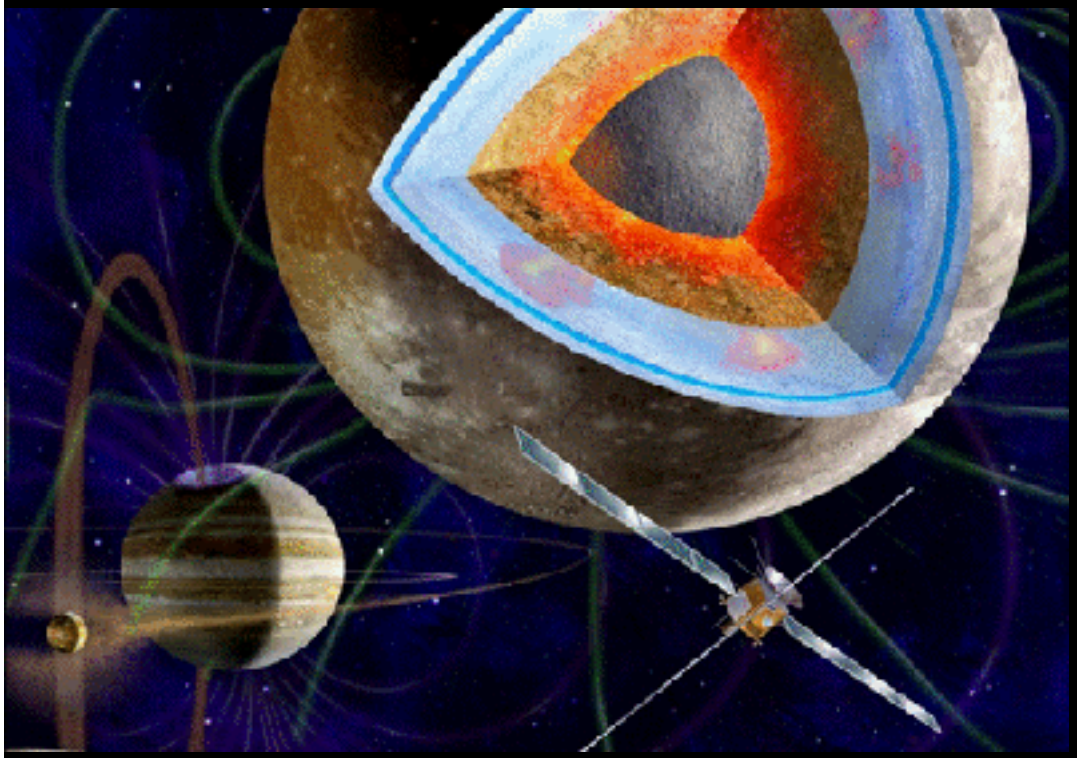
Jupiter Icy Moons Explorer (JUICE): exploring the emergence of habitable worlds around giant planets

Federico Tosi*

on behalf of the JUICE Science Study Team

***INAF-IAPS, Rome**

Istituto Nazionale di Astrofisica (INAF),
Sede centrale, Roma, 30 ottobre 2012



JUICE Science Themes

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

Outline

- *Overview of over-arching questions*
- *The science of JUICE*
- *Conclusion*

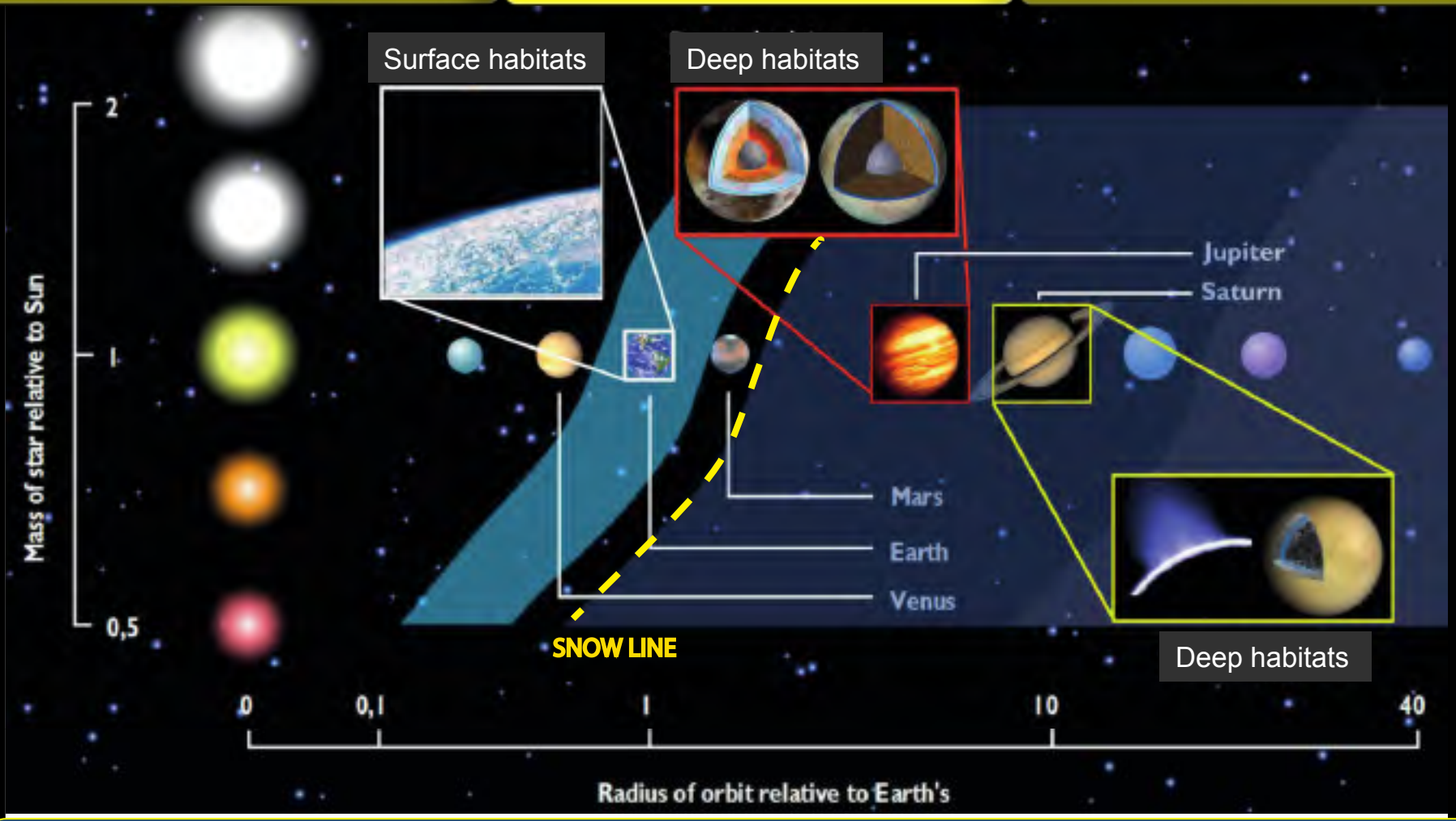
JUICE concept

- *European-led mission to the Jovian system*
- *First orbiter of an icy moon*
- *JGO/Laplace scenario with two Europa flybys and a moderate-inclination phase at Jupiter*
- *JGO model payload is fully compatible with JUICE objectives*

