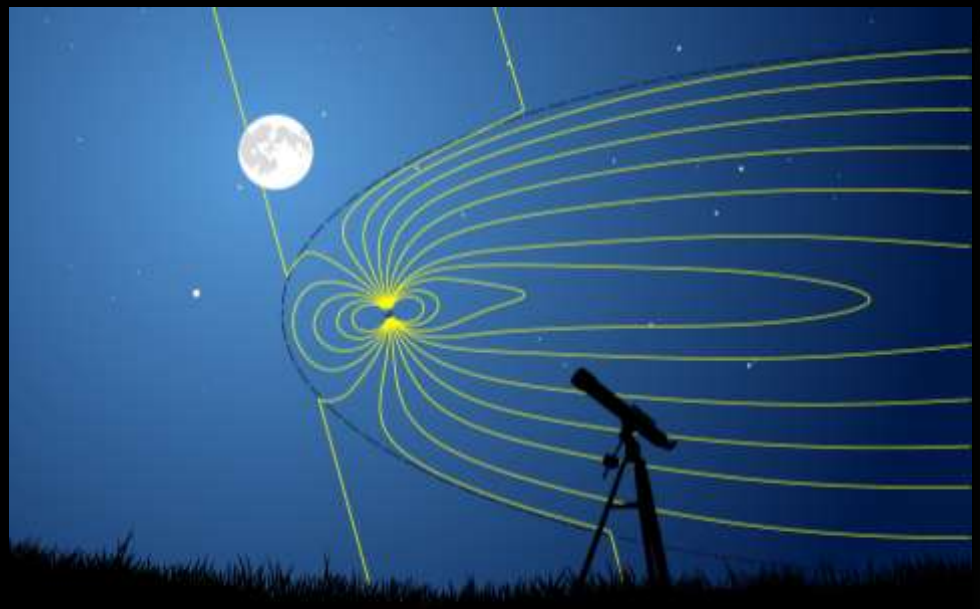


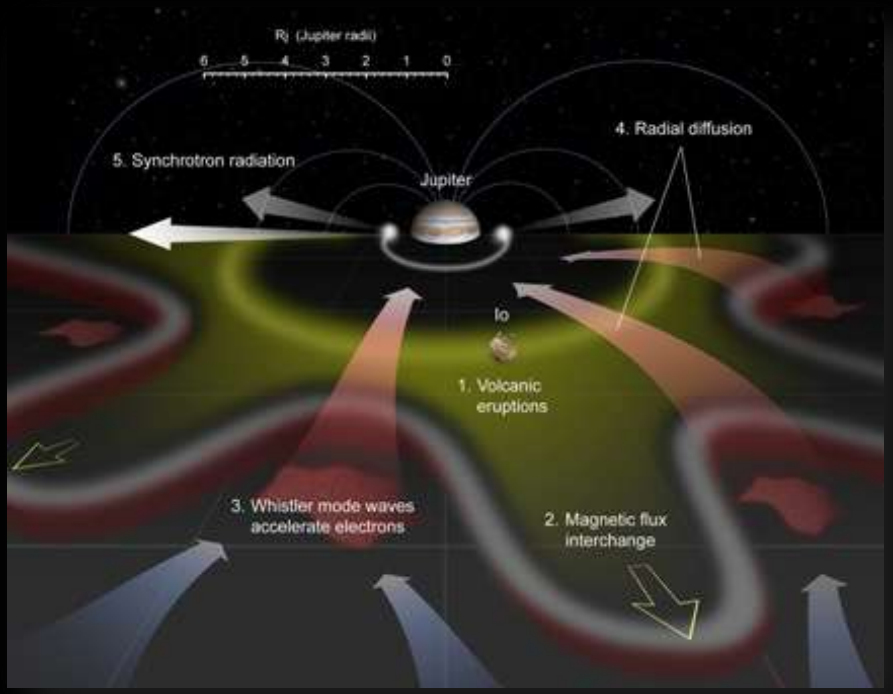
Surface composition and degradation processes