From the Jupiter system to extrasolar planetary systems

JUICE

Waterworlds and giant planets | Habitable worlds | Astrophysics Connection



Cosmic Vision: The quest for evidence of life in the Solar System must begin with an understanding of what makes a planet habitable

Ganymede and Europa are the archetypes of two classes of habitable worlds

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

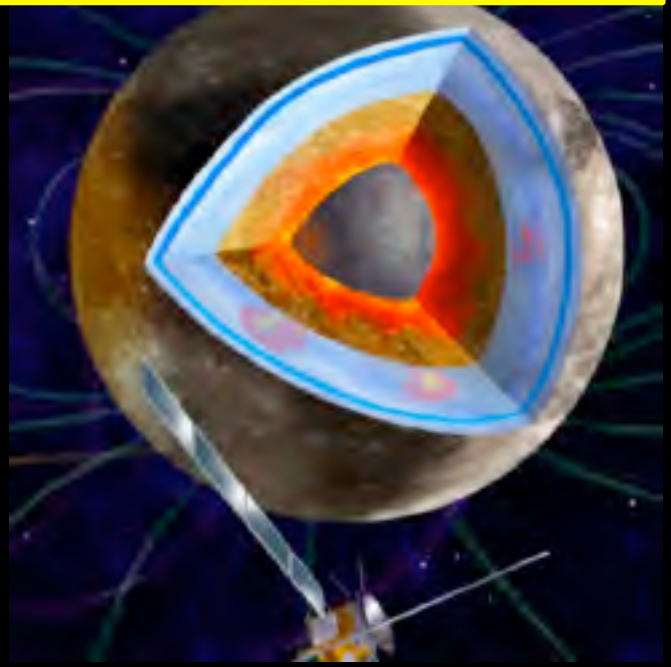
Callisto

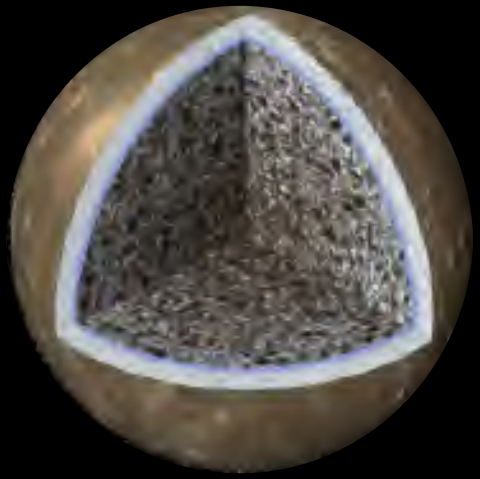
- Best place to study the impactor history
- Differentiation – still an enigma
- Only known example of non active but ocean-bearing world
- The witness of early ages

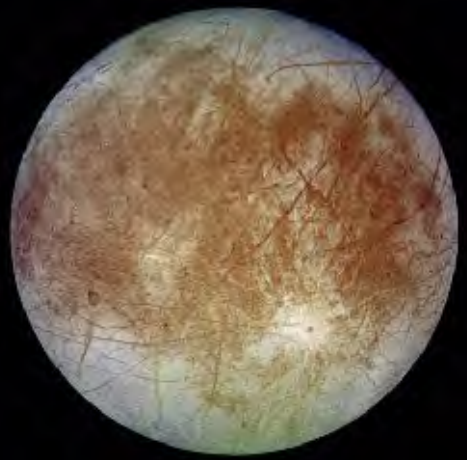
Europa

- A deep ocean
- An active world?

- Best example of liquid environment in contact with silicates







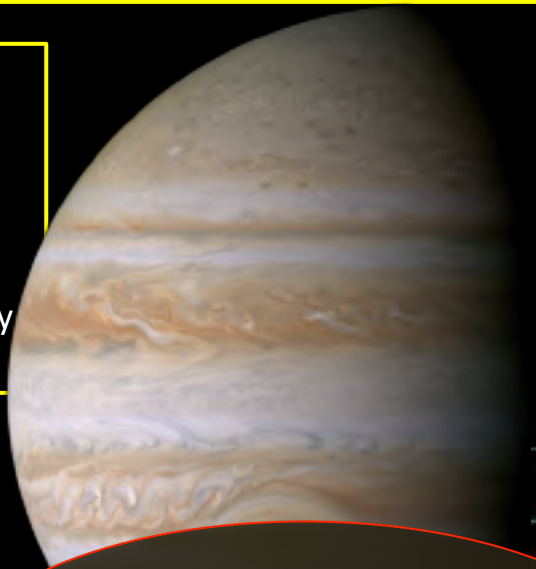
Exploration of the Jupiter system

JUICE

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

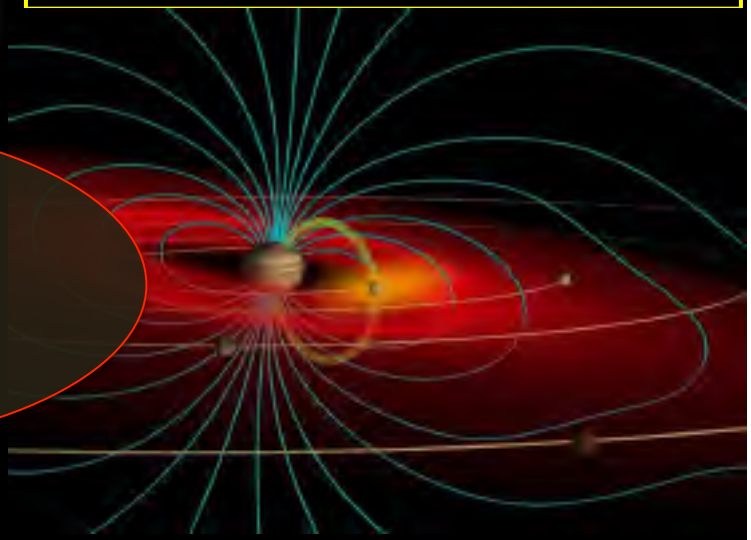
Jupiter

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



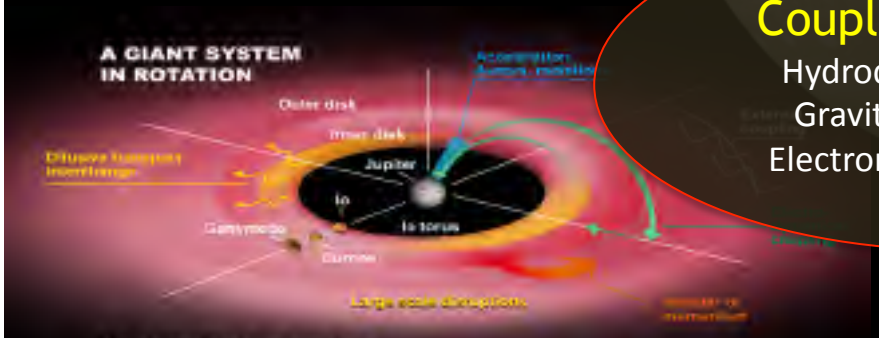
Magnetosphere

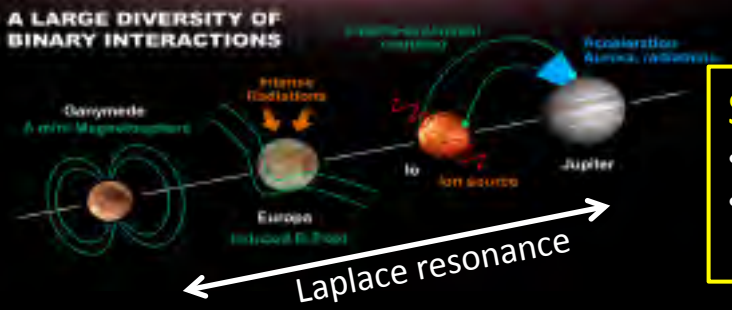
- Largest object in our Solar System
- Biggest particle accelerator in the Solar System
- Unveil global dynamics of an astrophysical object