Cratering record and early geological history

Explore the Jupiter system as an archetype for gas giants

Explore the Jovian magnetosphere





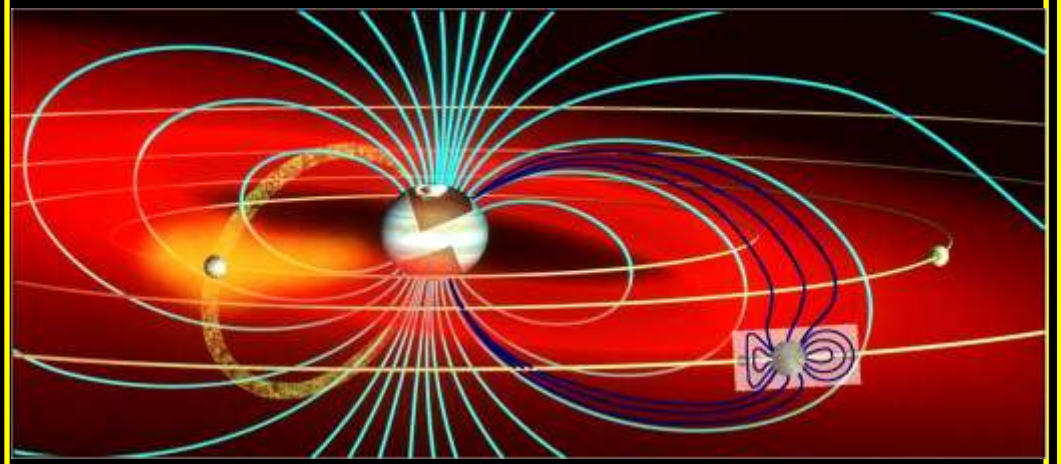
JUICE objectives

- Study the dynamics of magnetosphere in and out of the magnetodisc
- Determine the electrodynamic coupling between the planet and the satellites
- Assess global and continuous acceleration of particles

Explore the Jovian magnetosphere

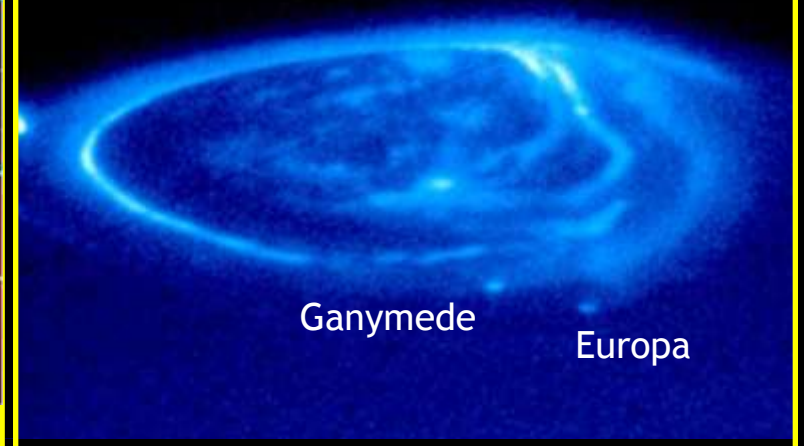
1 and 2. Study the dynamics and the coupling processes