Coupling processes

Hydrodynamic coupling
Gravitational coupling
Electromagnetic coupling



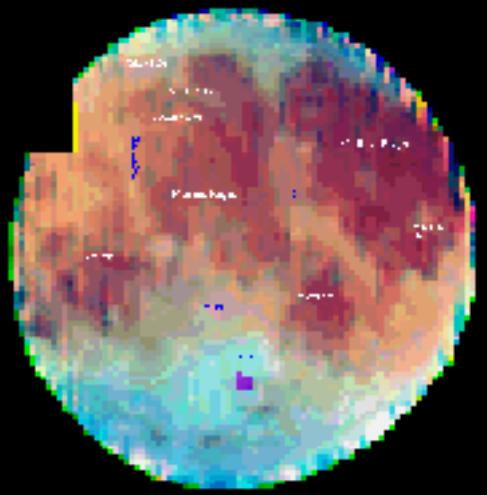


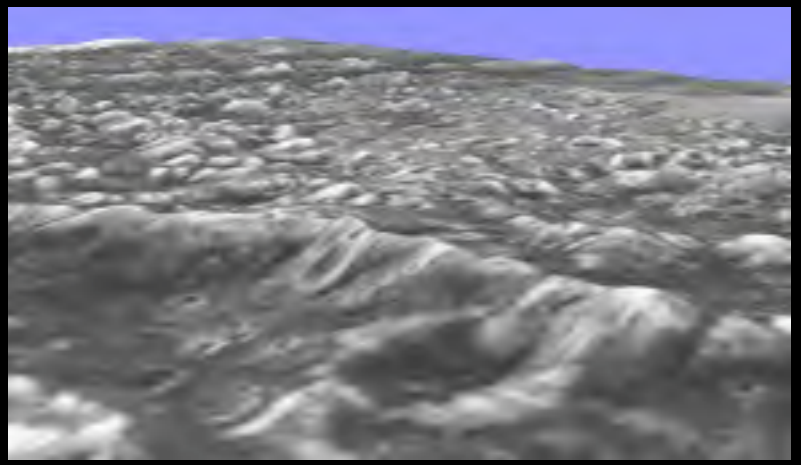
Satellite system

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

Exploration of the habitable zone

Characterise Ganymede as a planetary object and possible habitat





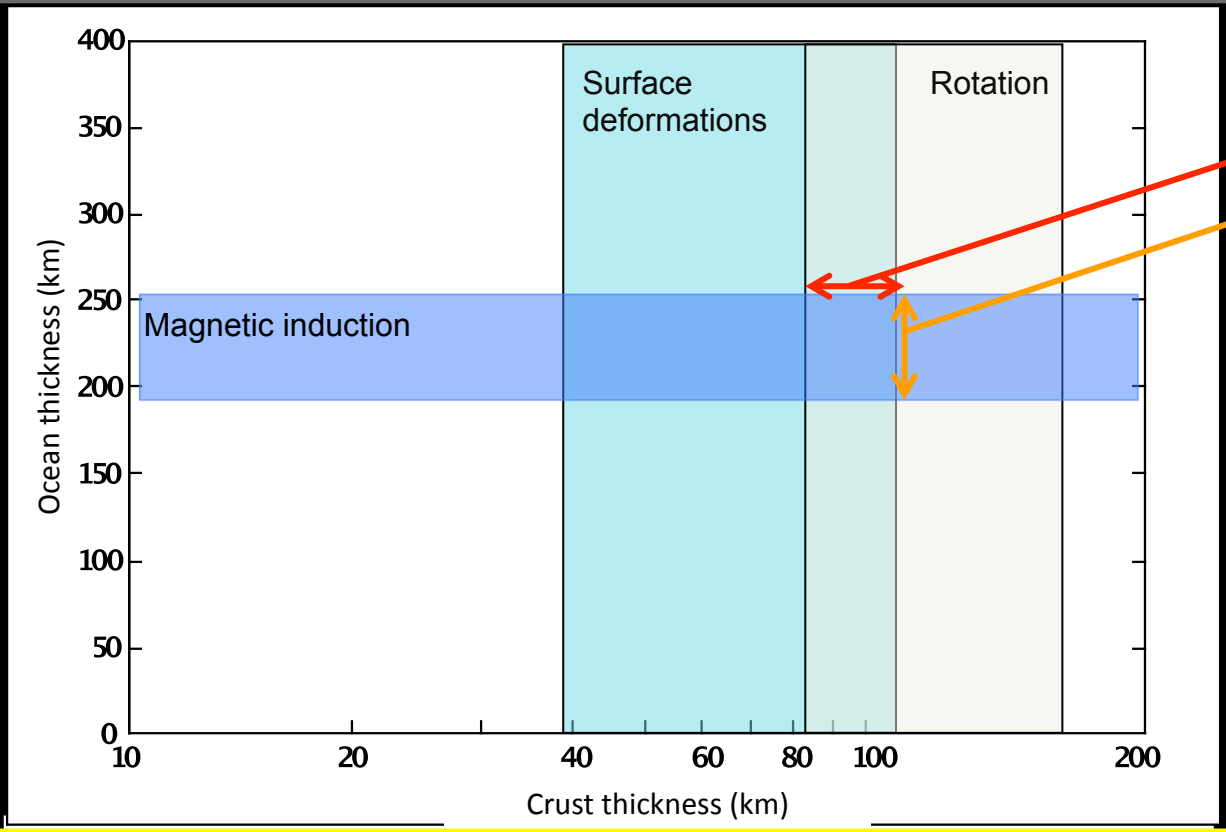
Galileo Regio

JUICE OBJECTIVES

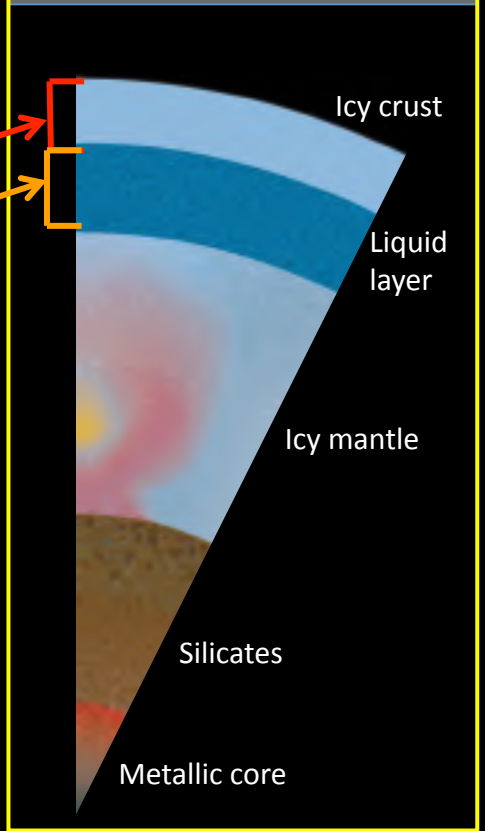
- Characterise the ice shell, the extent of the ocean and its relation to the deeper interior
- Determine global composition, distribution and evolution of surface materials
- Understand the formation of surface features and search for past and present activity
- Characterise the local environment and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

- Surface deformations
- Rotation
- Magnetic induction

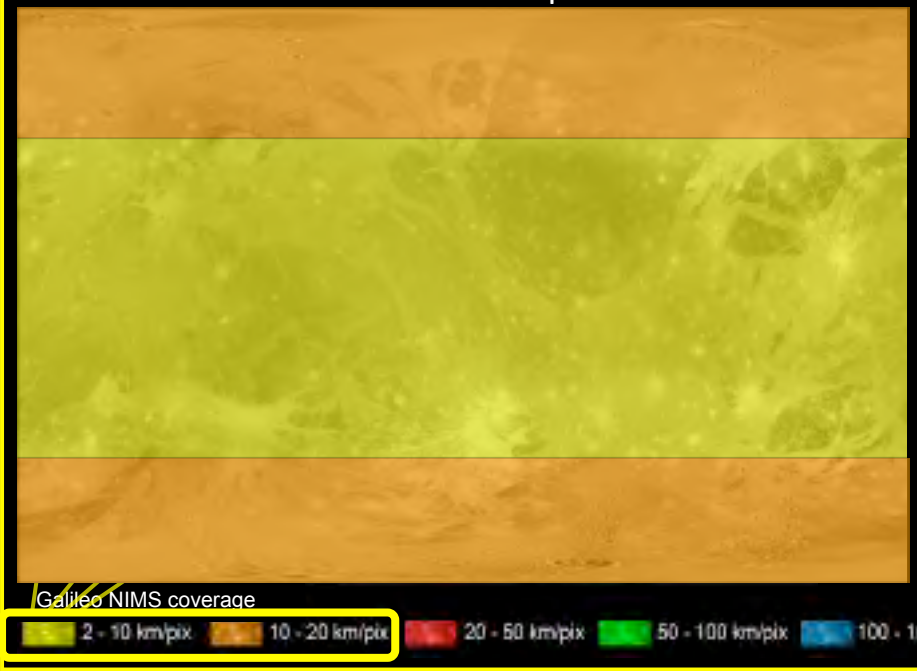
Instrument Packages

- 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 resolution

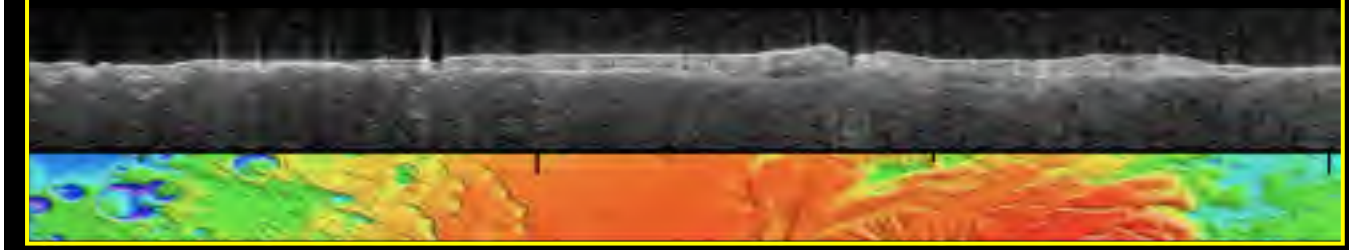
- **>4 times better than Galileo/NIMS in the IR**
- **Close to lab data quality when needed**

Exogeneous / endogeneous ?