Properties



Energy transfer in the coupled system

UV aurora – main oval and moon footprints

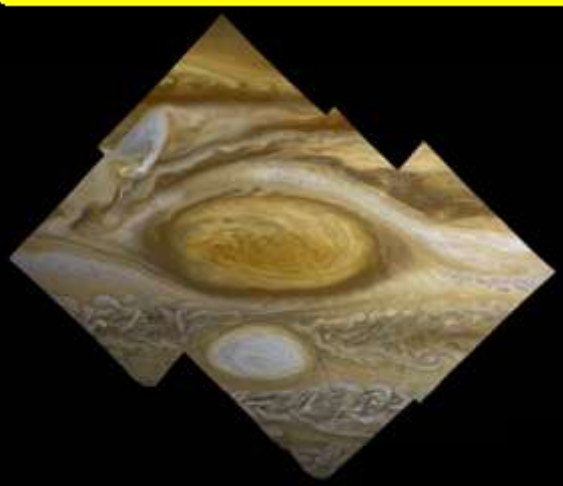


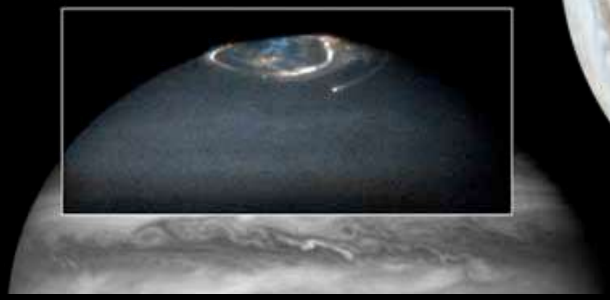
Instrument Packages

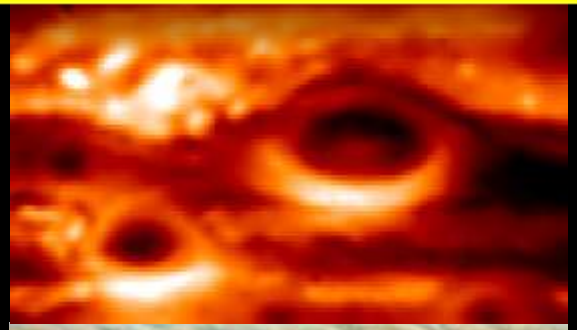
- In situ Fields and Particles
- Imaging
- Spectroscopy
- Radio science

Explore the Jupiter system as an archetype for gas giants

Characterise the Jovian atmosphere







JUICE OBJECTIVES

- Characterise the atmospheric dynamics and circulation
- Characterise the atmospheric composition and chemistry
- Characterise the atmospheric vertical structure

Characterise the Jovian atmosphere

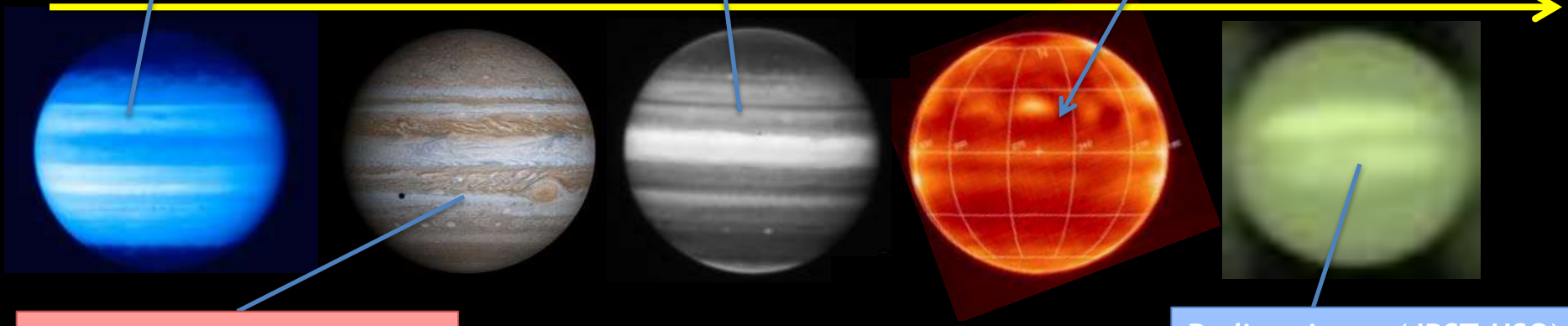
3. Evaluate the variability, *on multiple timescales from hours to years*, of the processes transporting energy, momentum and material from place to place.

Ultra-Violet (UVIS):
Stellar occultations, high-altitude hazes, chemistry, ionosphere/thermosphere

Near-IR (VIRHIS):
5-10 nm resolution; cloud studies; resolve NH3/H2O ice features; extend beyond 5 μm thermal emission

Sub-mm (SWI):
Middle atmosphere, stratospheric winds & waves, temperatures, H_2O and trace species

λ



Visible Camera (HRC/WAC):
Narrow filters to probe strong CH_4 absorptions, cloud structure, wind tracking, lightning studies, cloud colouration

Advanced instrumentation for global & regional observations with broad spectral coverage from UV to radio wavelengths

Radio science (JRST-USO)
Temperature & density sounding; e- density profiles; tropospheric NH3, H2S, PH3 opacity at depth

Conclusions

- Orbiter of an icy moon
- European led mission to outer solar system
- Subsurface exploration of icy moons
- Opportunity to characterise the waterworlds class of planetary bodies
- Opportunity to completely explore Ganymede's unique combination of magnetic fields
- Prolonged study of mid-high latitudes of Jupiter's magnetosphere
- Direct measurements of atmospheric circulation in Jupiter's middle atmosphere

Conclusions

JUICE

Internat. Interest | The Firsts | Cosmic Vision | Impact | Timeliness

Time to progress from exploration to characterisation of habitable worlds