Volatiles

Ions and Neutrals

How does the surface relate to the subsurface ?

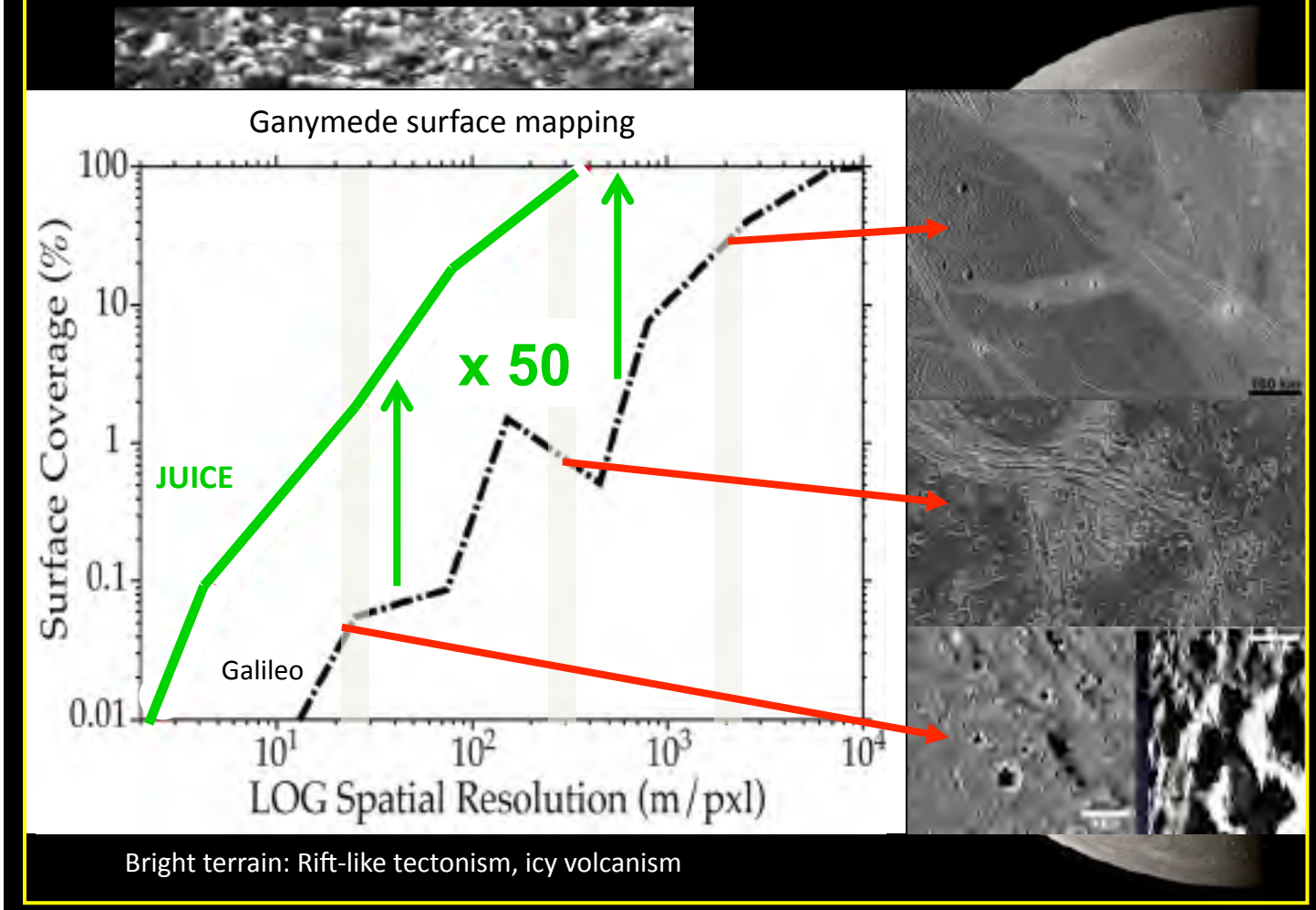


Instrument Packages

- 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

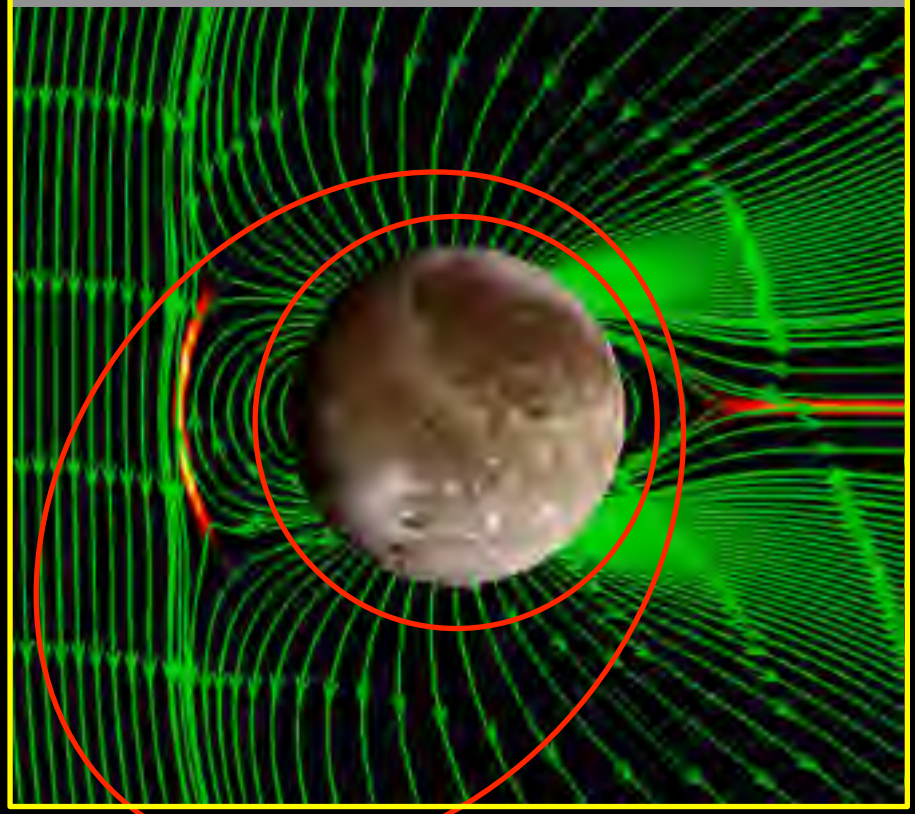
Instrument Packages

- Imaging
- Spectrometers
- Sounders

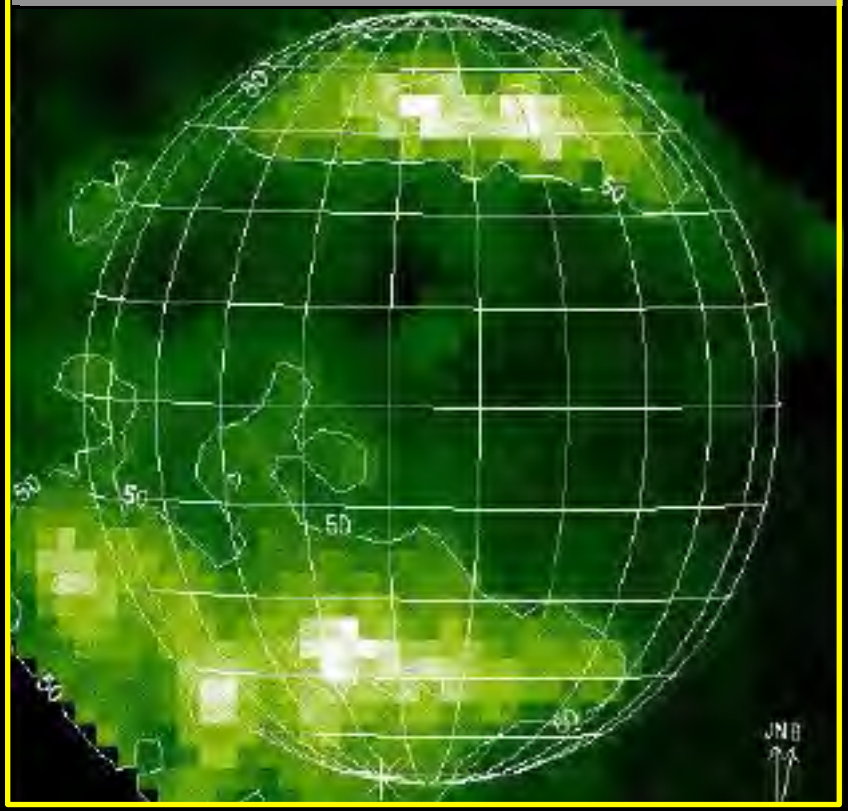
Characterise Ganymede as a planetary object and possible habitat

4. Characterise the local environment

Dipole magnetic field and mini-magnetosphere



Coupling to Jupiter's magnetosphere



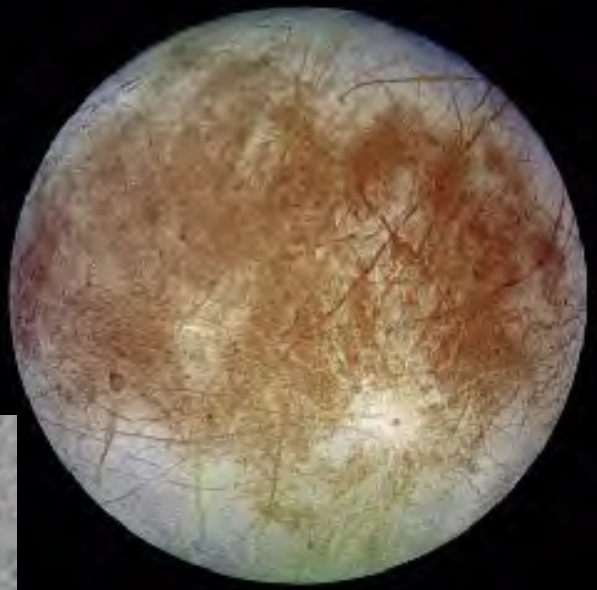
- In situ Fields and Particles
- Imaging
- Spectroscopy
- Radio science

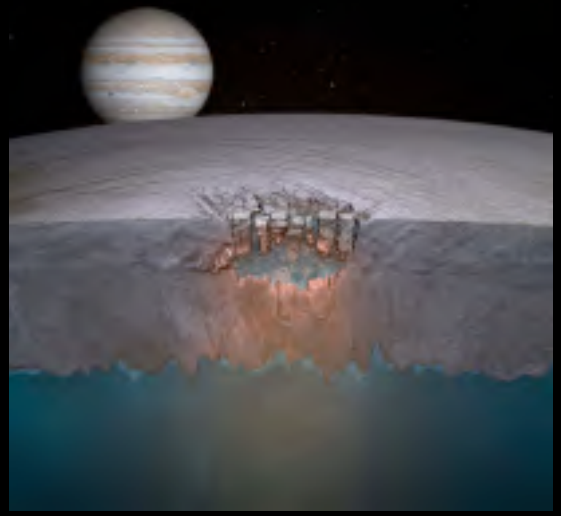
Exploration of the habitable zone

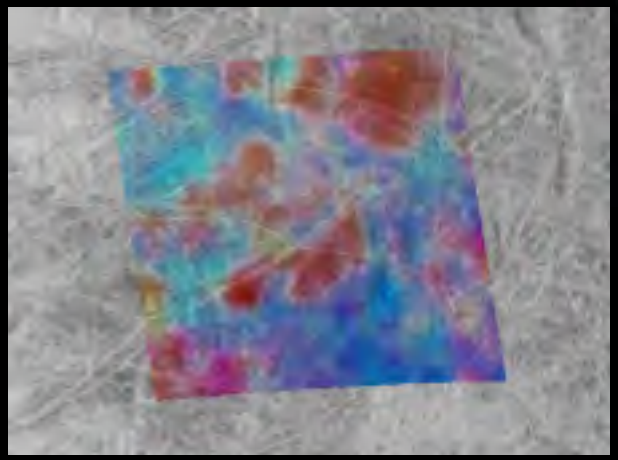
Explore Europa recently active zones

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



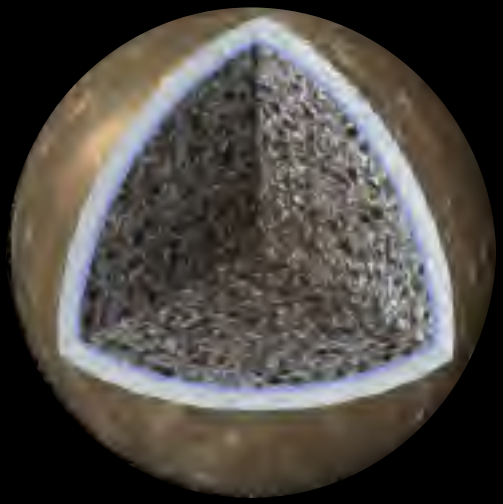


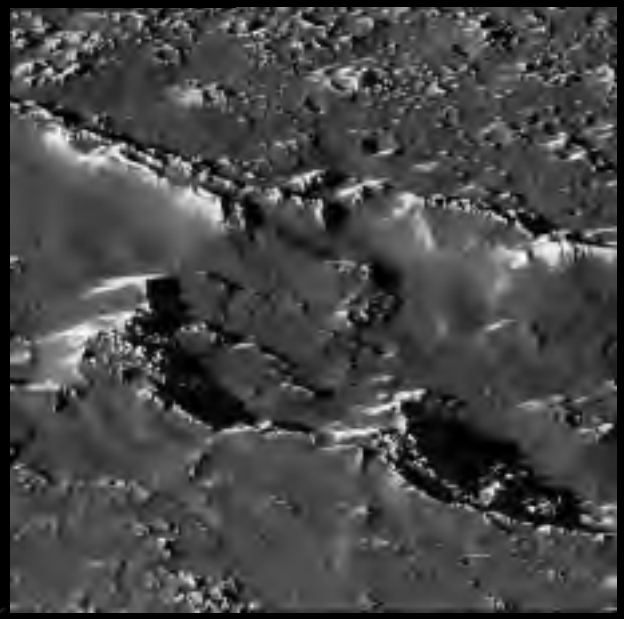


Europa				
Year	2030	2031	2032	2033

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

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

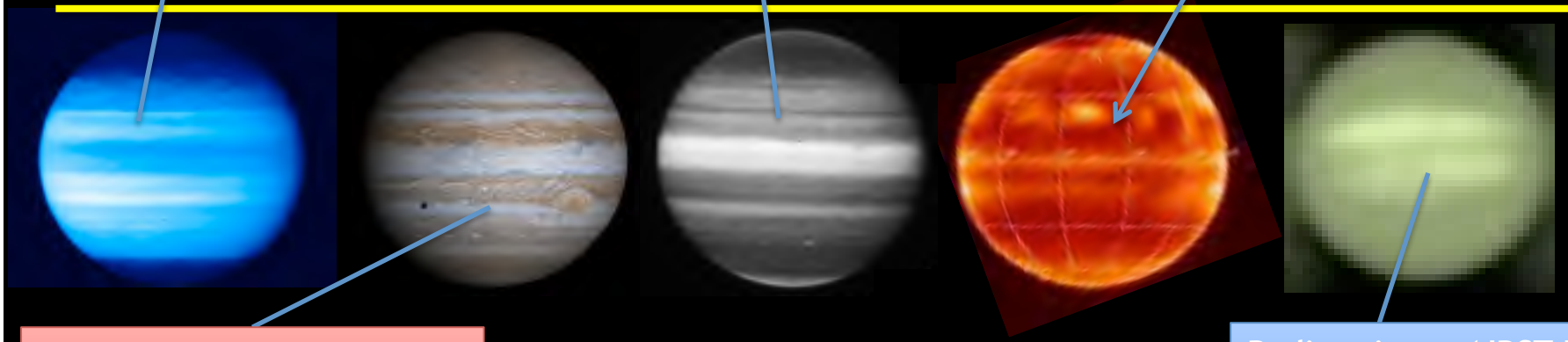
3. Evaluate the variability, ***on multiple timescales from hours to years***, of the processes transporting energy, momentum and material from place to place.

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



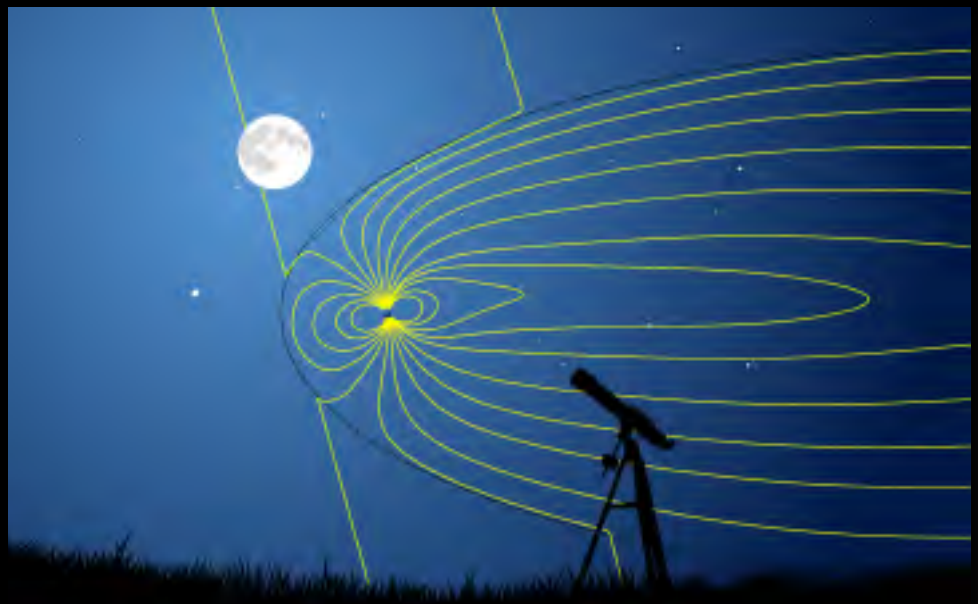
Visible Camera (HRC/WAC):
Narrow filters to probe strong CH_4 absorptions, cloud structure, wind tracking, lightning studies, cloud colouration

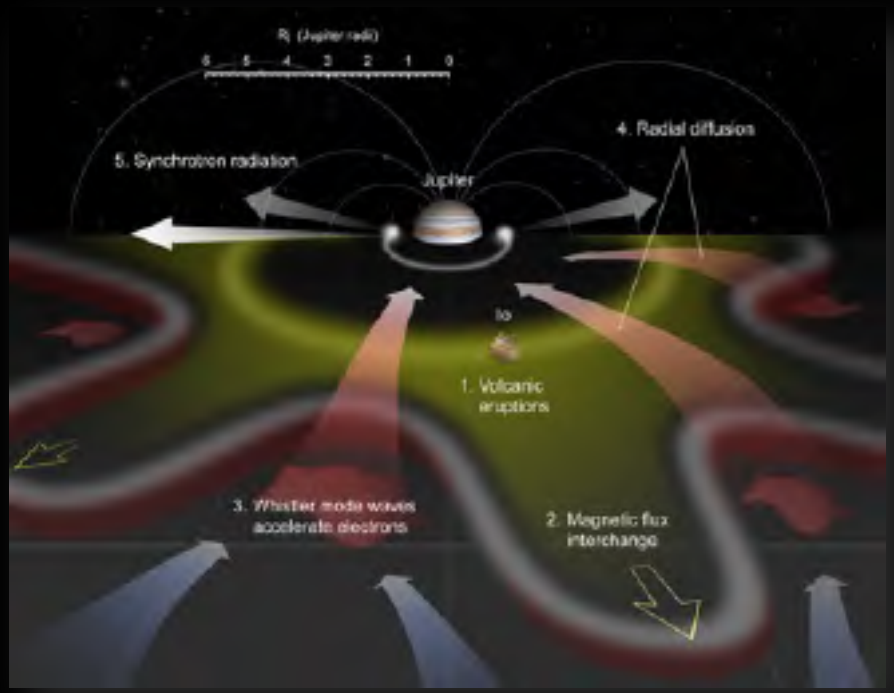
Advanced instrumentation for global & regional observations with broad spectral coverage from UV to radio wavelengths

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

Explore the Jupiter system as an archetype for gas giants

Explore the Jovian magnetosphere

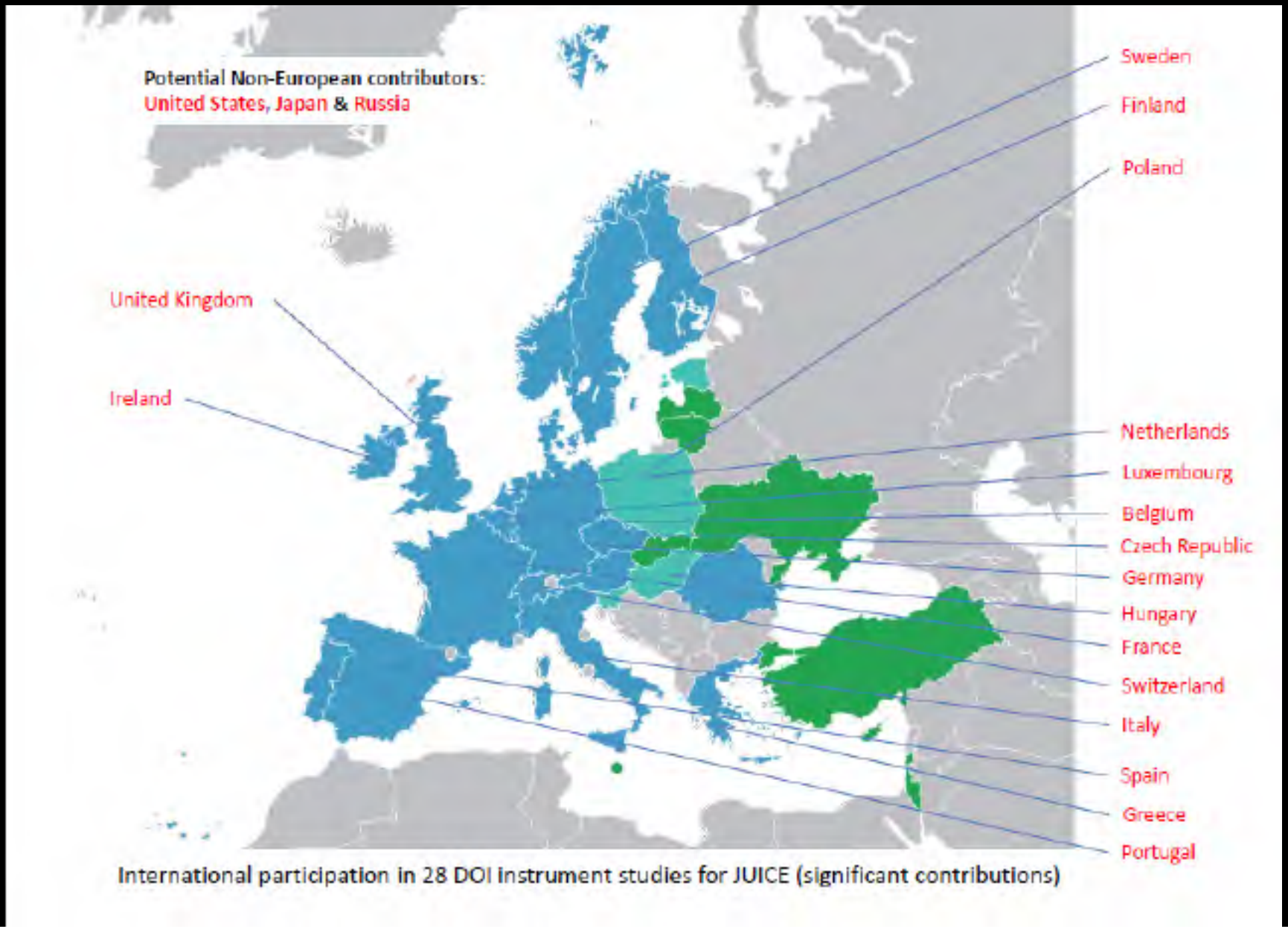




JUICE objectives

- 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

Conclusions



International participation in 28 DOI Instrument studies for JUICE (significant contributions)

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

Cosmic Vision Themes

- *What are the conditions for planet formation and emergence of life?*
- *How does the Solar System work?*

JUICE Science Themes

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

Community interests

Atmospheric sciences

Geology and geophysics

Plasma and Magnetospheric physics

Chemistry

Planetary system dynamics and evolution

Origin of the solar system and exoplanetary systems

Habitability in the solar system and beyond

Conclusions

JUICE

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

Time to progress from exploration to characterisation of habitable worlds